DEVELOPMENT OF A PRESSURE SWING ADSORPTION PROCESS FOR RECOVERY OF TRITIUM FROM SOLID CERAMIC BREEDER HELIUM PURGE GAS OF A FUSION REACTOR

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ABSTRACT

A new PSA (Pressure Swing Adsorption) process for recovering hydrogen isotopes from the helium purge of a fusion reactor breeder blanket has recently been developed by Ontario Hydro. The PSA process is based on using a molecular sieve (5A) at 77 K, with pressure cycling from about 1.1 MPa during the adsorption cycle, to a rough vacuum (≈ 0.2 kPa) during regeneration. Laboratory studies on a small scale PSA column were carried out at the University of New Brunswick (UNB). The results of the laboratory study confirm that PSA is a feasible process for ITER (International Thermonuclear Experimental Reactor) and high purity (> 90%) hydrogen isotopes can be obtained from the ITER blanket containing only 0.1% total hydrogen isotopes in helium. The preliminary design of a PSA pilot plant on a scale of one fortieth of the ITER (or about 3 g T/day) has been developed by Ontario Hydro on behalf of the Canadian Fusion Fuels Technology Project (CFFTP). The laboratory test results and the preliminary PSA pilot plant design are presented in this paper.

INTRODUCTION

Lithium-based compounds have been proposed for breeding tritium in fusion reactors, thereby reducing the need for external fuel supply. The reference breeding blanket for ITER is a solid Li_2O ceramic blanket. Tritium is recovered from the blanket by purging with He. The composition of the purge stream is approximately 0.1% hydrogen isotopes in He. The hydrogen isotopes are approximately 99% H and 1% T. If all the hydrogen isotopes can be removed in a single pass, then the purge stream flowrate is approximately 0.6 m^3/s (STP). It is desirable for the product stream to have a hydrogen isotope concentration as high as practical, but in a final step, the hydrogen isotopes should be enriched to about 100% before being introduced into the Isotope Separation System (ISS).

A design of a tritium recovery system has recently been proposed [1] where the hydrogen isotopes are removed from the He stream using a cryogenic molecular sieve bed. The bed is regenerated by raising its temperature to liberate the hydrogen isotopes. This process is known as Temperature Swing Adsorption (TSA). Due to the considerable thermal mass of a TSA bed large enough to handle the ITER He purge stream flowrate, a cycle time of at least four hours is required.

An alternative PSA process is proposed by Ontario Hydro as a better option than the reference TSA design for ITER. PSA is an industrially established process [2], widely used for hydrogen and helium purification and for air separation. For blanket tritium recovery, the PSA process is advantageous because it allows much faster cycling and therefore has significantly lower tritium inventory. For example, a PSA cycle of 10 minutes has 48 times less tritium inventory than an 8 hour TSA cycle.

Since PSA is inherently a non-steady state process, a dynamic simulation was developed to facilitate system design and optimization. The dynamic simulation model and the gravimetrically measured He/H_2 adsorption isotherms on molecular sieve 5A at a temperature of 77 K were described in [3].

The PSA proposed for ITER is significantly different from conventional PSA for three reasons. Firstly, the ITER PSA columns are deliberately operated to complete breakthrough. In a recirculating system, there is no need for complete hydrogen isotope removal from the He purge stream on each pass through the PSA column. It is quite sufficient from a practical standpoint to remove 50-80% of the hydrogen isotopes. Secondly, the pressure ratio required for enriching the 0.1% hydrogen isotope concentration in the feed to greater than 90% in the product is unusually high ($> 10^3$). Finally, H_2 is added to the column at the beginning of the evacuation cycle in order to displace adsorbed HT, and thus increase the HT partial pressure during column pumpout.

EXPERIMENTAL STUDIES ON A SMALL SCALE PSA COLUMN

Laboratory studies on a small scale PSA column were carried out at the University of New Brunswick [4]. The schematic of the experimental set-up used in this study is shown in Figure 1. It consists essentially of a He/H_2 supply, a dehydration column, a PSA column, a rotary vane two stage vacuum pump (Model Balzers DUO 1.5A), a novel H_2 detector (developed by UNB) with the associated humidifier, wet test meter, voltmeter, opposing voltage supply and chart recorder, the associated instrumentation, valves and piping.

Measurement of Breakthrough Curves

A dehydration column containing molecular sieve 5A was used to prevent any moisture (if present in bottled helium) from entering the experimental PSA column. The feed gas was pre-mixed stream containing 0.16 - 0.18% H_2 in He.

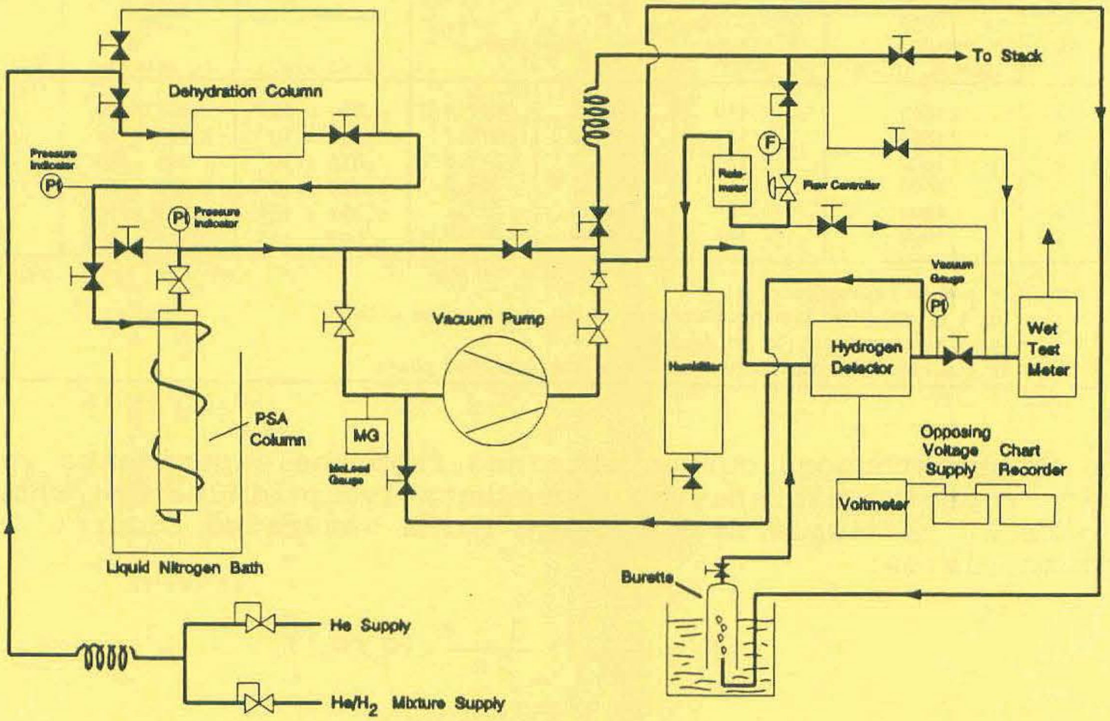

Figure 1: Schematic of the PSA Experimental Apparatus

The PSA column used for this study was a stainless steel column (length 15.6 cm x ID 0.77 cm) packed with 0.07 cm (diameter) 5A particles (bed voidage of 0.31 and adsorbent density of 1.12 g/cc). The column was completely immersed in a Dewar vessel containing liquid nitrogen at 77 K. Prior to the experiments, the PSA column was regenerated by purging overnight with helium at about 350°C. With the regenerated column in place, the required flow and corresponding column pressure were adjusted with the helium supply. The length to velocity ratio in all of the experiments was about 4.76 s. The flow of helium was then replaced by the feed gas (1600-1800 ppm H_2 in He) through switching of valves. The column effluent was continuously monitored using the H_2 detector, which was precalibrated with pure H_2 and/or He/H_2 gas mixture of known compositions.

The adsorption breakthrough was run to completion i.e., the PSA bed was completely saturated with the feed gas. The feed was then cut off, and the desorption was measured using a helium purge at the same pressure. The experimental conditions for the breakthrough measurements are shown in the second and third columns of Table 1.

Table 1

Summary of the Breakthrough Experiments and Equilibrium Data

Run	Feed Composition (ppm H_2 in He)	Operating Pressure (MPa)	τ (s)	q_o/c_o	c_o (g mole/cc)	q_o (g mole/cc)	V cc(STP)/g
2	1600	1.13	6288.5	597.8	2.836×10^{-6}	1.695×10^{-3}	33.9
3	1600	2.16	3934.0	370.7	5.420×10^{-6}	2.009×10^{-3}	40.18
4	1600	1.13	6288.5	597.8	2.836×10^{-6}	1.695×10^{-3}	33.9
5	1600	2.16	4042.5	383.3	5.420×10^{-6}	2.078×10^{-3}	41.552
8	1800	2.16	3627.5	347.2	6.097×10^{-6}	2.117×10^{-3}	42.336
9	1800	2.16	3735.0	351.9	6.097×10^{-6}	2.146×10^{-3}	42.912

Note: τ = Mean residence time
q_o = H_2 adsorbed phase concentration in equilibrium with c_0
c_o = H_2 concentration in feed gas
V = H_2 equilibrium concentration in the adsorbed phase

The H_2 breakthrough curves obtained from the experiments were quite reproducible and the representative profiles are shown in Figure 2. A simple mass balance for a saturated adsorption column yields:

$$\tau = \frac{L}{\upsilon} \left\{1 + \frac{1 - \epsilon}{\epsilon} (q_o/c_o)\right\} \tag{1}$$

The mean residence time, τ, was determined from the breakthrough curves (Figure 2). The length to velocity ratio, L/υ was about 4.76 s and the bed voidage, ϵ, was about 0.31. The q_o to c_o ratio and therefore the q_o and V values for different H_2 partial pressures were easily obtained from the experimentally measured breakthrough curves. The experimental results are summarized in Table 1.

The H_2 equilibrium data obtained from the breakthrough experiments are also compared with the previously measured gravimetric data [3] in Figure 3. The close agreement between breakthrough and gravimetric H_2 equilibrium data suggests that, in the range of the present investigation, the capacity for H_2 adsorption is not significantly affected by the presence of high pressure helium (i.e., the sorption of H_2 and He is non-competitive). The recent experimental data also indicate that the isotherm for D_2 (and by extrapolation for tritium) is similar to that for H_2 but slightly higher.

The He isotherm was also measured from the experimental column. The column was first equilibrated with helium at various pressures up to 2.16 MPa. It was then depressurized down to atmospheric pressure through a mass flow controller at a constant desorption rate. The amount of helium released upon desorption was estimated by measuring the time required for the column

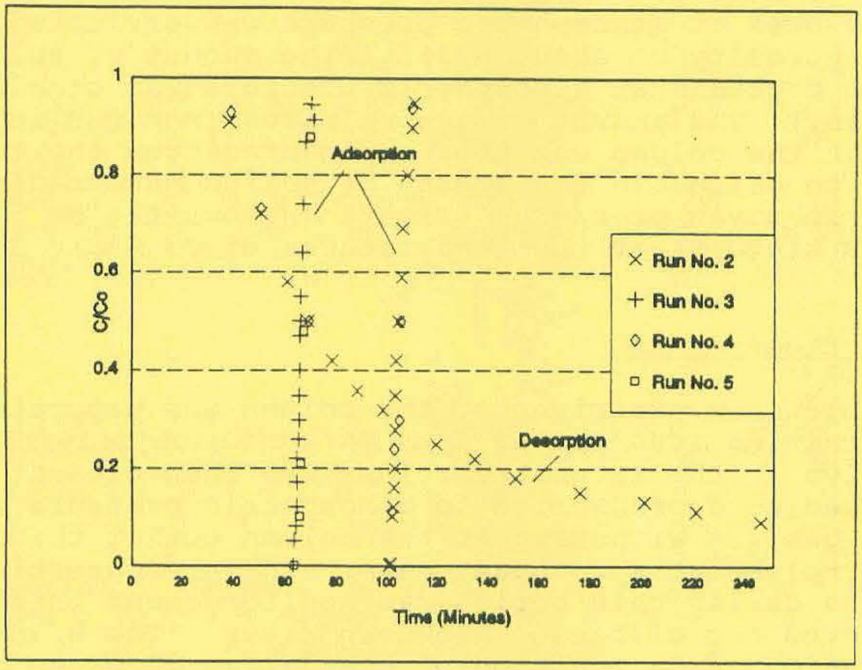

Figure 2: Reproducibility of the Experimental Adsorption and Desorption Breakthrough Curves

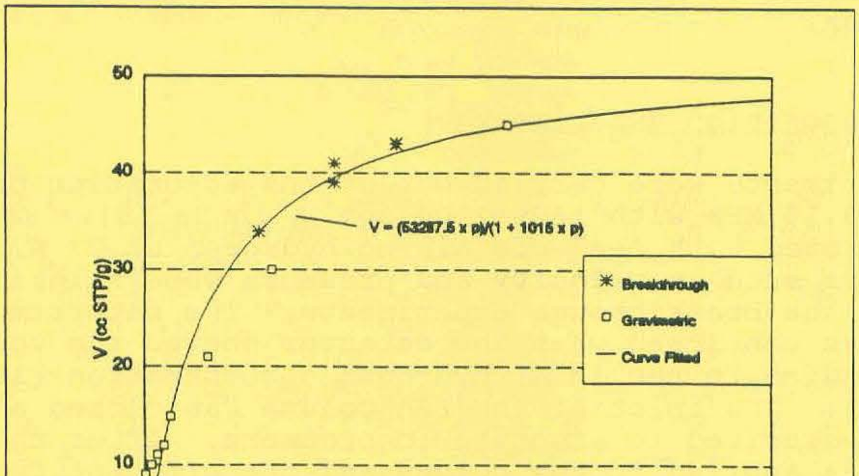

Figure 3: Comparison of Breakthrough and Gravimetric Equilibrium Data of Hydrogen on Molecular Sieve 5A at 77K

pressure to fall to atmospheric. The amount of helium present in the macropores at atmospheric pressure was estimated assuming the particle porosity of about 0.33. (The amount of helium adsorbed in the 5A crystals at atmospheric pressure was considered negligible.) The amount of gas released from the inter-particle voidage of the column was then subtracted from the total gas quantity to calculate the amount of helium adsorbed by molecular sieve 5A at given pressure. Figure 4 shows the He isotherms on molecular sieve 5A at the temperatures of 77 K and 303 K.

Blowdown Experiments

For the blowdown experiments, the column was saturated with a feed containing 1600 ppm of H_2 in He at about 2.16 MPa. The inlet valve to the saturated column was then closed. The column was allowed to depressurize to atmospheric pressure while the blowdown gas was withdrawn at the column outlet through the mass flow controller at a constant rate. The pressure-time history of the column during this period was monitored and this procedure was repeated for different blowdown rates. The H_2 effluent concentrations as a function of cumulative blowdown gas volumes for different blowdown rates are shown in Figure 5. The areas under the profiles in Figure 5 represent the loss of hydrogen during blowdown. The maximum loss of hydrogen during blowdown was estimated to be less than 1% of the total hydrogen loading at saturation.

Vacuum Desorption Experiments

The experiments were carried out at the adsorption pressures of 1.13 to 2.16 MPa with 1800-2100 ppm H_2 in He [5]. The PSA column was saturated with feed containing hydrogen at 77 K. The parameters such as velocity and pressure were maintained same as those in the breakthrough experiments. The saturation of the column was confirmed when the detector showed the voltage corresponding to the inlet hydrogen concentration (1800 or 2100 ppm). The inlet of the PSA column was closed and the column was depressurized to atmospheric pressure. After the blowdown, vacuum was applied to the column and the effluent from the vacuum pump discharge was collected in an inverted burette placed in a bucket filled with water as shown in Figure 1. The volume of the gas collected for each run is shown in the fourth column of Table 2.

The rate of vacuum desorption depends on the kinetics of desorption and the efficiency of the vacuum pump. In all the vacuum desorption runs, it took less than 15 seconds to achieve a vacuum close to 0.01 kPa. If the mass transfer resistance is only due to molecular diffusion in the macropores, then it will be insignificant during vacuum desorption, as the molecular diffusivity varies inversely with pressure.

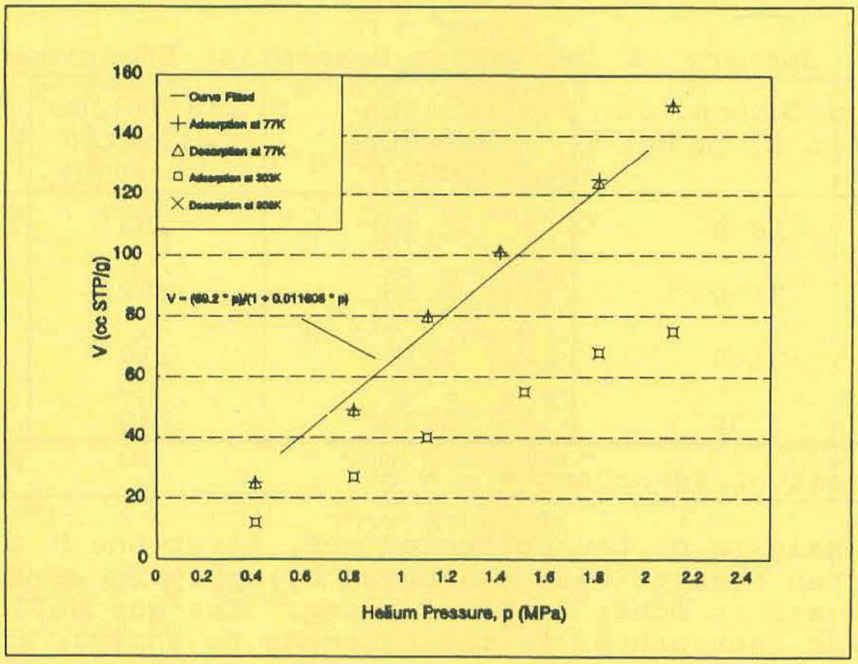

Figure 4: Helium Isotherms on Molecular Sieve 5A at 77 K and 303 K

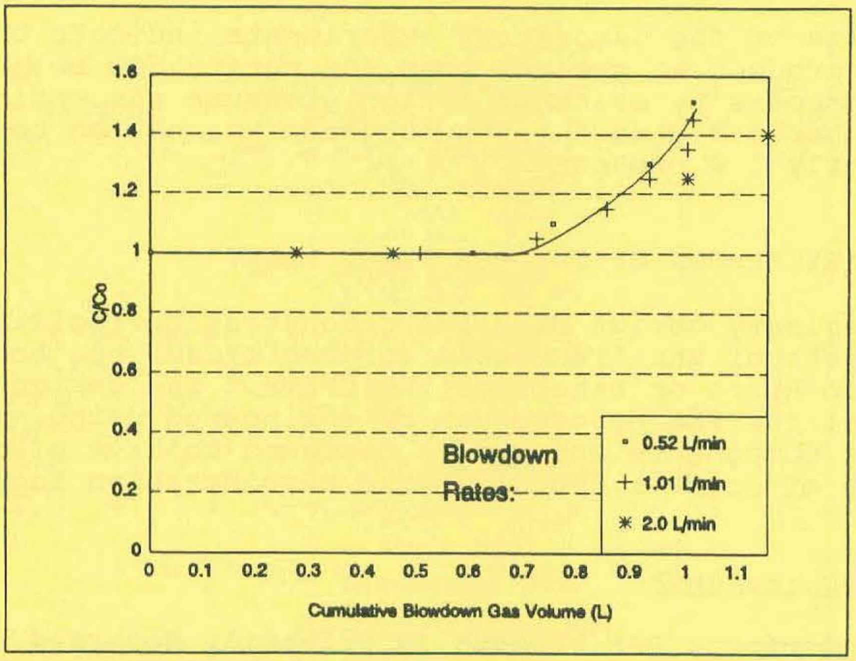

Figure 5: Volume and Composition of Effluent Gas During Blowdown of An Equilibrated Bed

Table 2

Summary of the Vacuum Desorption Experiments

Run	Feed Composition (ppm H_2 in He)	Column Pressure (MPa)	Gas Volume Collected (cc STP)	Effluent Gas Composition (% H_2)
1	1800	1.13	105	-
2	2100	2.16	202	97
3	2100	1.13	110	93
4	2100	2.16	210	92.5
Note: Mass of adsorbent = 5.6 g				

For the analysis of the collected gas, first the H_2 detector and the inverted burette were evacuated by applying a vacuum, so as to remove air or other impurity gases. The gas collected in the burette was then passed to the detector to analyze for the H_2 content. It was found that the H_2 content in the effluent gas was greater than 92% (see Table 2).

Conclusion

The results of the laboratory experiments indicate that the hydrogen product at greater than 90% purity can be obtained from the PSA process by means of a high pressure adsorption, followed by atmospheric blowdown and subsequent evacuation to a sufficiently low pressure.

PRELIMINARY DESIGN OF THE PSA PILOT PLANT

The preliminary design of a PSA demonstration facility on the one fortieth of the ITER scale (or 3 g T/day) has been developed by Ontario Hydro on behalf of the CFFTP. The design study has shown that the PSA process can be engineered using, mostly, available components and can be designed to have a low tritium inventory of about 1,000 Ci in the demonstration loop.

Design Requirements

The design of the PSA process is primarily governed by the helium purge gas processing requirements for the ITER solid ceramic breeder blanket. The design requirements of the PSA pilot plant are to demonstrate that:

1. PSA is a feasible process for recovery of tritium (at the rate of 100-120 g T/day) from the ITER solid ceramic

breeder helium purge gas, which contains about 0.1% hydrogen isotopes and 99.9% helium.

2. The PSA process will have a drastically (40 to 50 times) lower tritium inventory than the reference TSA process for ITER due to much faster cycling (10 vs. 480 minutes).

The pilot plant will also provide useful data on the lifetime of molecular sieve 5A under PSA conditions as well as the verification of the dynamic simulation results [3], thus allowing us to scale up the pilot plant data directly to reflect the performance of a full scale PSA process for ITER.

Process Description

The PSA process is based on using a 5A molecular sieve at 77K, with pressure cycling from about 1.1 MPa during adsorption cycle, to a rough vacuum (≈ 0.2 kPa) during regeneration. The major components of the PSA demonstration loop are a buffer tank, a feed tank, a compressor[•], two PSA columns, vacuum pump sets, recombiner, dryer, heat exchangers, the associated valves, piping and instrumentation. A preliminary flow schematic for PSA demonstration facility is shown in Figure 6.

The two PSA columns, operating in parallel, are designed for continuous processing the helium feed gas from the feed tank TK2. The pressure in the tank TK2 is maintained by the compressor P1. The feed flows to one PSA column while the other column is being evacuated for regeneration. The flow in the column is the same direction during feed and evacuation. Also, the PSA column pumpout time is the same as the pressurization and feed time. The cycle time for the PSA process is estimated to be about 10 minutes.

During the adsorption step of the process, the PSA column is pressurized to about 1.1 MPa by means of the high capacity feed compressor P1, which draws the tritium-bearing helium/hydrogen feed gas from the buffer tank TK1. The feed gas rate is approximately 2.2 mol/s at 1.1 MPa, 300 K with 0.1% hydrogen and balance helium (see Table 3).

A cooler HX4 is provided at the outlet of compressor P1 to maintain the feed gas temperature at about 300 K. Prior to entering the PSA column, the feed gas is cooled from 300 K to about 77 K by a countercurrent heat exchanger (HX1, HX2).

[•] The exact number of compressors and vacuum pumps required will be determined during the detailed design phase.

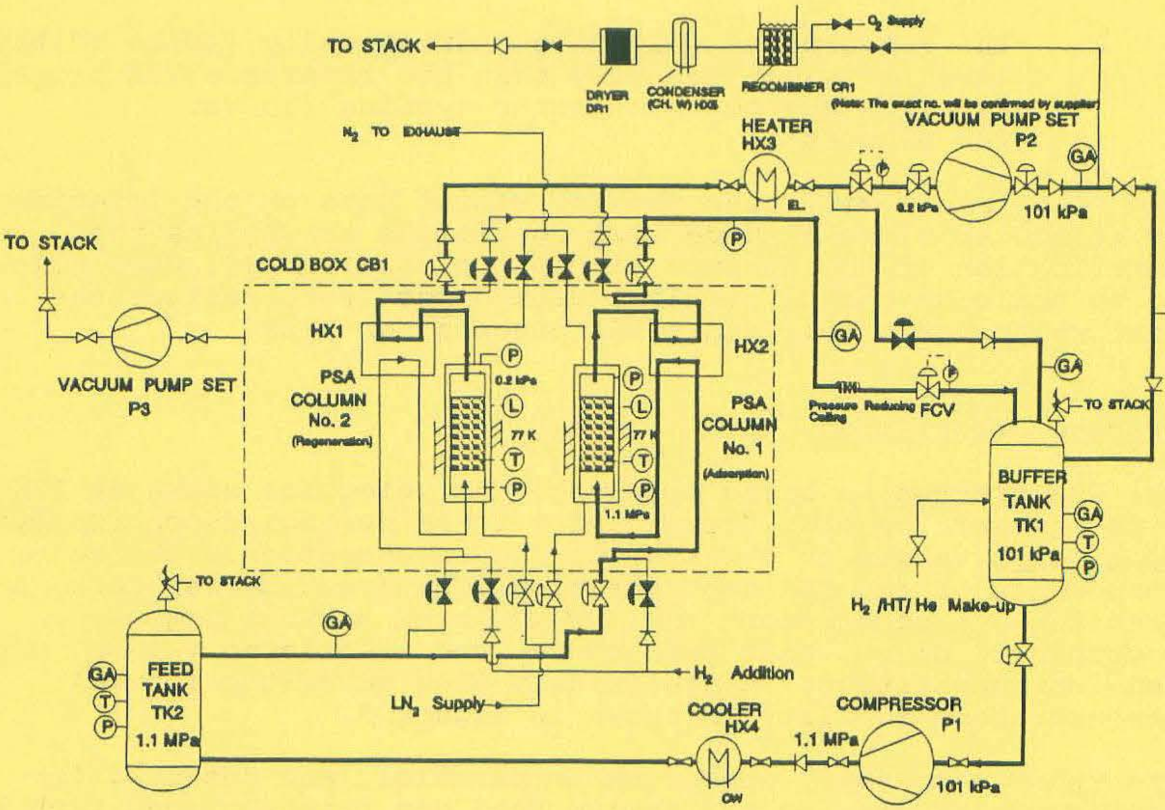

Figure 6: Preliminary Schematic for PSA Demonstration Facility

Table 3

Feed Gas Flow, Temperature and Composition

Parameter	PSA on 1/40 ITER Scale
Feed Flow	2.2 mol/s
Feed Temperature	300 K
Feed Composition	99.9% He and 0.1% Hydrogen Isotopes (99 parts H and 1 part T)

The pressure in the PSA column is maintained at about 1.1 MPa by a pressure reducing coil and a flow control valve through which the hydrogen isotope depleted helium is recycled back to the buffer tank TK1. The feed gas will continue to pass through an adsorber bed in the PSA column for about 5 minutes at 1.1 MPa. During this time, the adsorber bed will become fully loaded with hydrogen isotopes and helium.

At the end of the adsorption cycle, the hydrogen isotopes/helium feed stream is switched over to the second PSA column that has been regenerated and pressurized. The first PSA column is then isolated from the feed gas and is depressurized to atmospheric pressure to release the bulk of helium adsorbed in the bed. The released helium is recycled back to the buffer tank TK1. The first column is then connected to the Normetex vacuum pump set P2 and the column is evacuated to a pressure of about 0.2 kPa.

For a short initial evacuation time, the exhaust from the vacuum pump set P2 contains mainly helium, since the mole fraction of hydrogen isotopes is still low. The hydrogen isotope concentration in the exhaust increases gradually with further column pumpout. At the later part of the evacuation process, the exhaust gas from the vacuum pump set P2 contains mainly hydrogen isotopes. In order to verify the performance of the PSA demonstration loop, the gas mixture compositions in the feed line and the exit line from each PSA column are continuously monitored by on-line gas analyzers.

The regenerated hydrogen isotopes are then pumped back to the buffer tank TK1. (Note: For a few experimental runs, pure H_2 may be introduced into the column to raise the hydrogen partial pressure in the column to about 20 kPa in order to purge out any residual tritium from the bed. This excess hydrogen will be routed through a catalytic recombiner and a dryer unit to recover tritium prior to sending it to the stack.)

At the end of the pumpout and regeneration, the column is repressurized to about 1.1 MPa by the feed gas and kept ready for the next adsorption cycle. During the adsorption and regeneration cycles, the PSA columns are maintained at a temperature of 77 K using liquid nitrogen.

System Arrangement

Due to the presence of radioactivity (tritium) in the facility, all of the major equipment in the PSA demonstration loop is located within a secondary containment in the form of glove box, cold box or vacuum vessel.

The two PSA columns and associated heat exchangers HX1 & HX2 are located inside the cold box CB1.

Component Design Description

A list of the major process equipment used in the PSA demonstration facility is shown in Table 4. The important design features of the equipment are outlined below.

Design of Buffer Tank TK1 and Feed Tank TK2. These are cylindrical tanks. Each tank has a holding capacity of about 3 m^3. The tanks TK1 and TK2 shall be fabricated from stainless steel and be provided with fittings for pressure and temperature measurements, overpressure protection device and for sampling and gas analysis of tank contents.

Design of Compressor P1. The compressor, P1, is provided to pressurize the feed gas from 101 kPa to 1.1 MPa at the flowrate of 50 L(STP)/s.

Design of Vacuum Pump Set P2. This is a vacuum pump set for evacuating the PSA column contents during regeneration. The column must be pumped down within 5 minutes from 101 kPa to 0.2 kPa. For this purpose, the pumping speed should be on the order of 15 Nm^3/h. A Normetex Model PV12 Dry Vacuum Pump may be used as the main vacuum pump, and a diaphragm pump (Normetex Model D7) may be used as the backing pump.

Design of Heat Exchangers HX1, HX2 & HX4. These are compact, highly efficient, countercurrent flow heat exchangers [6]. The process gas to be cooled flows through the inner pipe and the cooling water (or gas) flows through the outer pipe or shell. The pipes shall be made of stainless steel and the extended heat transfer surface shall be made of copper.

Design of PSA Columns. The PSA columns are maintained at their normal operating temperature of 77 K using liquid nitrogen. Each column is provided with an individual jacket for liquid nitrogen supply. Liquid nitrogen supply to each PSA column is controlled by a level controller in the jacket side. Drain and vent connections are also provided on the jacket to facilitate filling and draining of liquid nitrogen.

The PSA columns are designed to operate on a 10 minute cycle (i.e., 5 minutes of adsorption and 5 minutes of regeneration). The column contains molecular sieve 5A and spring mounted pressure plates to prevent the adsorbent bed moving. The particle size of molecular sieve adsorbent should be 20 to 40 mesh to minimize diffusional resistance to mass transfer during the adsorption step. The quantity of the molecular sieve 5A

Table 4

Equipment List

Equipment Description	Operating Conditions		Design Conditions	
	Temp. K	Press. kPa	Temp. K	Press. kPa
Buffer Tank TK1	300	101	350	500
Feed Tank TK2	300	1100	350	1500
Compressor P1	300	101-1100	350	1500
Vacuum Pump Set P2	300	0.1-101	350	Full Vac/1500
Heat Exchangers HX1 & HX2	77-300	0.1-1100	77/350	Full Vac/1500
Cooler HX4	300-400	1100	450	1500
Condenser HX5	423	101	573	200
PSA Columns	77-300	0.1-1100	77/350	Full Vac/1500
Cold Box CB1	77-300	0.001	77/350	Full Vac/1500
Vacuum Pump Set P3	77-300	0.001-101	77/350	Full Vac/200
Heater HX3	300	0.1-1100	350	Full Vac/1500
Recombiner CR1	423	101	573	200
Drier DR1	300	101	573	200

required for a 10 minute PSA cycle is about 2.34 L (length 16.84 cm x ID 13.3 cm).

Since the PSA are deliberately operated to complete breakthrough, the bed dimension was estimated based on the superficial flow velocity of 10 cm/s. At this low superficial flow velocity, the pressure drop across the adsorbent bed is minimized. Thus, the pressure through the PSA column can be considered to be uniform. The PSA columns are located within a vacuum insulated cold box CB1. The material of the construction of PSA columns shall be 316L stainless steel.

Design of Cold Box CB1. The two PSA columns and associated heat exchangers HX1 & HX2 are located in cold box CB1. The cold box is a vacuum insulated vessel which contains a minimum of 10 layers of super-insulating mylar insulation, and serves also as a secondary containment. The cold box shall be maintained at a pressure of less than 1 Pa by a vacuum pump set P3, and the vacuum shall be continuously monitored. The material of the construction of cold box shall be 316L stainless steel.

Design of Vacuum Pump Set P3. Vacuum pump set, P3, consists of one small oil diffusion pump and one small rotary vane pump, which are operated in series to maintain the pressure in cold box CB1 at ≤ 1 Pa.

Design of Heater HX3. HX3 is a tubular electric heater and it is provided to heat the process gas stream to about 300 K, before the gas enters the vacuum pump set P2.

Design of Catalytic Recombiner. The catalytic recombiner, CR1, is provided to recover tritium from the exhaust gas prior to sending it to the stack. The recombiner operates at a temperature of about 423 K to combine any free hydrogen isotopes (H_2, HT) with oxygen to form water. It contains 1% Pd on Alumina catalyst and is electrically heated to maintain its operating temperature. A temperature controller automatically regulates the heating. The recombiner vessel is fabricated from stainless steel and is of all-welded construction.

Design of Condenser HX5. Condenser, HX5, is provided to remove all the water vapour generated by the catalytic recombiner CR1. It is a double pipe, counter-current heat exchanger. The heat exchanger is constructed of two concentric tubes, with turbulence promoters in the inner tubes. The process gas to be cooled flows through the inner tube and the coolant (chilled water) flows through the annulus. The material of construction shall be stainless steel.

Design of Drier DR1. After leaving the condenser HX5, the moisture-laden exhaust gas enters a drier bed (filled with molecular sieve) for further moisture removal. The drier provides 99.95% moisture-free exhaust gas prior to sending it to the stack.

Valves and Piping. All major process lines shall be constructed and examined in accordance with the requirements specified in ANSI B31.1. The size of main process lines shall be less than 5.1 cm. All cryogenic lines shall be insulated in order to prevent accidental contact of personnel with extremely cold surfaces.

All valves installed on the PSA columns and vacuum pump set P2 for switching/directing flow between adsorption and regeneration cycles shall be pneumatically operated, rated for rough vacuum and 1500 kPa operating conditions. These valves shall be equipped with compact pneumatic operators, solenoid valves, limit switches and three-position (Close-Auto-Open) handswitches. Manual valves can be used for the purpose of equipment isolation.

Control System

Operation of the PSA process is automated to the extent possible. It is envisaged that monitoring and control of the PSA process will be performed via a microprocessor based system. In general, the PSA process parameters are monitored with the use of the following devices:

- Temperature measurements are made by RTD's (Resistance Temperature Detectors).
- Pressures are measured by conventional transmitters or pressure gauges.
- Flows are measured by conventional differential devices, such as modified venturi. The flow elements are located in the piping, and flow transmitters are located close to the piping.
- Liquid levels are measured by conventional level transducers.
- Helium and hydrogen isotope concentrations in the process streams are measured by gas analyzers, such as gas chromatography, mass spectrometer and/or ionization chamber.
- Pneumatic valve positions are monitored by miniature analog proximity transducers.
- The status of pumps and compressors is monitored by MCC (motor control) relays.

Other Design Considerations

Overpressure Protection. The following sources of overpressure have been identified in the PSA demonstration facility:

- Cryogenic Fluids: Liquid or vapour at cryogenic conditions could undergo significant volume expansion if it is allowed to warm up to ambient temperature. This could lead to overpressure under confined conditions.
- Electric Heaters, Pumps and Compressors: These could cause overpressure as a result of instrumentation and control or operating errors.
- Failure of Interfacing Systems: A high pressure utility (helium, cooling water), if leaked into the process, could pressurize it above the design limits.

- Failure of valves to open or to close: Valve failing in inappropriate positions could possibly result in overpressure.

The PSA demonstration facility will be protected against all the potential causes of overpressure by means of relief valve and/or rupture disks.

Tritium Inventory. The tritium inventory in the PSA demonstration facility is primarily that of the tanks TK1 to TK2, PSA columns, vacuum pumps and compressor. The maximum tritium inventory in the facility is estimated to be about 0.1 g (1000 Ci).

The majority of the tritium inventory will exist in the buffer/feed tanks TK1 and TK2, and the two PSA columns. Only very small amount of tritium will exist in the vacuum pumps and compressor.

Material Considerations. In order to minimize the release of tritium, the PSA demonstration facility is constructed using metal components whenever possible. Austentic stainless steels (316 series) are most preferred, since they have good physical and corrosion resistance properties.

Future Design Work

Spectrum Engineering Corporation Ltd. (SECL) has been awarded a contract to carry out the detailed engineering design of the PSA demonstration facility. The detailed design tasks provided by SECL will include the preparation of equipment and I & C specifications, assembly and detail drawings, logic and control diagrams, safety analysis report and design manual. Procurement, fabrication/assembly, test and delivery of the pretested PSA package will then follow.

ACKNOWLEDGEMENT

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