Argon Purification
Reference and
Recommendation

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Approved: Kent J. Rumpf Date: 5-31-91

Overview:

This engineering note is a reference for future consideration on the purification of argon. The original concern was for the possibility of argon contamination from components in the cryostats over long-term storage. An argon purification system could also be useful for purifying the contents of the argon dewar. The general conclusion is that most of the systems researched are too expensive at this time, but the recommended choice would be Centorr Furnaces.

Types of Purification Considered:

There were three basic types of purification systems which were to be considered. The first was the molecular sieve. This method would have been the preferred one, because it was claimed that it could purify liquid argon, removing liquid oxygen from the argon. However, none of the commercial companies researched provided this type of purification for use with liquid argon. Most companies said that this type of purification was impossible, and tests at IB-4 confirmed this. The second system contained a copper oxide to remove gaseous oxygen from argon gas. The disadvantage of this system was that the argon had to be heated to a gas, and then cooled back down to liquid. The third system was similar to the second, except that it used tungsten or another material like titanium. This system also needed to heat the argon to gas, however the advantage of this system was that it supposedly removed all contaminants, that is, everything except for inert gases. Of the three systems, the third is the type manufactured by Centorr Furnaces, which uses a titanium charge.

Specifications:

The specifications decided upon when researching different companies were as follows:

- 1) A starting O₂ level (the main contaminant to be reduced) of approximately 2 ppm.
- 2) An ending O₂ level of approximately 0.5 ppm.
- 3) A cryostat pressure of about 5 psig, and a dewar pressure usually around 5 psig, but variable up to 13 psig.
- 4) The preferred method of purification would be to keep the argon in its liquid state, so that a vaporizer would not be necessary. However, there were no companies found which could purify argon in its liquid state.
- 5) The shortest possible time schedule for the purification of the argon.

Required Flow Rate:

This was determined as follows: For a time schedule of one week (7 days), operating 24 hours per day, this corresponds to 168 hours. Assume a cryostat volume of 5000 gallons of saturated liquid argon is to be purified. This means that a flow rate of 29.76 gph, or 3.979 cfh Lar is required. However, if the argon is to be purified as a gas, then the necessary flow rate is

$$\frac{5000 \text{ gal Lar}}{168 \text{ hrs.}} \times \frac{0.13368 \text{ ft}^3}{1 \text{ gal}} \times 1373.424 \frac{\text{mg Ar}}{\text{cc Lar}} \times \frac{1}{7.766} \frac{\text{cc Gar}}{\text{mg Ar}}$$

$$= 703.6 \text{ cfh Gar,}$$

where the densities are taken at a pressure of 1.4 bars = 20.3 psia = 5.61 psig. Note that the pressure is an important factor, because it changes the argon density. The larger the pressure, the smaller the required flow rate. One idea would be to use a pump to increase the pressure. For reference, the next page shows a table of the required flow rates for some other pressures.

<u>Pressure (bars)</u>	<u>Pressure(psia)</u>	<u>Density Ratio</u> <u>(Lar/Gar)</u>	<u>Flow Rate (acfh)</u>
1	14.5	240.74	957.80
2	29.0	127.48	507.17
3	43.5	87.64	348.66
4	58.0	67.06	266.80

The above numbers are based on a starting cryostat pressure of 5.61 psig, or 1.4 bars, for liquid argon, and an ending state of saturated gaseous argon at the pressure indicated. The density of liquid argon is 1373.424 mg/cc at 1.4 bars, and the densities of saturated gaseous argon were taken from engineering note 142 - Thermophysical Properties of Argon. A complication in the purification process, however, is that most companies, including Centorr, require room temperature gas at the inlet to the purifier. In this case, the increase in temperature from the saturated temperature to room temperature at 294 K, reduces the density of gaseous argon greatly. In the case of a constant pressure of 1.4 bars, the density changes from 7.766 mg/cc to 2.297 mg/cc, which results in a required flow rate of 2379 cfh. These calculations are based on a time schedule of one week.

Companies:

The following is a list of companies considered. The list was based on the company listings in the Thomas Registers, volume 10, under the heading, "PURIFIERS: GAS". Notes about each company are included.

1) Resource Systems, Inc.

(201) 884-0650

East Hanover, NJ

palladium-alloy hydrogen purification

catalytic/molecular sieve gas purifiers

industrial gas purifiers

2) Airco Gases Div. of B.O.C. Group

for removing oil, water, oxygen...

3) Matheson Gas Products

4) Linde Specialty Gases, Union Carbide Corp.

1-800-982-0030

Somerset, NJ

pure and ultra-pure gases

gas handling equipment

5) Johnson Matthey Fabricated Equipment

(215) 341-8535

Wayne, PA

2 to 400 scfh hydrogen

palladium alloy diffusion cell

total impurities < 10 ppb

6) Ergenics

Wyckoff, NJ

hydrogen and noble gas purification

non-evaporable getters

7) Vacuum/Atmospheres Co.

Hawthorne, CA

recirculating inert gas

8) Gas Equipment Engineering Corp.

(203) 874-6786

fax: (203) 878-4123

sales rep: Jeram Kamlani

Milford, CT

packaged plants for purification of He, Ar, N₂, air, or other gases

capacities of 6-100 cfm (360-6000 cfh)

9) Superior Air Products Co.

Tyler, TX

oxygen, nitrogen, liquid air and argon producing plants

single and double recitification

hydrogen and helium

Most of the companies could not work with the high flow rate required for our application. The companies which gave some response are the following:

1) Resource Systems, Inc. sent some literature about their systems (see Appendix 1). Although a price quote was not received, there is a form included to request one. This company would be worth investigating as an alternative to Centorr Furnaces. They advertise up to 20,000 cfh flow capabilities, but they prefer 100 cfh for assembly and testing purposes.

2) Linde representative Brian Hutchens noted that the high flow rate and large volume would cause problems. He suggested developing something with their bulk group to handle the large volume.

3) Gas Equipment Engineering Corp. representative Jeram Kamlani said that there could be a problem if the vaporizer could not handle the large flow rate. Also, the system would have to be designed from scratch. The idea was to add hydrogen gas to the argon with an H_2O catalyst to remove water, and then to recondense and vent the H_2 gas. The projected cost of design and manufacture was at least \$100,000.

4) Centorr Furnaces was the manufacturer of a smaller unit located at the M-6 beam line. This company provided the best specifications and price.

Centorr Furnaces:

The address of Centorr Furnaces is 542 Amherst Street, Nashua, NH, zip code 03063. The representative for Centorr Furnaces was Chuck Miller at (603) 595-7233. There is currently one of Centorr's standard models at the M-6 line. The unit is a model 2G-100-SS getting furnace, with a model 2A-100-SS inert gas purifier with oxygen analyzer. The unit works very well, producing O_2 levels below 0.1 ppm. For our purposes, the flow rate must be much higher than the standard 40 lpm (85 cfh) available for argon gas. Preliminary analysis by Centorr resulted in a design of a

purifier which could handle a flow rate of 250 cfh. The proposed unit was approximately 4 feet tall, 2 feet wide, and 2 feet deep, and the price was about \$12,700. Without considering temperature or pressure effects, we would require a flow rate of 1000 cfh in order to meet the time schedule of one week. However, with the change in density of gaseous argon at different temperatures and pressures, a more detailed analysis would be necessary to determine the exact flow rate required. Centorr Furnaces recommends a maximum inlet pressure of about 30 psig, or 45 psia. Their system uses a 3/8" pipe at the inlet and exit. As of this time, Chuck Miller is investigating the design of a purifier which could handle a flow rate of 1000 cfh, but he believed that this flow rate might be too large for their design. He could not give any estimate of the price. Appendix 2 includes some information from Centorr and a price quotation. These are not relevant to our particular application, but are useful for reference.

Appendix 1

Information from Resource Systems, Inc.

resource systems, inc.

SIX MERRY LANE • EAST HANOVER, NJ 07936 • 201/884-0650 • FAX 201/515-3166 • TELEX 64-2043

The enclosed literature describes Resource Systems' line of gas purification equipment used by leading manufacturers and research institutions in the electronics, fiber-optics, nuclear and metallurgical industries. Included are brochures describing Resource Systems' RSD and RCP Series of Hydrogen Purifiers, our compatible MSD Series of Molecular Sieve Dryers, our DSPS Series of Purifier Protection Systems and our GP Series of General Purpose Purifiers.

RSD-Series palladium alloy hydrogen purifiers behave as "absolute filters" passing only hydrogen and its isotopes. They represent the recognized state of the art in hydrogen purification. RCP Series purifiers combine hydrogen and oxygen catalytically at ambient temperature and can be used to remove either in the presence of an excess or stoichiometric amount of the other in a wide variety of gas streams. GP-Series purifiers are capable of removing multiple contaminants from various non-reactive process gases on a continuous basis.

RSI is a "Systems House" specializing in the engineering and manufacture of gas purifiers to order. We would be pleased to examine your requirements for the purification or up-grading of nitrogen, argon, oxygen or other process gases.

Sincerely yours,
RESOURCE SYSTEMS, INC.

Leonard R. Rubin
President

LRR/mac
Encs.

resource systems, inc.

REQUEST FOR QUOTATION

Ref.: _____ Date: _____

Name: _____ Title: _____

Affiliation: _____ Telephone: _____

Address: _____

Please supply the information requested about your process. Attach diagrams or further explanations concerning special requirements or special problems. Please fill out separate questionnaires for each feed stock to be processed.

(A) FEED STOCK SPECIFICATIONS	Maximum	Normal	Minimum	Units
Inlet Flowrate				
Inlet Temperature				
Inlet Pressure (specify absolute or gauge.)				
Allowable pressure drop from feed to product (if applicable)				
Complete feed analysis (Include H ₂ O, O ₂ & H ₂ concentrations.)				

(B) PRODUCT SPECIFICATIONS	Maximum	Normal	Minimum	Units
Outlet Flowrate				
Outlet Temperature				
Outlet Pressure (specify absolute or gauge.)				
Complete product analysis (Include H ₂ O, O ₂ & H ₂ concentrations)				

(C) SERVICES		Maximum	Normal	Minimum	Units
Electricity (Indicate phase, Voltage $\pm$ %, Hz.)					
Cooling Water	Pressure				
	Inlet Temperature				
	Hardness				
Steam	Pressure				
	Temperature				
Compressed Air	Pressure				
	Temperature				
	Dew Point				

D: FURTHER INFORMATION

1. Where will the unit be located? (Circle One) INDOORS/OUTDOORS.

What is the ambient temperature at location? _____ °C (Max) _____ °C (Min.)

2. If drying is required, approximately 10% of the product gas is used to purge and reactivate the dryers. If this is objectionable, a separate purge can be provided, a vacuum reactivation system can be provided, or provisions can be made to recycle the purge gas to the inlet of the process.

Do you prefer: (Circle One) SELF PURGE/SEPARATE PURGE
VACUUM REACTIVATION/RECYCLE?

3. What is the number of hours per working day: 8, 16, 24? _____

What is the number of working days per week? _____

4. What is the end use of the purified gas? _____

5. DESIGN CODES. Pressure vessel code _____

Others _____

6. Country of destination _____

7. Do you have any special inspection requirements? Explain. _____

8. Do you have any special documentation requirements? Explain. _____

GP-SERIES GENERAL PURPOSE GAS PURIFIERS

GP-100A

GP-100

GP-SERIES DESIGN FEATURES:

- ABILITY TO SERVICE VARIOUS PROCESS GASES
(argon, nitrogen and other non-reactive gases)
- SIMULTANEOUS REMOVAL OF MULTIPLE CONTAMINANTS
(oxygen, water vapor, carbon dioxide, ammonia,
halides, sulfides and other reactive or polar molecules)
- CONTINUOUS OPERATION
(regeneration without interruption of flow)
- FULL OR SEMI-AUTOMATIC REGENERATION
(operator not required during regeneration)
- RECHARGEABILITY
(convenient replacement of catalyst and/or desiccant)
- FINELY "POLISHED" PROCESS STREAMS
(automatic removal of unsuspected trace impurities)

GP-SERIES GAS PURIFIERS

General Statement

In the GP-Series of General Purpose Gas Purifiers, redox reactions and absorption at ambient temperature are used to remove impurities from non-reactive gases. These reactions take place as the feed stream is conducted over beds of two different solid reactants. Both beds require regeneration from time to time. Uninterrupted delivery of high purity gas is provided by means of duplicate gas trains. This design allows one train to function as a purifier while the two beds of the other train undergo automatic regeneration.

Process

As shown in the accompanying diagrams, each gas train contains a reactor and an absorber. A switching arrangement allows the user to change from one train to the other so that at least one functioning train is always available for continuous through-put of purified gas. The reactor section of each train contains a highly dispersed reductant which behaves as a reagent in the oxygen binding reaction and provides the necessary surface area to promote the redox reaction at room temperature. The absorber section contains molecular sieve.

Oxygen, water vapor, carbon dioxide, ammonia, and other polar molecules are removed from the feed stream by the combined redox-absorption sequence. In addition, the GP-Series supplies a fine "polish" to the process stream with respect to trace amounts of unsuspected impurities. For example, hydrogen sulfide or other sulfur containing gases will be chemisorbed on the reactant bed to form a tightly held product. Since the quantities of this type of impurity are generally small, their affect on the life of a GP-Series system will be minimal. Clean out plugs are provided for the replacement of the reductant and absorbent charges if the system becomes poisoned.

Operation

Once the GP-Series purifier has been connected to the user's gas supply, process equipment, vent line and a 120 VAC power source, all that is required is for the operator to pressurize the system. To insure continuous production, the impure gas is automatically fed to one of the two parallel trains (see diagrams.) While that train functions to supply high purity gas to the user's process stream, the other is being regenerated or is in the stand-by mode.

When the user determines that regeneration of the first train is required, he initiates a series of steps that automatically switches the feed stream from the first train to the second or stand-by train. While the second train takes over the job of supplying purified gas, the first train undergoes regeneration. When the second train needs regeneration, the switching process is again initiated by the user and the same sequence of events occurs automatically. On-board valves, flow meters and gauges are used to make the initial adjustments of pressure and flow rate to meet process specifications. Annunciators display the status (operating, regenerating or stand-by) of both trains continually.

Regeneration

The beds are regenerated by back-flushing with a reducing gas in the case of the reductant bed and a dry gas in the case of the absorbent bed. Regeneration sequencing and timing are fully automatic once initiated. Initiation is by key switch on the GP-100A, by manual switch on the GP-100. Switching of gas trains occurs automatically in the GP-100A and is done manually on the GP-100 prior to initiating regeneration.

Options

For circumstances in which unusual quantities of entrapped oil may be present in the feed gas, RSI can supply a guard chamber charged with activated charcoal. Inclusion of this option between the gas source and the GP-Series purifier will maintain the normal performance of the purifier by preventing the oil from fouling the reactant beds. A particulate filter is available for feed gases containing entrained solids.

CODE	ITEM
S	SOLENOID VALVE
C	CHECK VALVE
V	METERING VALVE
TC	TEMP. CONTROL
R	ROTAMETER, W/VALVE
G	PRESSURE GAGE

SPECIFICATIONS

GP-Series Purifiers, are completely contained within metal cabinets, and are installed between user's source of feed gas and his process equipment. Since the system operates at ambient temperature, power is required only for the operation of solenoid valves and to heat the off-stream beds during regeneration.

Detailed specifications for the **GP-100** and **GP-100A**, the smallest units of the standard line, are as follows:

CABINET DIMENSIONS: 24" wide x 20" deep x 32" high.

SHIPPING WEIGHT: Approximately 250 lbs.

POWER: 1000 watts maximum @ 120 VAC, 50/60 Hz. (240 VAC available.) Power used only during regeneration. Power drain is 10 watts (GP-100A) during normal operation.

MATERIAL OF CONSTRUCTION: All reactors, valves, fittings and tubing in contact with the process stream are stainless steel.

TERMINATIONS: Terminations are 1/4" Swagelok. All inlet and outlet gas lines emerge from the top panel for ease of connection to user's equipment. Pressure gauges, flow meters, electrical switches, annunciators and fuses are located on the front panel.

IN-PUT PRESSURE: 100 PSIG

THROUGH-PUT: 100 SCFH

PRESSURE DROP: 5 PSID total (due mainly to presence of check valves in the line.) Flow related ΔP is minimal.

IMPURITY LEVEL REDUCTION: 100 ppm O_2 and H_2O reduced to <1 ppm in the product.

CONSUMABLES: Approximately 30 cubic feet of commercial grade hydrogen at 10 PSIG is required for each regeneration cycle.

TIME BETWEEN REGENERATION: 100 hours (lesser quantities of impurities, lower flow rates yield longer times between regenerations.)

Larger capacity, higher pressure and/or larger flow rate systems are available on special order. Resource Systems will be pleased to respond to requests for additional information.

PRODUCT LISTING

- Industrial Gas Purification Systems
- Catalytic Hydrogen Purifiers
- Palladium Alloy Hydrogen Purifiers
- Molecular Sieve Dryers
- Hydrogen Reclamation/Recirculation Systems
- Engineering Service

resource systems, inc.

SIX MERRY LANE • DORINE INDUSTRIAL PARK • EAST HANOVER,
NEW JERSEY 07936 • TELEPHONE (201) 884-0650
TELEX: 64-2043 • CABLE ADDRESS: PURIFIERS

Represented by

INDUSTRIAL GAS PURIFICATION SYSTEMS

Resource Systems is a systems house specializing in the design and manufacture of special purpose gas purifiers. RSI also manufactures several lines of standard purifiers which are described adequately elsewhere. As a systems house, we welcome inquiries concerning your specific needs in gas purification.

Each purifier designed is, in essence, a chemical plant of specific function, equipped with appropriate unit processes to accomplish the specific end required by the client. Our strengths in this field consist of matching available technology and available hardware to the often conflicting parameters specified by our clients, e.g., high flow rates vs. low pressure drop, large capacity vs. small size, specificity vs. flexibility. As in most practical circumstances, rational trade-offs must be made from time to time to accommodate incompatible ends. We believe that the ability to make appropriate trade-offs or offer viable alternatives is one of our greatest strengths.

RSI, INC. • 1000 E. 10TH AVE. • DENVER, CO. 80202

TELEPHONE (303) 733-1111 • CABLE RSIDEN

SYSTEM CHARACTERISTICS

FEED STOCKS/IMPURITY LEVELS/FINAL PURITY

The system designed and built will depend on your definitions of what constitutes an impurity and what constitutes a pure gas. We would appreciate the opportunity to quote on your system. Specific problems, e.g., selective oxidation of one component in preference to another, may not be soluble in a practical manner. If there are obvious problems from your definitions in the attached questionnaire, our staff will contact you prior to the preparation of a quotation.

FLOW RATES

There is no upper limit to flow rates. As flows get larger, however, catalyst beds and the like also get larger and one eventually reaches the point where the final system would best be assembled at the point of operation. We feel most comfortable with units of 1000 CFM or less, which allows assembly, testing and shipping of a complete system.

There is similarly no lower limit to flow rates except the practical economic one of how large an investment is justifiable for vanishingly small flows.

PRESSURES

We will quote to your requirements. We have quoted from time to time for systems to operate at over 3000 PSIG (200 atm). Large diameter heavy wall chambers are obviously more expensive than thinner wall chambers. Our design and methods of construction already include ample safety factors. There is no need to specify pressure ratings above those you will actually encounter in service and many economic reasons not to.

PRESSURE DROP

Tall reactors can use a thinner wall at a given pressure than shorter ones of equivalent volume and cost less. Low pressure drop low profile systems will generally require a premium in cost over standard systems. Under normal circumstances, pressure drops in catalyst and desiccant beds are less than those associated with particulate filters and valves which may be in series with them.

MATERIALS OF CONSTRUCTION

Corrosion resistant materials are used as required.

COMPLEXITY

We can quote on fully automatic microprocessor controlled turnkey operations, or completely manual devices or anything in between. We will also quote on subassemblies (reactors, manifolds) for use in already existing gas trains. Complexity or simplicity will be appropriate to your requirements.

INTERFACING OTHER EQUIPMENT

In as much as each purifier system is built to order, special terminations, flanges, pipe sizes etc. can be specified during initial negotiations, e.g., "Feed Gas to enter rear of machine, 2" FPT. Product to exit from top 1/2" Swagelok." Information concerning floor loadings, maximum height and the like is best supplied early in the negotiations.

CODES

RSI standard equipment is designed and built to meet the requirements of good industrial practice. Electrical wiring is per NEMA 1 and pressure vessels are designed per ASME code. If special certification is required for specific prototype vessels, the cost will be included in the quotation. Wiring can be provided to appropriate NEC requirements for environments up to Class I Group B. Please indicate any special local, national or company codes which must be met.

resource systems, inc.

SIX MERRY LANE • DORINE INDUSTRIAL PARK • EAST HANOVER,
NEW JERSEY 07936 • TELEPHONE: (201) 884-0650
TELEX: 642043 • FAX (201) 515-3166

Represented by

Additional copies of this questionnaire are available from Resource Systems, Inc. or our nearest sales representative

resource systems, inc.

SIX MERRY LANE • EAST HANOVER, NJ 07936 • 201-884-0650 • Telex 64-2043 • Fax 201-515-3166

PRICE LIST

GENERAL PURPOSE GAS PURIFIERS

<u>MODEL</u>	<u>DESCRIPTION (SPECIFY VOLTAGE*)</u>	<u>PRICE</u>
GP-100	Semi-Automatic Gas Purifier, 100 SCFH	\$11750.
GP-100A	Automatic Gas Purifier, 100 SCFH	13250.
GP-400A	Automatic Gas Purifier, 400 SCFH	23600.
CC-100-1300-4SS	Activated Charcoal Bed, 100 SCFH, 1/4" Swagelok Terminations	320.
CC-500-1300-8SS	Activated Charcoal Bed, 500 SCFH, 1/2" Swagelok Terminations	755.
SS-4TF-0.2	0.2 Micron Particulate Filter, 1/4" Swagelok Terminations	195.
SS-8TF-0.2	0.2 Micron Particulate Filter, 1/2" Swagelok Terminations	280.

* 110-120 VAC, 50/60 Hz and 208/240 VAC, 50/60 Hz standard

Larger capacity, higher flow units available on special order. Prices on request.

All prices are FOB Factory (East Hanover, NJ).

Terms of Sale are Net/30 days.

Prices subject to change without notice.

PL/890926

Supersedes PL/861222

MOLECULAR SIEVE DRYERS

- Dries Gases to below -100°F Dew Point
- High Pressure Capabilities
- Large Water Capacity
- Wide Choice of Terminations
- Removes CO_2 , H_2S , SO_2 , NH_3 , HCl Other Polar Molecules
- Recommended for Use with RCP Series Catalytic Purifiers
- Convenient Desiccant Regeneration
- High Flow Rate Capabilities
- Quick-Change Configurations Available
- All-Welded Stainless Steel Construction

MOLECULAR SIEVE GAS DRYING SYSTEMS

RESOURCE SYSTEMS' MSD Series of molecular sieve dryers takes advantage of the well known capabilities of artificial zeolites to absorb and desorb large quantities of water reversibly. Because absorption on sieve material is a physical rather than chemical reaction, complete regeneration is practical and the materials of construction of the MSD have been chosen to allow for vigorous thermal regeneration of the desiccant charge without the need to dump and refill the dryer chamber. MSD dryers can be heated repetitively to temperatures as high as 1000° F (550° C) during regeneration without damaging the sieve material and effecting only the cosmetic aspects of the chamber exterior.

USES: The MSD Series of dryers was originally designed to complement Resource Systems' RCP Series of catalytic hydrogen purifiers, which produce water vapor as a by-product. To be compatible, the MSD dryer had to be capable of matching the high pressure and high flow rate capabilities of the RCP purifiers as well as the requirement for long uninterrupted runs between regenerations or dryer changes. The MSD chamber and all pads, screens and fittings are of 300-series stainless steels, which makes these dryers compatible with most process streams. This combination of properties defines a system of general utility in the drying of gases falling between discardable charges on one extreme and fully automatic two-bed cycling systems on the other.

The MSD dryer also reversibly absorbs polar molecules such as NH₃, HCl, H₂S, SO₂, CO₂, and some of the smaller organics. It should be noted that water is more strongly absorbed than these other molecules and will displace them. For this reason, breakthrough may occur of the coabsorbed species before breakthrough of water occurs.

The MSD dryer is most effective at ambient and lower temperatures. It will operate well at reduced capacities at bed temperatures up to 300° F (150° C) and can absorb water at temperatures as high as 600° F (300° C) if it has been regenerated at temperatures above 600° F.

DRYING CAPABILITIES: Freshly regenerated molecular sieve is capable of reducing water to approximately 35 ppb at 1 atmosphere, a dew point of -140° F. This is a transient phenomenon in that the sieve has relatively little capacity in equilibrium with water at this vapor pressure. Practical water contents of 1 ppm (dew point, -105° F) are easily achieved over long terms with the MSD, capacity being defined in terms of breakthrough at 1 ppm. Further advantages are available if process streams are dried at the highest pressures appropriate to the MSD and then used at lower pressures. The sieve traps more water in equilibrium with the higher vapor pressures in the feed gas and the effluent dew point is further reduced by expansion.

REGENERATION: The MSD is purged *in situ* to remove the process stream, assuming that the process stream is inflammable, toxic or otherwise dangerous. The purged MSD may then be removed to an appropriate tube or muffle furnace and heated to 400-600° F (200-300° C). One end of the MSD should be left connected lightly to a source of clean air or a safe purge gas. The purge gas should be turned on at 1-2 CFH when there is evidence of vapor leaving the open end of the dryer. Time at temperature while purging should be at least four hours, with overnight regeneration desirable if practical. If temperatures to 1000° F (550° C) are available, absorbed water can be removed to extremely low levels and both the total capacity of the MSD and the initial dew points of the process stream improved considerably. The exterior of the dryer will darken during the regeneration process. This is normal and does not impair the function of the dryer.

TERMINATIONS: Standard MSD Dryers are available with Swagelok (compression) tube fittings, Cajon VCR fittings and with female pipe threads. MSD dryers are available on special order with any terminations which can be welded to the dryer end plates, e.g., male pipe threads, Parker UltraSeal fittings or GraTec quick connect fittings.

ORIENTATION: MSD Dryers are intended for operation in a vertical position with the feed gas entering at the top. Up-flow may cause fluidization of the bed and attrition of the sieve material. Use in the horizontal position may cause settling and allow bypassing of the desiccant bed.

specifications

MODEL (a)	CAPACITY SCFH-%-hrs(b)	MAXIMUM OPERATING PRESSURE	TERMINATION	DIMENSIONS		WEIGHT Lbs.
				Diameter	Length (c)	
MSD - 50 - 110 - 4FF	50	1100 PSIG	¼" FPT	1.9"	11½"	2.1
MSD - 50 - 1100 - 4SS	50	1100	¼" Swagelok	1.9"	12"	2.1
MSD - 50 - 1100 - 4 VCR	50	1100	¼" VCR	1.9"	11¼"	2.1
MSD - 100 - 1300 - 4FF	100	1300	¼" FPT	2.9"	11¼"	5.3
MSD - 100 - 1300 - 4SS	100	1300	¼" Swagelok	2.9"	11¼"	5.3
MSD - 100 - 1300 - 4 VCR	100	1300	¼" VCR	2.9"	11"	5.3
MSD - 250 - 1100 - 8FF	250	1100	½" FPT	3.5"	16¼"	10.
MSD - 250 - 1100 - 6SS	250	1100	¾" Swagelok	3.5"	17"	10.
MSD - 250 - 1100 - 4 VCR	250	1100	¼" VCR	3.5"	17"	10.
MSD - 250 - 1100 - 8 VCR	250	1100	½" VCR	3.5"	17"	10.
MSD - 500 - 800 - 12FF	500	800	¾" FPT	4.5"	18¼"	19.
MSD - 500 - 800 - 8 VCR	500	800	½" VCR	4.5"	18¼"	19.
MSD - 1000 - 750 - 12FF	1000	750	¾" FPT	5.6"	23"	34.

Notes: (a) The model number is coded to indicate capacity, maximum operating pressure and termination. Terminations are coded M for male pipe thread, F for female pipe thread, S for Swagelok (compression) fittings and VCR for Cajon VCR couplings. The termination code includes a number which indicates the size of the pipe or compression fittings in 1/16's of an inch.

e.g. -12FF indicates ¾" female pipe fittings, both ends.

-4SS indicates ¼" Swagelok tube fittings, both ends.

-4 VCR indicates ¼" Cajon VCR fittings, both ends.

(b) Capacity is defined in terms of the amount of gas that can be treated prior to breakthrough. For convenience, the definition includes the number of hours, gas feed rate and gas moisture content.

e.g. 100 hrs. @ 100 SCFH @ 0.1% water in feed = 1000 SCFH-%-hrs.

100 hrs. @ 10 SCFH @ 1% water in feed = 1000 SCFH-%-hrs.

MSD dryers can treat gas flows at rates equal to or smaller than the "capacity" indicated by the code number. An MSD-100, for instance, can treat up to 100 SCFH of gas. If the flow rate is larger than 100 SCFH, a larger dryer should be specified, even though the MSD-100 might have adequate calculated capacity on the basis of breakthrough time.

(c) Length includes fittings.

Examples of Use of Graph

- (A) The flow rate of the feed gas is 100 SCFH. The dew point of the feed gas is -20°F when tested at 1 atm. The minimum allowable running time between regenerations is 100 hours. Find the smallest appropriate dryer.

Draw a vertical line to the curve from -20°F and a horizontal line to the right axis from the curve. Read approximately 0.04% H_2O by volume.

$$0.04\% \times 100 \text{ SCFH} \times 100 \text{ hrs.} = 400 \text{ SCFH-\%hrs.}$$

The smallest unit with sufficient capacity is the MSD-500.

- (B) A feed gas is at 5 atm. The dew point of the product gas from an MSD is -100°F at 5 atm. Find the dew point of the dried product gas when expanded to 1 atm.

Draw a vertical line to the curve from -100°F and a horizontal line to the left axis from the curve. Read approximately 0.001 torr. Divide 0.001 by 5. Reduced vapor pressure is approximately 0.0002 torr. Draw a horizontal line from 0.0002 torr to the curve and a vertical line to the temperature scale. Read a dew point of -120°F for the expanded product stream.

OTHER PRODUCTS

- Industrial Gas Purification Systems
- Catalytic Hydrogen Purifiers
- Palladium Alloy Hydrogen Purifiers

resource systems, inc.

SIX MERRY LANE • DORINE INDUSTRIAL PARK • EAST HANOVER,
NEW JERSEY 07936 • TELEPHONE (201) 884-0650
TELEX: 642043 • CABLE ADDRESS: PURIFIERS

Represented by

resource systems, inc.

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Telex 64-2043 • Fax 201/515-3166

PRICE LIST MOLECULAR SIEVE DRYERS

<u>MODEL</u>	<u>SCFH-%-hrs</u>	<u>TERMINATION</u>	<u>PRICE</u>
MSD-50-1100-4SS	50	1/4" Swagelok	\$205.00
MSD-50-1100-4VCR	50	1/4" VCR	\$235.00
MSD-100-1300-4SS	100	1/4" Swagelok	\$320.00
MSD-100-1300-4VCR	100	1/4" VCR	\$350.00
MSD-250-1100-4SS	250	1/4" Swagelok	\$525.00
MSD-250-1100-6SS	250	3/8" Swagelok	\$535.00
MSD-250-1100-4VCR	250	1/4" VCR	\$555.00
MSD-250-1100-8VCR	250	1/2" VCR	\$585.00
MSD-500-800-6SS	500	3/8" Swagelok	\$730.00
MSD-500-800-8SS	500	1/2" VCR	\$755.00
MSD-500-800-8VCR	500	1/2" VCR	\$805.00
MSD-1000-750-8SS	1000	1/2" VCR	\$990.00
MSD-1000-750-8VCR	1000	1/2" VCR	\$1040.00

Larger units available on special order. Variations in terminations available. Prices on request.

PRICES SUBJECT TO CHANGE WITHOUT NOTICE

Prices are FOB Factory (E. Hanover, NJ)

Terms Net/30

PL/890720
Supercedes PL/121787

Appendix 2

Information from Centorr Furnaces

CENTORR

FOR THE PURIFICATION OF INERT GASES

APPLICATIONS:

Ideal for research & development laboratories and other facilities where ultra-pure inert gas, such as argon or helium, is required.

- CONTROLLED ATMOSPHERE FURNACES
- CRYSTAL GROWTH
- SPUTTERING
- VAPOR DEPOSITION
- GLOVE BOXES
- GAS CHROMATOGRAPHY
- WELDING
- LASERS
- OPTICAL FIBER DRAWING

GENERAL

The original CENTORR Gettering furnace was developed for use in conjunction with our High Temperature High Vacuum/Controlled Atmosphere Furnaces. Demand for other uses soon demonstrated that these units had a market of their own.

Our current models incorporate a solid state controller which compensates automatically for changes in gas flow or for fluctuation in line voltage. On the cabinet front are located a Deviation Meter (for temperature), flow meter with valve, On-Off switch, and Power-On and Heater-On Lights. Gas Inlet and Outlet ports are located at the rear.

Installation requires only to plug into a standard 120 volt outlet and to make the gas connections. (220 volt units come with electric cord ready to be wired into your utility or plug of your choice.) We recommend the use of Stainless Steel Tubing and Fittings from the Gettering furnace to your process.

NEW SOLID STATE MODEL PROVIDES FULL AUTOMATIC CONTROL

Housed within the cabinet is the resistance heated furnace inside of which is located the replaceable Titanium charge. An internally mounted fan prevents overheating of the inside of the cabinet. The gettering charge is fabricated from high purity titanium wire (not dusty titanium sponge) and is fired in our high vacuum furnace to assure complete outgassing. After testing and Mass Spectrometer leak checking, the furnace is back-filled with pure argon and sealed-off to prevent contamination during storage or shipping.

When an inert gas, such as argon or helium, is allowed to flow through hot titanium, OXYGEN, NITROGEN, CARBON and WATER are removed. Tests utilizing an Oxygen Analyzer have shown that it is possible to purify argon having 9-10 ppm initial impurity to LESS THAN 10^{-6} ppm. Although no comparable test method exists for nitrogen and carbon, their equilibrium pressures over titanium are correspondingly low and they are removed quantitatively.

S P E C I F I C A T I O N S

Model	2G-100-SS-120	2G-100-SS-220
Gettered Gas Purity	Less Than 10^{-6} ppm	
Gas Flow: Argon	40 LPM (85 CFH)	
Helium	120 LPM (254 CFH)	
Maximum Pressure	500 kPa (73 PSIG)	
Getter Charge	90 g (.2 Lb) Titanium	
Charge Container	Stainless Steel (with proprietary liner)	
Typical Charge Duration	2.5×10^6 Liters (90,000 Cu Ft)	
Furnace Temperature	700-800 °C	
Power	1400 Watts	
Electrical Utility	120/1/50-60	220/1/50-60
Overall Dimensions *	53cm(21") Wide x 32cm(12.8") High x 55cm(21.5") Deep	
Weight	25 Kg (55 Lbs)	

* In Cabinet. Unit can also be mounted in standard 19" rack.

INERT GAS – THE ALTERNATIVE TO HIGH VACUUM

Much effort in our modern technology goes into producing HIGH VACUUM for an ever increasing number of applications. It is not always recognized that in many situations an INERT GAS of comparable purity can perform as well as vacuum and sometimes better. For example; Evaporation Rates are much slower in Inert Gas than in Vacuum. A vacuum of 1 millitorr has a gas pressure of about 10^{-6} atmospheres, usually composed of air, water vapor, or pump oil. The argon supplied in tanks usually contains from 5-25 ppm O_2 , N_2 , and H_2O , while argon from liquid supplies may contain a third of this total. Helium supplied from tanks contains these impurities plus some residual hydrocarbons. Thus these inert gases have total impurity contents of 2 to 50 ppm (about 2 to 50×10^{-6} atm.), and so corresponds to a vacuum of 2 to 50 Millitorr – not a particularly high vacuum by today's standards.

It is a simple matter to decrease the impurities in these gases by gettering to levels corresponding to those of really high vacuum. Titanium metal at 800-C has a great affinity for the impurities found in inert gases and these impurities diffuse rapidly into the bulk of the metal.

Because all of the getter is utilized, hot titanium getters have a very high capacity. A charge of 100g of titanium removes 32g O_2 before it begins to lose efficiency. A typical tank of argon contains 330 cubic feet of gas. If this contains 10 ppm O_2 , there will be . 12g in each tank, and 100g of titanium could remove all the oxygen in 300 tanks of gas or 100,000 cubic feet of gas. (Of course, a less pure gas or leaky fittings will consume the getter more rapidly.)

The dissociation pressure of TiO is about 10^{-44} atmospheres at 800 -C. Theoretically, the partial pressure of oxygen in inert gas can be maintained at this level until all the titanium metal is converted to TiO . The equilibrium partial pressure of N_2 over $Ti-TiN$ is 10^{-34} atm. Hydrocarbons are broken down in the getter and carbon absorbed almost as efficiently as N_2 and O_2 . Titanium also removes oxygen from H_2O , releasing hydrogen.

The impurities remaining after gettering are reduced far below the levels at which they can be measured directly and well below the lowest pressures produced in the highest vacuum (10^{-22} atmospheres have been measured in the gases purified by titanium gettering.) C & N_2 are probably reduced to similar levels although they cannot at present be measured.

CENTORR Manufacturers a complete line of High Temperature Vacuum and Controlled Atmosphere Furnaces for the Research and Development Laboratory, the Materials Testing and Evaluation Laboratory, and for Production.

CENTORR ASSOCIATES, INC. Route 28, Suncook, N. H. 03275

Tel: 603 485-9504 TELEX - 943434
CENTORR SUNC

CENTORR

GAS PURIFICATION APPLICATIONS NOW EXPANDED TO INCLUDE AN O₂ ANALYZER AS INTEGRAL UNIT OF THE POPULAR GETTERING FURNACE

APPLICATIONS:

Ideal for research & development laboratories and other facilities where ultra-pure inert gas, such as argon or helium, is required.

- CONTROLLED ATMOSPHERE FURNACES
- CRYSTAL GROWTH
- SPUTTERING
- VAPOR DEPOSITION
- GLOVE BOXES
- GAS CHROMATOGRAPHY
- WELDING
- LASERS
- OPTICAL FIBER DRAWING

The CENTORR Model 2A-100-SS combines the features of our standard Model 2G-100-SS GETTERING FURNACE and our Model 2D OXYGEN MONITOR. *Please see separate data sheets on each of these for more complete description of this unit.*

SPECIFICATIONS

Model	2A-100-SS-120	2A-100-SS-220
Electrical Utility	120/1/50-60	220/1/50-60
Gettered Gas Purity	Better than 10^{-6} ppm	
Gas Flow: Argon	40 LPM (85 CFH)	
Helium	120 LPM (254 CFH)	
Maximum Pressure	500 kPa (73 PSIG)	
Getter Charge	90g (.2 Lb) Titanium	
Monitoring Range	10^6 (Air) To 10^{-7} PPM	
Alarm Range	10^6 (Air) To 10^{-7} PPM	
Sample Flow Rate	.9 L.P.M.	
Monitor Sensor	Zirconium Dioxide Cell	
Furnace Temperature	700 - 800 °C	
Power	1400 Watts	
Electrical Utility	120/1/50-60	220/1/50-60
Overall Size *	53cm(21") Wide x 32cm(12.8") High x 55cm(21.5") Deep	
Weight	26.3 Kg (58 Lbs)	

*In Cabinet. Unit can also be mounted in standard 19" rack.

CENTORR Manufacturers a complete line of High Temperature Vacuum and Controlled Atmosphere Furnaces for the Research and Development Laboratory, the Materials Testing and Evaluation Laboratory, and for Production.

CENTORR ASSOCIATES, INC.

Route 28, Suncook, N.H. 03275-2399

Tel. 603 485-9504

TELEX - 943434 CENTORR SUNC

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Centorr Furnaces

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542 Amherst Street
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FAX (603) 595-9220

Vacuum Industries

Vacuum Industries
542 Amherst Street
Nashua, NH 03063
Phone (603) 595-7233
FAX (603) 595-9220

CENTORR SERIES 2 PRICE SHEET**GETTERING FURNACES**

2B-20-Q-120	D61-0027-120	\$2,400.00
2B-20-Q-220	D61-0027-220	\$2,525.00
2G-100-SS-120	D61-0023-120	\$2,725.00
2G-100-SS-220	D61-0023-220	\$2,825.00

GETTERING FURNACE/OXYGEN MONITOR

2A-100-SS-120	D61-0055-120	\$6,000.00
2A-100-SS-220	D61-0055-220	\$6,125.00

OXYGEN MONITORS

2D-120	D58-0131-120	\$4,400.00
2D-220	D58-0131-220	\$4,525.00

ACCESSORIES/SPARES

ZIRCONIUM CELL (2A&2D)	A61-0021	\$1,000.00
TITANIUM CHARGE (2A&2G)	D61-0001-9	\$ 370.00
COPPER CHARGE (2A&2G)	D61-0001-11	\$ 370.00
TITANIUM CHARGE (2B)	B61-0030	\$ 240.00
COPPER CHARGE (2B)	B61-00666	\$ 240.00
PARTICLE FILTER	21888-4-5	\$ 30.00
GASKETS		\$ 3.00

ABOVE PRICES ARE IN U.S. DOLLARS, F.O.B. ROCKFORD, IL USA
AND ARE SUBJECT TO CHANGE WITHOUT NOTICE.

These prices do not include representatives' commission.
These units are available for 2 week delivery ARO.
Acceptable payment terms are Net 30 Days.

EFFECTIVE DATE: February 1991

ff\S2Prices

A member of the TI Group

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(215) 244-4900