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DEMONSTRATION OF A CYLINDER FILL SYSTEM BASED ON SOLID ELECTROLYTE OXYGEN SEPARATOR (SEOS) TECHNOLOGY: EARLY FIELD ASSESSMENT AT A USAF MAINTENANCE FACILITY

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711 Human Performance Wing
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The goal of the effort was to conduct an early field assessment of SEOS oxygen-generation technology. A SEOS breadboard for charging high pressure oxygen cylinders was installed in a maintenance facility at Oklahoma City-Air Logistics Center (OC-ALC), Tinker AFB OK. The SEOS breadboard was capable of generating 99.9+% oxygen at pressures up to 2,200 psig using electric power. The oxygen was stored in high pressure cylinders. The oxygen was tested per MIL-PRF-27210, Aviator's Breathing Oxygen (ABO), and it passed the ABO specification. The SEOS oxygen production unit worked well to fill aircraft oxygen bottles. On 20 Nov 09 the first aircraft oxygen bottle was filled with SEOS oxygen. During the effort several electrical problems on the compressor and ancillary electrical equipment were addressed. The SEOS electrochemical stacks used to generate the high purity oxygen functioned as expected. Tinker AFB operating personnel found the system very easy to use and it reduced safety risks associated with frequent change-out of vendor-supplied oxygen bottles. The early field assessment effort will be continued under USAF Contract F41624-00-C-6000.</td></tr>
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Section

Executive Summary

The goal of the effort was to conduct an early field assessment of SEOS oxygen-generation technology and obtain user feedback and lessons learned. A SEOS breadboard for charging high pressure oxygen cylinders was installed at a maintenance facility at Oklahoma City-Air Logistics Center (OC-ALC), Tinker AFB OK. OC-ALC, Air Products and Chemicals, Inc., Ceramatec Inc., and the Air Force Research Laboratory (AFRL) worked collaboratively on this effort. Tinker AFB modified the facility to allow integration of the SEOS breadboard into its existing high pressure oxygen system. The SEOS breadboard was capable of producing 99.9+% oxygen at pressures up to 2,200 psig. The oxygen was stored in high pressure cylinders and was used to fill aircraft oxygen bottles. The oxygen was tested several times per MIL-PRF-27210, Aviator's Breathing Oxygen (ABO), and it passed the ABO specification. On 20 November 09 the first aircraft oxygen bottle was filled with SEOS oxygen. During the effort several electrical problems on the compressor and ancillary electrical equipment were addressed. The SEOS electrochemical stacks used to generate the high purity oxygen appeared to function as expected. The program goal was to operate the breadboard for one (1) year at the user site. This report documents the first six (6) months of the early field assessment period. The effort will be continued for an additional six (6) months under USAF R&D Contract F41624-00-C-6000.

The SEOS oxygen production unit worked well to fill aircraft oxygen bottles. The system successfully delivered oxygen at a flow rate, purity, and pressure meeting ABO requirements, and the Tinker AFB operating personnel found the system very easy to use. However, there were operating issues with some of the auxiliary equipment, which should be addressed in future units.

1.0 Introduction and Background

1.1 Introduction

This effort assessed the "real-life" performance of an advanced breadboard comprising oxygen-generation and cylinder-fill compression equipment developed under a research contract between Air Products and AFRL. The oxygen generation is accomplished using a planar ceramic, electrolytic membrane consisting of an advanced electrolyte. User feedback provided valuable information on the performance of the system and the technology, and will be beneficial in directing future development of this advanced oxygen-generation technology.

A six (6) standard liter per minute Advanced SEOS Breadboard (previously built and demonstrated to the Air Force under R&D contract F41624-00-C-6000) was modified and installed on a mobile cart with oxygen compression equipment. This breadboard was then integrated into the existing high pressure oxygen system at a maintenance facility at Tinker AFB OK. An important element of the integration was that the breadboard could be easily disconnected and replaced by a vendor supplied high pressure oxygen cylinder, if the breadboard malfunctioned.

1.2 Background: Design and Operation of SEOS Stacks

The ITM SEOS Oxygen Generator uses a stack of electrically-conductive ceramic membranes to separate and recover oxygen from air. At its most basic level, a solid electrolyte oxygen separator consists of an interconnect and an electrolyte plate with two electrodes, as illustrated in Figure 1. An oxygen-containing stream passes over the electrolyte plate; oxygen molecules are electrochemically reduced to oxygen ions on the cathode and are transported through the electrolyte as oxygen ions due to an applied electric potential. On the opposite side, the oxygen ions combine to produce oxygen molecules and free electrons. The interconnect serves to isolate the oxygen permeate stream from the air stream and to pass the electrons (current) to the next system. In practice, additional components are also required, including glass seals and structurally-supporting materials. Because these devices typically operate at elevated temperatures (600-750°C, 1100-1400°F), the interconnects are made from electrically-conductive ceramics.

The ITM SEOS stack (Figure 2) consists of several SEOS membranes arranged in a planar fashion, such that they are in series electrically and are in parallel with respect to the flow of the feed gas. The SEOS stack is electrically isolated from the remainder of the system in a way analogous to the electrically-isolating methods used for high-voltage towers. Additional details on general SEOS technology are included as Appendix A.

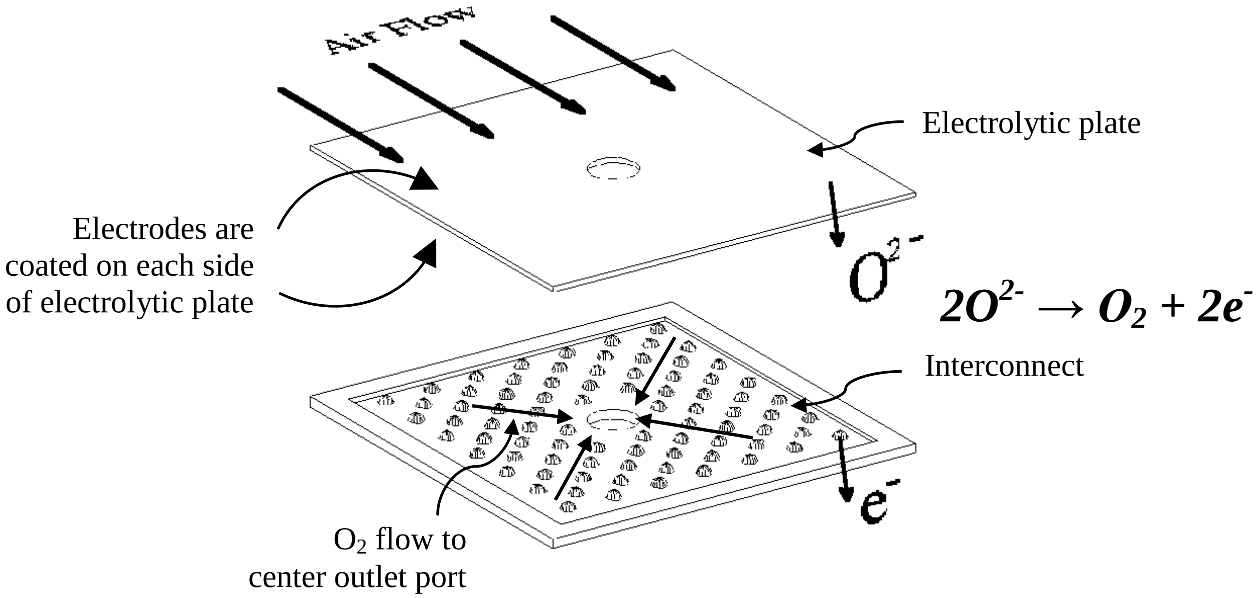

Figure 1. In this "exploded" view of a SEOS oxygen-generating couplet, air flows across the electrolyte. Oxygen is ionized on the cathode (not shown) and is transported through the electrolyte as oxygen ions due to an applied electric potential.

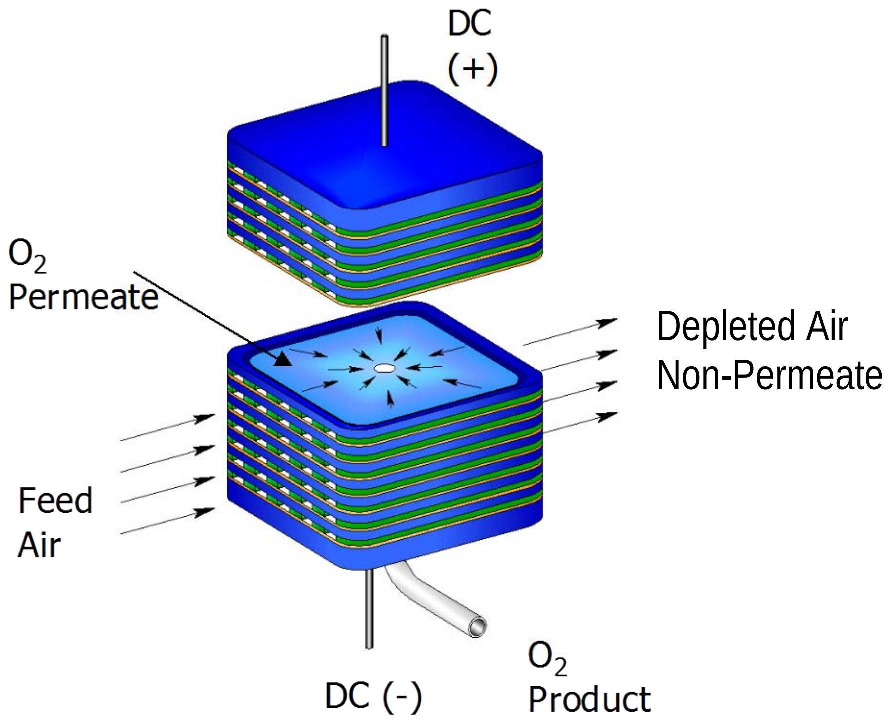

Figure 2. In this "exploded" view of an ITM SEOS stack, air flows in parallel through channels in the stack face and across the electrolyte. The oxygen product is isolated by a seal between the rim of the interconnecting plate and the electrolyte, collected in the central manifold, and exits from the stack through the centrally-positioned oxygen piping.

2.0 Discussion of Results

2.1 Design

Prior to beginning the effort, a SEOS breadboard oxygen sample was collected and analyzed at a Wright-Patterson AFB laboratory to ensure SEOS oxygen conformed to MIL-PRF-27210G, Aviators' Breathing Oxygen. The results exceeded the military specification purity requirements. The analysis results are included in Appendix D.

Tinker AFB accomplished modifications to its facility to allow the integration of the SEOS breadboard into the facility's high pressure oxygen system. Tinker AFB also provided a piping and instrumentation drawing showing the modifications. Air Products was permitted to review the drawings. Site modifications also included a new 30A/120V AC electrical service for the SEOS unit.

Air Products conducted a Hazard Analysis of the modified breadboard. The methodology identified and analyzed potential safety hazards and defined safeguards to mitigate or minimize the risk level. All of the corrective actions identified in the hazard review, including materials changes, relief scenario evaluations, back flow prevention, secondary containment and documentation updates, were completed prior to operation of the unit.

2.2 Equipment Modifications

The breadboard was modified to adapt it to the high pressure oxygen system. The system changes included high/low pressure shutdowns, relocating compressor control switches and the adding independent air manifolds for each of the 3 slpm generators. Air Products also improved the general safety features of the breadboard installation, such as adding a locking mechanism on the cart to prevent rolling and securely mounting the generators to the cart. A simplified schematic of the breadboard is shown in Figure 3.

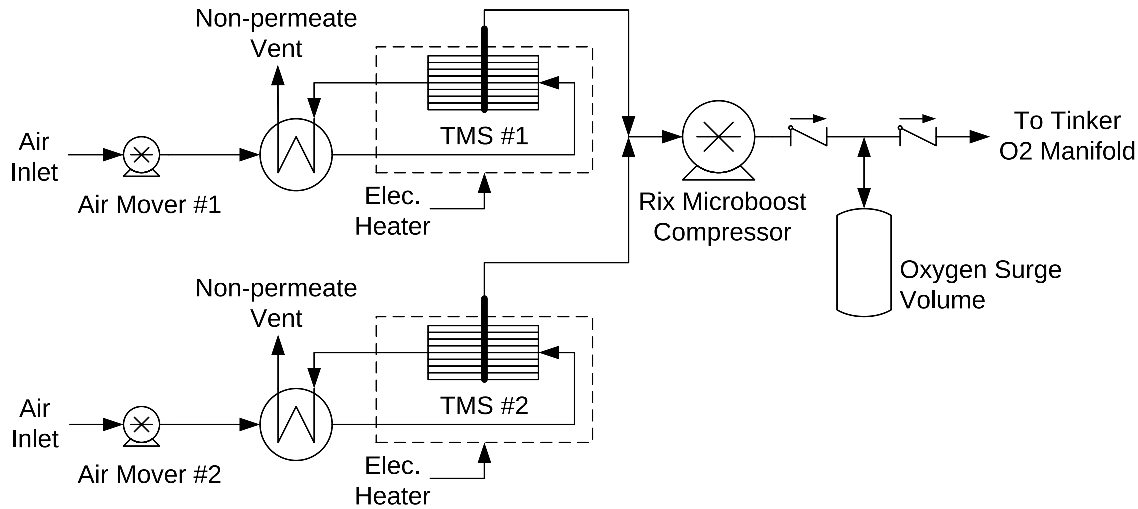

Figure 3. Simplified schematic of 6 slpm cylinder fill breadboard

Initial start-up tests showed the Rix Microboost Compressor could not properly restart when the discharge outlet line was pressurized. Modifications were implemented to depressurize the outlet discharge prior to a compressor restart. A solenoid valve was installed and interlocked to the compressor electronics, allowing it to open for one (1) minute to vent oxygen prior to compressor start. A performance test of the entire system was successfully completed at the Air Products facility prior to shipment to Tinker AFB.

2.3 Installation

The SEOS cylinder-fill system was installed at OC-ALC, Tinker AFB on 15-20 November 2009. The Tinker AFB modifications allowed successful integration of the breadboard to the facility. The breadboard began producing oxygen within 72 hours of the Air Products startup team arriving on site, including unpacking, setup, installation, checkout, heat-up and start-up.

2.4 Start-up

The SEOS breadboard was started, tested and operating in the fully automatic mode at completion of the installation period. Tinker AFB personnel were trained in start-up, operation, shutdown, oxygen sampling and data logging of the system.

On 20 November 2009 Tinker personnel took two oxygen samples and submitted them to the Tinker AFB laboratory for analysis. The Tinker AFB laboratory confirmed that the oxygen samples met MIL-PRF-27210G, Aviators' Breathing Oxygen. In general, oxygen samples were collected and analyzed every forty-five (45) days.

Pictures below show the SEOS breadboard at Tinker AFB.

Photograph #1. SEOS breadboard installed at OC-ALC maintenance facility.

Photograph #2. SEOS breadboard shown with facility high pressure oxygen supply system.

2.5 Operation and Maintenance

The purpose of the early field assessment at a user site was to evaluate the performance of the breadboard in an actual operating environment. A Narrative Logbook of some events during the effort is provided in Appendix C, and the operating manual for the breadboard is in Appendix B. The system operated normally from 20 November 2009 to 1 December 2009, when the Rix oxygen compressor shut down. A loose power cable was discovered and then secured; and the unit returned to normal operation.

On 4 December 2009, the Rix compressor began to intermittently fail to restart after normal cyclical on/off operation. Tinker personnel observed the compressor would restart normally if the system was "re-booted" by powering down the control system. The oxygen generators were not affected. The root cause for the compressor control issue was a switch on the compressor suction interlock circuit. The interlock is designed to prevent the Rix compressor from operating without sufficient feed pressure; this feature prevents contamination of the oxygen product. However, the compressor feed circuit did experience low pressure conditions when the compressor shut down for extended periods. This issue was corrected by adding a five second delay timer.

The inlet air movers experienced mechanical and electrical problems on 13 January 2010, which resulted in some system downtime. It was discovered that both air movers and an air mover power supply malfunctioned. Both air movers showed significant wear on the diaphragm and inlet and exhaust flappers. Air Mover #1 (Oxygen Generator #1) was replaced with a spare unit, and an attempt was made to rebuild Air Mover #2 by installing a new head gasket, filter, inlet and exhaust flappers, diaphragm, and hold-down screws. The rebuild was unsuccessful, and Air Mover #2 required replacement on 8 March 2010. It is likely that electrical over-load caused the power supply to fail. The power supply was replaced during an Air Products maintenance trip on 16-18 February.

Oxygen Generator #1 and the compressor were returned to normal operation on 18 February. Oxygen Generator #2 was returned to normal operation on 8 March. The complete breadboard was on-line 26 March 2010 following a successful oxygen purity analysis.

The system remained on-line until 23 April 2010, when the oxygen compressor began to experience control issues. The compressor would occasionally not automatically restart. However, the compressor would start if the manual restart button was held for 90 seconds. A preliminary evaluation suggests that this condition was caused by a timer sequencing upset. This issue was resolved with a system restart, but it will be further investigated during the next maintenance visit scheduled under USAF R&D contract F41624-00-C-6000.

Tinker AFB experienced several prolonged power outages in May and June due to local construction activity. These events caused intermittent oxygen generator operation. Air Mover #1 (Oxygen Generator #1) failed on 4 June 2010 and Oxygen Generator #2 was operating at 80% capacity after the power outages. These issues will be addressed during the upcoming maintenance visit. The breadboard is currently supplying oxygen at a reduced capacity. However, this reduced oxygen production capacity appears sufficient to meet the OC-ALC facility needs.

3.0 Conclusions and Recommendations

A six (6) standard liter per minute Advanced SEOS Breadboard (built and demonstrated to the Air Force under Contract Number F41624-00-C-6000) was integrated into the existing high pressure oxygen system at the maintenance facility at OC-ALC, Tinker Air Force Base, OK.

Feedback from the Tinker AFB facility personnel was very positive. They rated the controls of the unit as very easy to navigate and use. They also noted that it was significantly safer, smaller and quieter than the system that it replaced, with an associated labor reduction (see the user questionnaire in Appendix E).

SEOS oxygen production is a viable alternative to cylinder delivered oxygen. The system successfully delivered oxygen at a flow rate, purity, and pressure sufficient to meet the needs of the Tinker facility. The breadboard successfully continues to deliver oxygen, even after several power outages.

Future efforts should focus on improving the reliability of the air movers and extending the preventative maintenance interval for the Rix Microboost compressor. Regular compressor preventative maintenance is currently conducted quarterly. It is expected this maintenance interval can be extended. Also, more reliable air movers should be investigated.

This early field assessment of SEOS technology will be continued under existing USAF R&D contract F41624-00-C-6000. The goal is to complete a full one (1) year assessment period at the user site.

APPENDIX A – SEOS Technical Background Information

OXYGEN GENERATION USING SEOS ION TRANSPORT MEMBRANES

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INTRODUCTION

Oxygen is used by the military in medical, breathing, and metal fabrication and cutting applications. Historically, this oxygen has been supplied as high purity, compressed gas in cylinders or bottles and as liquid in dewars. The distribution and handling requirements for these products necessitate a significant logistics infrastructure and associated cost. Point-of-use oxygen generation nearly eliminates the required logistics infrastructure and, for this reason, oxygen generators, based on adsorption technology, have made significant in-roads in oxygen supply for the military. Uses of these generators, however, have been limited to applications that will tolerate the lower oxygen purity provided by such systems. Applications, which demand high purity oxygen, have no alternative to distributed oxygen and its associated logistics infrastructure requirements. A new technology, employing ion transport membranes (ITM), has the potential to provide many of these applications with point-of-use generation of high purity oxygen [1].

The ITM solid electrolyte oxygen separation (SEOS) technology is based on the principle of oxygen ion migration through a dense ceramic electrolyte membrane under the influence of an externally applied electrical potential, as illustrated in Fig. 1. The relationship between the equilibrium oxygen partial pressures on the anode and cathode side of the electrolyte is governed by the Nernst equation:

$$V_N = \frac{RT}{4F} \ln\left(\frac{p_{O_2,anode}}{p_{O_2,cathode}}\right) \qquad (1)$$

Removal of the oxygen product from the anode side of the electrolyte membrane results in the continuous production of pure oxygen. The ITM SEOS process enables the production of high purity oxygen at elevated pressure from a feed stream of ambient pressure air.

STACK MATERIALS

The core of ITM SEOS technology is an electrochemical stack fabricated from high-temperature conductive ceramic materials [2]. The solid electrolyte is based on cerium oxide, with dopants added to enhance both ion transport and membrane processability. To achieve sufficient oxygen ion conductivity through the electrolyte, the device must be operated at a temperature above approximately 600 °C. At these temperatures, doped ceria exhibits a significant performance advantage over zirconia-based materials. For example, the conductivity of Gd-doped ceria at 800 °C is about 0.1 S/cm, and is approximately one order of magnitude higher than that of YSZ [3]. The doped ceria electrolyte is combined with appropriate electrode materials to form an electrochemical cell. The electrode materials must be chosen to minimize or eliminate electrolyte-electrode interfacial resistances, to exhibit high ionic and electronic conductivity, and to be catalytically active for the electrochemical reduction and oxidation reactions. An SEM image of a porous electrode layer over the dense ceria-based electrolyte is shown in Fig. 2. Electrochemical test data have established cell performance over thousands of hours and have enabled optimization of electrolyte and electrode characteristics.

The principle of electrically driven ion migration provides the mechanistic basis for ITM SEOS technology. However, a device comprising several cells, in series or in parallel, is required for commercial use. An efficient means for accomplishing this goal involves a flat plate multi-cell stack. Each cell, comprising a dense electrolyte coated with porous anode and cathode layers, is in contact with a dense interconnect made from an electronically conductive perovskite material. A 32-cell ITM SEOS stack is shown in Fig. 3.

Each interconnect is featured to provide appropriate passages for the feed and product streams. In contrast to the electrolyte, the interconnect must be an ionic insulator and an electronic conductor. Because the interconnects provide the mechanical backbone of the planar ITM SEOS device, the materials used must provide the required strength, stability, degradation, and other properties and must be compatible with the electrolyte and electrode materials.

The repeat units of the ITM SEOS stack, connected electrically in series, also include biasing electrodes and offset glass-ceramic seals to maintain seal integrity under operating conditions. These measures are necessary to avoid delamination at the interface between the glass-ceramic sealant and the anode side of the doped ceria electrolyte during operation [4,5]. In addition, all stack materials must be carefully selected to meet criteria for thermal expansion match, chemical compatibility, and mechanical robustness, as well as for ionic and electronic conductivity.

STACK PERFORMANCE

The two primary considerations for long term ITM SEOS stack operation are electrochemical performance and mechanical integrity. Electrochemical performance is characterized by the stack Area Specific Resistance (ASR) under operating conditions. Fig. 4 illustrates the electrochemical performance for a 3-cell test stack over more than 6500 hours. A relatively stable ASR of approximately 0.6 $\Omega \cdot cm^2$ is evident.

The mechanical integrity of the operating stack as a function of time was measured using flow efficiency measurements. These measurements are based on the general relationship between electrical current and oxygen produced in a multi-cell ITM SEOS stack. The flow efficiency is defined as the ratio of actual O_2 product flowrate to theoretical product flowrate.

In a flow efficiency experiment designed to detect leaks, the product O_2 pressure is raised incrementally to a test level of 5-10 psig. If a leak is present in the stack, the flow efficiency will decrease as some O_2 product is forced through the leak. The data may be characterized by the slope of flow efficiency versus O_2 product pressure, which can be directly related to product loss. Flow efficiency data after 6500 hours of operation for the same stack are shown in Fig. 5. The slope of this flow efficiency plot was $m = -3.1 \times 10^{-4}$ psi^{-1}, indicating the absence of significant leaks. This flow efficiency slope was essentially unchanged from initial testing at the start of stack operation. Using such tests, the effect of thermal cycling, pressure cycling, current changes, and other operating parameters may be assessed.

Analytical techniques employing a high sensitivity discharge ionization detector have indicated a purity of greater than 99.99% for oxygen produced by a SEOS stack. Other tests indicate that feed stream contaminants, such as live chemical agents, are not found in the oxygen product [6]. In many important cases, the contaminants are also removed from the oxygen-depleted air stream. Similar results would obviously be expected for other carbonaceous contaminants, such as hydrocarbons and biological agents. Together with the electrochemical and mechanical performance data presented in Figs. 5 and 6, these results are extremely encouraging from the standpoint of long term operation and durability and are unprecedented in the literature.

BALANCE OF DEVICE

ITM SEOS technology offers the potential for producing a high purity oxygen product at elevated pressure via on-site generation. This compressed product can be generated electrochemically, without an external oxygen compressor. A typical generator, as illustrated in Fig. 6, comprises one or more electrochemical stacks, a thermal management system, an air mover, a power supply, and appropriate controls.

A low pressure feed air mover is the only moving part in an ITM SEOS oxygen generator. This is expected to result in lower maintenance and higher reliability compared with the commercially practiced options of pressure swing adsorption (PSA) or vacuum swing adsorption (VSA). This system would also be extremely quiet while operating. In applications where a pressurized air feed is available, zero moving parts would be required, and an ITM SEOS oxygen generator would be virtually silent.

The practical application of ITM SEOS technology requires applied voltages higher than the Nernst voltage, V_N. This overpotential increases the productivity per cell. However, the increased overpotential also increases the specific power. This effect is analogous to a pipeline, in which flow is proportional to velocity, but power is proportional to the square of the velocity. Because the cells in an ITM SEOS stack are configured in series, the total oxygen production is directly proportional to the applied DC current and the number of cells in the stack. Thus, a direct trade-off may be made between the cost of the stack (proportional to the number of cells) and the specific power (kWh per unit of oxygen) required for operation.

For the majority of applications, the recovery of heat from the non-permeate stream is essential in operating an ITM SEOS oxygen generator. An effective means to accomplish this objective is via gas-to-gas heat exchange, as shown in Fig. 7. Because oxygen is removed from the feed stream by the ITM SEOS stack, the feed air stream will require an additional input of energy. In many cases, this energy can be supplied by the resistive heating of the stack itself. Alternatively, the oxygen product can also be included in the gas-to-gas heat exchange.

Although simple in concept, the design of a high-temperature gas-to-gas heat exchanger is complicated by many factors, including significant thermal radiation, low heat transfer coefficients, and strong coupling with the surrounding insulation system. In addition, the design is typically constrained by the need to maintain the steady-state and transient metal temperatures below certain thresholds to minimize both the generation of chromia-containing species and the rate of corrosion.

The DC power required by the stack can either be supplied directly from an external source or from a DC power supply, which converts externally supplied AC power to DC. Most applications will employ a constant current power supply. The acceptable amount of output ripple and noise can be relaxed because of the capacitive nature and low-pass filtering effect of the SEOS stack. Various regulated or rectified strategies can be incorporated into the power supply.

Control systems may vary widely depending on the specific application. An important feature is the regulation of oxygen flow by current regulation. Current measurement is more reliable and accurate than typical flow measurement techniques. Oxygen pressure control is typically used to keep the stack at a constant operating pressure when the oxygen use pressure is varying or lower than the desired stack operating pressure. Start-up and stand-by modes of operation may also be incorporated into the control system.

CONCLUSION

ITM SEOS technology utilizes the principle of oxygen ion migration through a dense ceramic electrolyte membrane under the influence of an externally applied electrical potential. The key to this technology is the careful selection of materials for the electrolyte and other ceramic components to ensure electrochemical stability and mechanical integrity. A stack incorporating a rare earth-doped ceria electrolyte, with appropriate electrode materials and other compatible ceramic components, has demonstrated excellent electrochemical stability and mechanical integrity over a 6500-hour operating period. An oxygen generator based on this technology has been designed, including a thermal management system, feed gas supply, power supply, and appropriate controls. A self-contained generator, with an air mover as the only moving part, requires only standard power from an electrical outlet, battery, or other power source, such as a fuel cell. The ability of this compact device to produce high purity oxygen at elevated pressure, with minimal moving parts and very low noise, will make ITM SEOS an attractive supply mode for many military oxygen applications.

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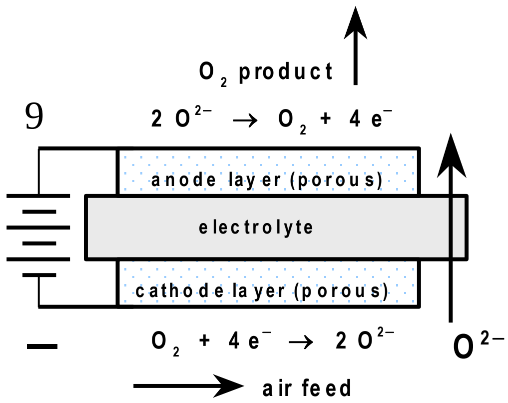

Figure 1
Operation of a SEOS electrochemical cell

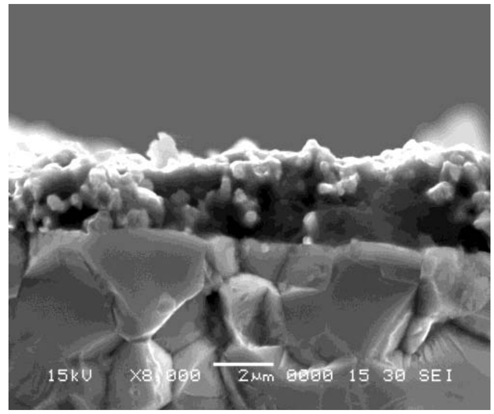

Figure 2
SEM image of porous electrode layer deposited on dense ceria-based electrolyte in an ITM SEOS electrochemical cell

Figure 3
A 32-cell ITM SEOS stack

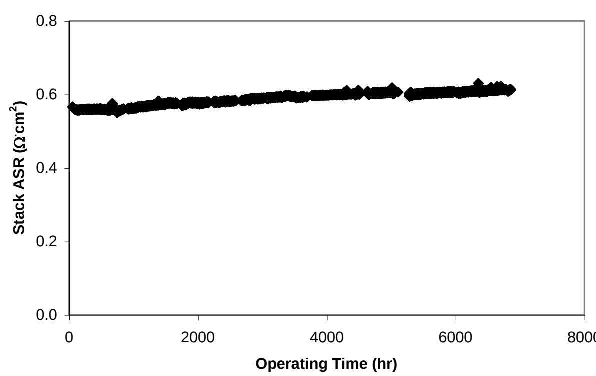

Figure 4
Area specific resistance (ASR) of a 3-cell test stack during operation

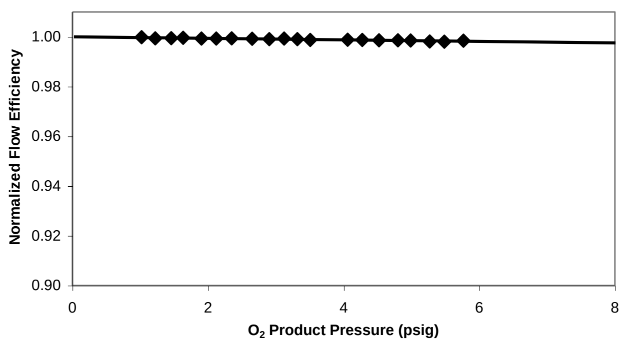

Figure 5
Flow efficiency data for the stack represented in Figure 4

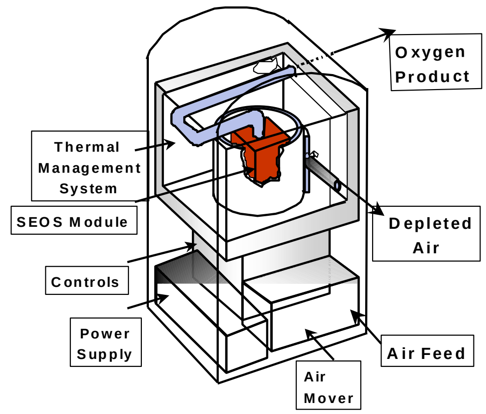

Figure 6
Schematic of a typical ITM SEOS generator system

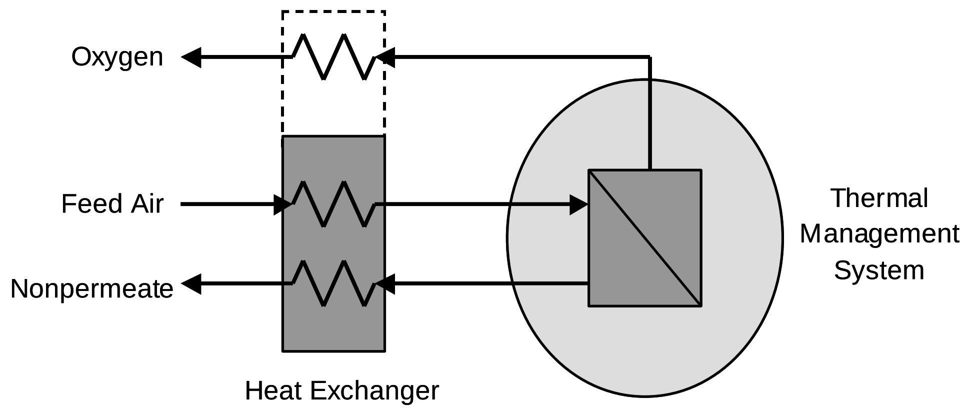

Figure 7
Schematic illustrating heating of the feed air stream via gas-to-gas heat exchange

APPENDIX B – Operating Manual

DEMONSTRATION OF A CYLINDER-FILL SYSTEM BASED ON SOLID ELECTROLYTE OXYGEN SEPARATOR (SEOS) TECHNOLOGY

FA8650-08-2-6824

Checklists and Operating Manuals
(CDRL A003)

September, 2009

Air Products and Chemicals, Inc.
7201 Hamilton Blvd.
Allentown, PA 18195

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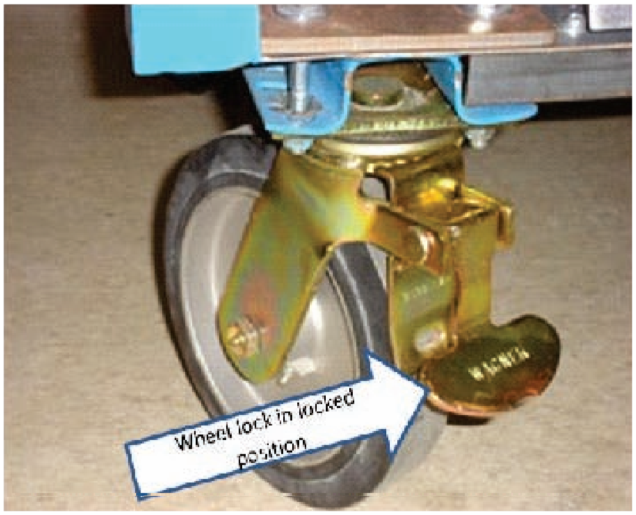
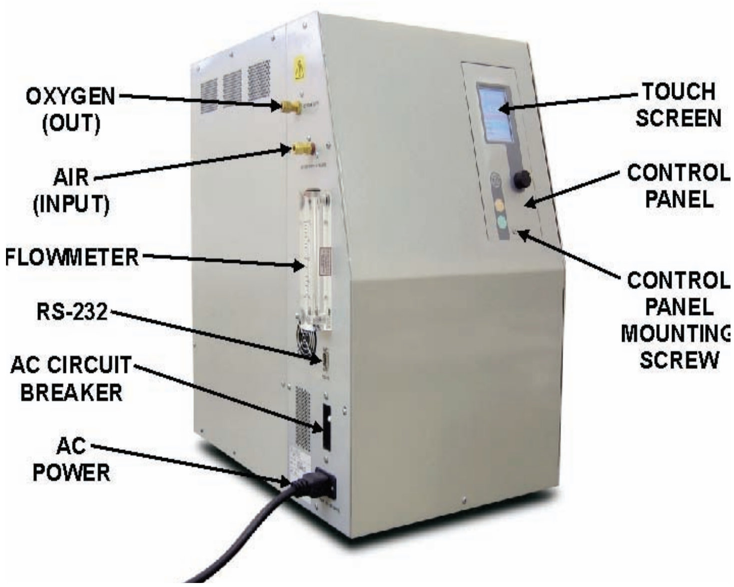
6LPM Advanced Breadboard Pre-startup Checklist

1) Oxygen Cart is in position at the intended start-up location.
2) Rotatable/swivel wheels are locked for stability.



3) Front cart wheels (non-swivel under cylinder end of cart) are chocked.
4) The two (2) TMSs are in their operating positions on the cart top shelf and secured with respective "tie-down" ratcheting straps.
5) The two (2) TMSs have 120V AC electrical cords plugged in the bottom left side of their respective cabinets.



6) The 120V AC circuit breaker, bottom left side of their respective cabinets, is set to "off" (down) position.

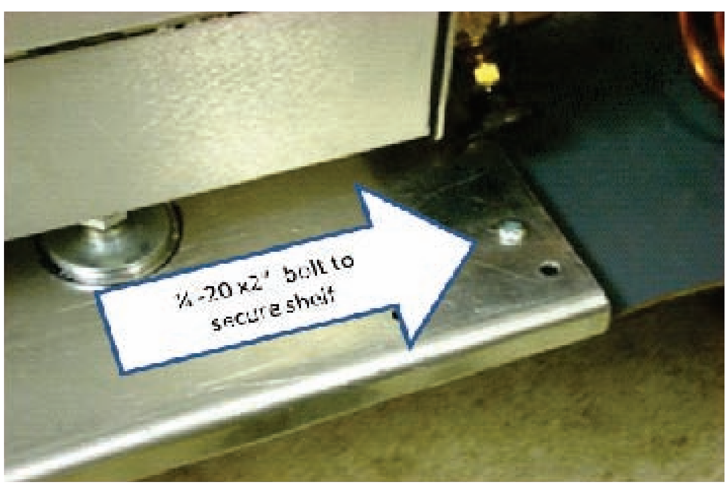
7) The oxygen outlet lines, one line per TMS, (1/4" teflon) is connected to the "oxygen (out)" port on the top left sides of the TMS cabinets. The other ends should be connected to CV201 and CV203, respectively, the oxygen check valves penetrating the top decking of the cart.

8) The air inlet lines, one line per TMS, (3/8" Teflon) is connected to the "air (in)" port on the top left side of the TMS cabinets. The other ends should be connected to the bulkhead fitting penetrating the top decking of the cart.

Rix Oxygen Compressor

9) The Rix Oxygen Compressor is positioned properly on the sliding compressor shelf (black, half moon markings on shelf indicate leg location for compressor).

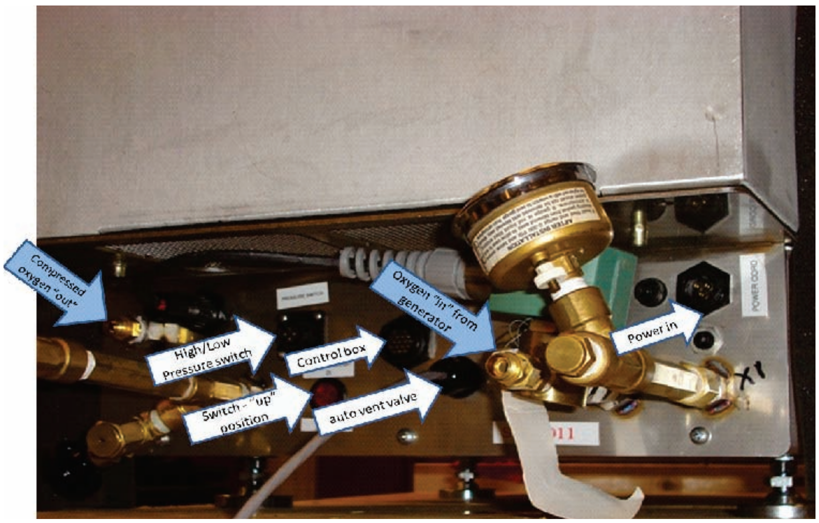
10) The sliding shelf is secured by two (2) 1/4x20 x 2 inch screws to the cart base so that the shelf can't move.



11) The oxygen inlet line is connected to the Rix and properly tightened.

12) The compressed oxygen outlet line is connected to the Rix and properly tightened.

13) All electrical connections to the compressor (1. Oxygen inlet solenoid, 2. Hp/Lp switch, 3. 120V. AC actuated compressor depressurization valve and 4. the 120V. AC power connector) are properly installed in their respective, keyed receptacles and secured.



14) Compressor 120V/20A AC power cord is plugged in to site power source.

15) The “power up auto start” switch, near the compressed oxygen outlet is in the up position not the “off” position.

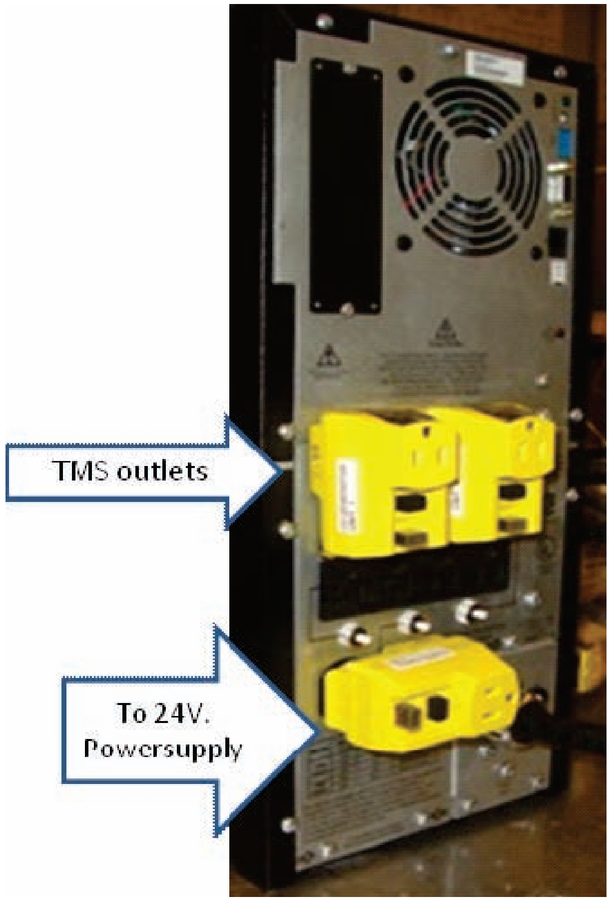
Uninterrupted Power Source (UPS) Checklist

16 UPS mounted and secured to cart.

17) UPS plugged into 120V/30A AC wall receptacle.

18) TMSs plugged into respective labeled GFCI outlet of UPS .

19) Power cord supplying 12V power supply for air handlers plugged into labeled GFCI outlet of UPS.



<u>Peripheral Checklist</u>

20) Oxygen Sample manifold mounted securely on cart with associated plumbing connected and secure.

21) Oxygen surge Cylinders on cart and secured by straps and ramp mechanism.

22) Connect outlet of CV326 (rear of cart) to inlet of Tinker AFB Oxygen Supply Manifold via ¼ O.D. X .049 wall, copper tubing, supported every 18” with rubber insulated tube clamp anchored to site wall.

23) V-324, **CLOSED**

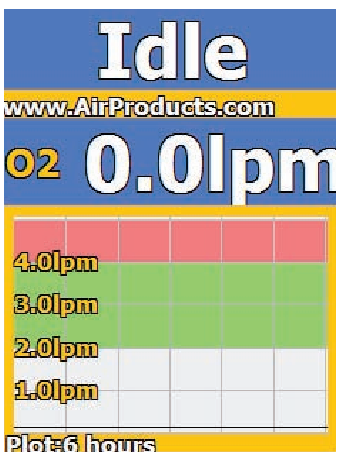
6lpm Advanced Breadboard System Start-up

Oxygen Generator Start-up Checklist

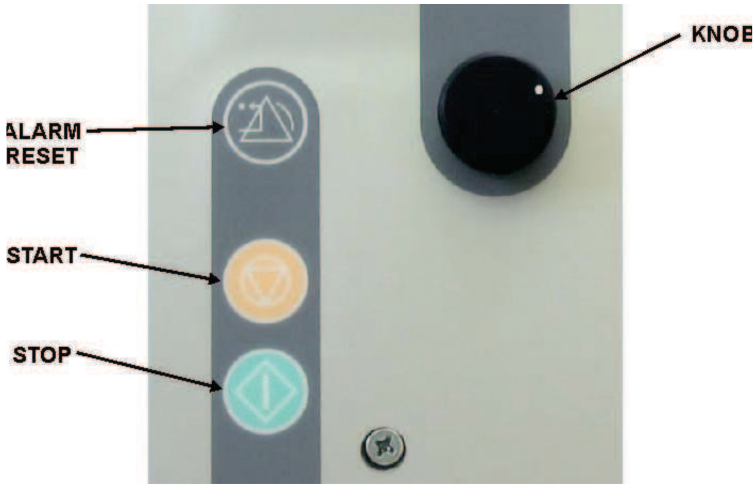
- *The following procedure should be used for start-up of the oxygen generators . This procedure assumes that all items on the* **6LPM Advanced Breadboard Pre-Startup Checklist** *have been completed.*

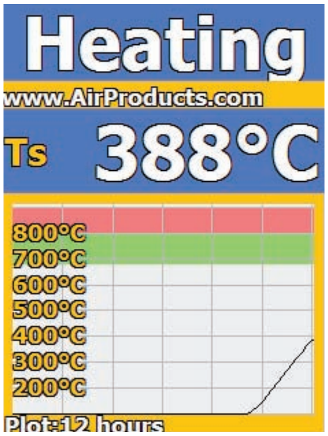
- *The following procedure can be used if there is a power outage that lasts for more than fifteen minutes (15 minutes is the amount of time that the Uninterrupted Power Supply, (UPS) will power up the generators and air movers when the UPS batteries are at full charge.*

1. Turn on/Verify the AC power switch on the lower left side of the respective generator cabinets. The LCD screen will appear. In a short time the Main screen will appear with Idle displayed on the top line.



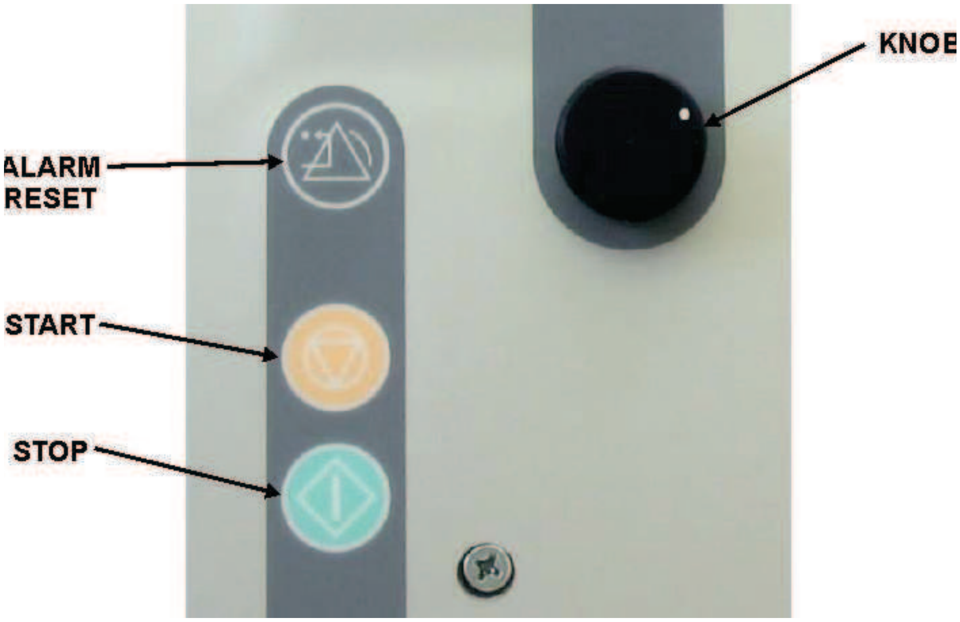
2. Press the **Start button** on the control panel. The touch-screen will display "Heating" and the oxygen generator will heat the stack to the stand-by temperature. This will take approximately 10 hours from room temperature and less time from an elevated generator temperature. (The generators heat-up at a rate of approximately 1°C/minute).



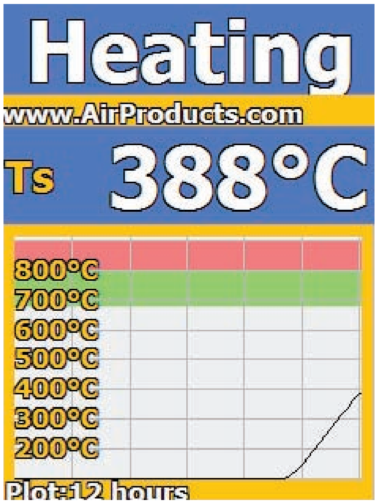


Upon reaching the stand-by temperature (e.g. 680C) the top most part of the screen will turn red and show a "PAL" alarm. (Incoming air pressure went below the minimum limit)

3. Push the "alarm reset" button on the control panel.

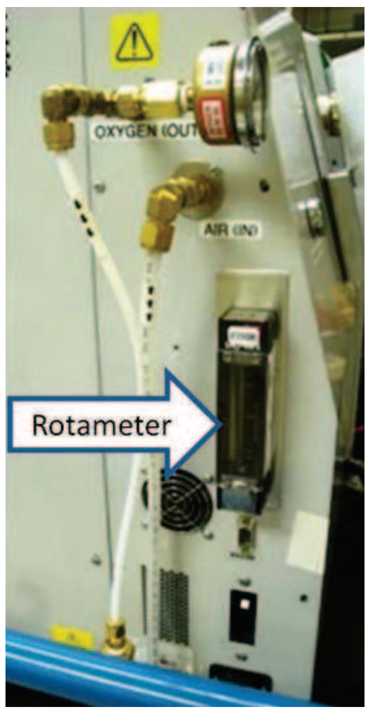


4. LCD screen should change to "Heating" and indicate the generator stack temperature (Ts).



5. Push and hold for 5 seconds, the "air mover startup", green button, on the face of the generator, TMS 1 cabinet. The air mover should start for TMS 1. Verify air flow by rotameter FI108 on left side of generator TMS1 cabinet.

6. Push and hold for 5 seconds, the "air mover startup," green button, on the face of the generator, TMS 2 cabinet. The air mover should start for TMS 2. Verify air flow by rotameter FI122 on left side of generator TMS2 cabinet



7. If the air movers don't start the LCD screen will display "Heating" on the top line. Wait 5 minutes and repeat steps 5-6 (above) until air movers start.

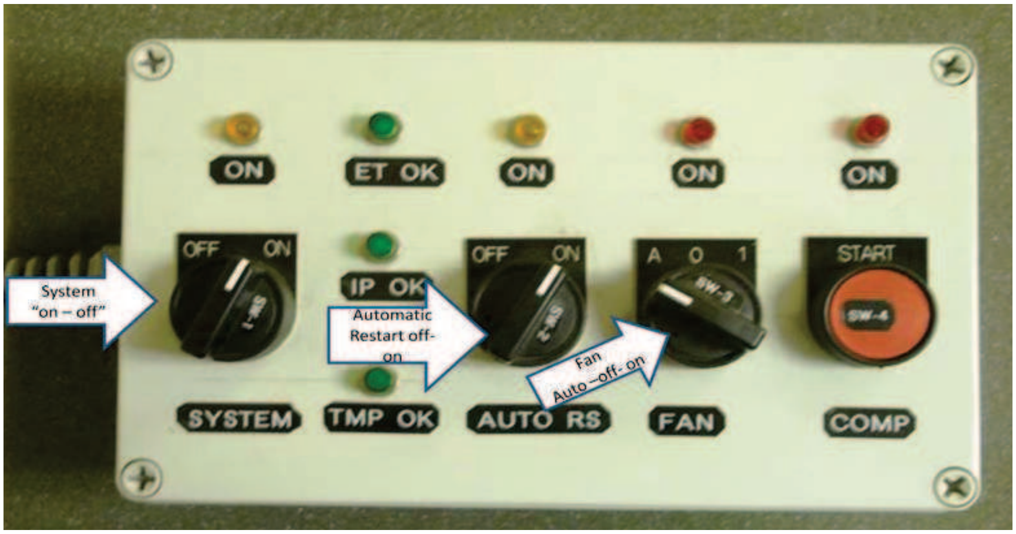
8. The generators will start ramping up the production of oxygen when the air movers are running. After approximately 90 minutes both generators should be producing 2.9-3.1lpm of oxygen. (**NOTE:** At this point the LCD will not show the proper oxygen flow rate. The Rix Compressor must be running to for the LCD to show the proper oxygen production).

Rix Compressor Start-up Checklist

- *This procedure assumes that all items on the* **6LPM Advanced Breadboard Pre-startup Checklist** *have been completed.*
.
- *This procedure assumes that all items on the* **Oxygen Generator Start-up Checklist** *have been completed and the air movers are running with respective generators producing 2.9 – 3.1 lpm oxygen product.*
- ***The Rix oxygen compressor is configured to run automatically after its initial manual start/ restart. If the compressor fails to restart or does not compress to 2200psig contact Air Products personnel.***
- *The following* ***Rix Compressor Start-up Checklist*** *is applicable in the instance of a power outage lasting more than fifteen minutes. The Uninterrupted Power Supply (UPS) will supply power to run the oxygen generators and their respective air handlers for fifteen (15) minutes when the UPS batteries are at full charge. In the event of a power outage of more than 15 minutes the Rix Compressor will have to be restarted manually after the oxygen generators have been restarted and are producing 2.9- 3.1lpm of oxygen.*

Valve Status:

9. **Verify** V314, V316, Surge cylinder #1 block valve, **OPEN.**
10. **Verify** V318, V320, Surge cylinder #2 block valve, **OPEN.**
11. **Verify** V324, valve to Tinker manifold, **OPEN.**
12. **Verify** V322 **CLOSED** .
13. **Verify** V410, **CLOSED**.
14. **Verify** V414, **CLOSED**.
15. **Verify** Rix Compressor control box on (SW-1). First switch "system- **ON**".
16. **Verify** Rix Compressor control box automatic restart switch (SW-2) to "**ON**".
17. **Verify** Rix Compressor control box fan switch (SW-3) to **"A"** automatic position.



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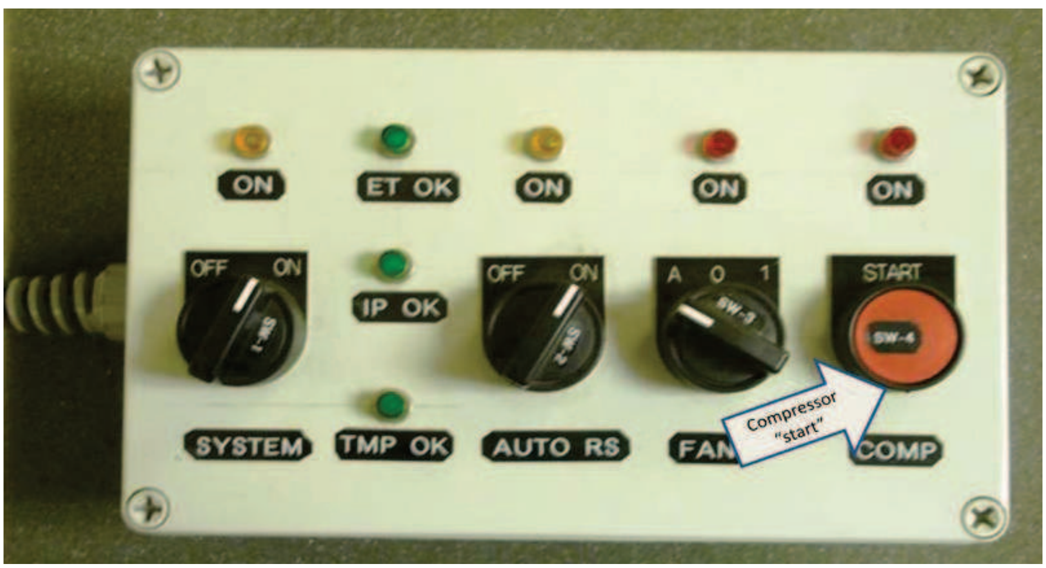
18. **Push and hold down** Rix Compressor control box **"start"** button until compressor runs continuously.



Rev Date: 10Sept09 1505

Procedure for Sampling from the Oxygen Surge Cylinders

- *This procedure assumes both oxygen generators are producing 2.9- 3.1 lpm per unit*
- *The Rix compressor is operating and Surge Cylinders #1 and# 2 are pressurized above 1200psig (read pressure on PI308).*

1) Verify that surge cylinders #1 and #2 are pressurized above 1200 psig by ensuring cylinder valves are **OPEN**, V314 **OPEN**, V318 **OPEN**, and checking pressure at PI308
2) Verify that V322 is **CLOSED** (inlet valve to sampling manifold)
3) Install oxygen sample cylinder (pipe plug end down, V418) into sample cylinder rack until the pipe plug engages in the copper base stabilizer.
4) Hand tighten the oxygen sample cylinder ring clamp to secure the sample cylinder.
5) Check pressure of PI411. (should be 0 psig)
6) **SLOWLY OPEN** V414 to depressurize the manifold (downstream of V410) to reduce pressure in lines if it exists (line pressure PI411).
7) Remove ¼ " Swagelok plug" from inlet of sample cylinder (V416).
8) Remove ¼ " Swagelok cap" from outlet of sample line pigtail.
9) Connect outlet of sample line pigtail to inlet of (V416) of sample cylinder.
10) Status Check of oxygen sampling manifold valves -

    CLOSED: V322, V410, V414,
11) PCV-402 backed out (turn counter-clockwise) allowing no flow of gas.
12) Valve status check of 1 L. sample cylinder

    CLOSED: V416, V418
13) **SLOWLY OPEN** V322.
14) PI400 will read the surge cylinder pressure.
15) **SLOWLY OPEN** 410

PURGE SAMPLING MANIFOLD and Oxygen Sample Cylinder

15) Adjust PCV402 clockwise until PI404 reads 1200psi (oxygen is now filling sampling manifold to V416).

16) **CLOSE** V322

17) **SLOWLY OPEN** V414 (vent lines until PI411 reads 100psig).

18) **CLOSE** V414.

18) Repeat Step #12 –step #18 two more times

19) **OPEN** V322.
20) **SLOWLY OPEN V416** (inlet to oxygen sample cylinder).
21) Pressurize cylinder to 1200psig (PI411…will take 2-3 minutes)
22) **CLOSE** V410.
23) **SLOWLY OPEN** V414 to vent/purge oxygen sample cylinder until PI411 reads 100psig, **CLOSE** V414
24) **SLOWLY OPEN** V410
25) Pressurize cylinder to 1200psig (PI411…will take 2-3 minutes)
26) **CLOSE** V410.
27) **SLOWLY OPEN** V414 to vent/purge oxygen sample cylinder until PI411 reads 100psig, **CLOSE** V414
28) **REPEAT Steps #24 -#27 (**to purge sample cylinder of residual air).

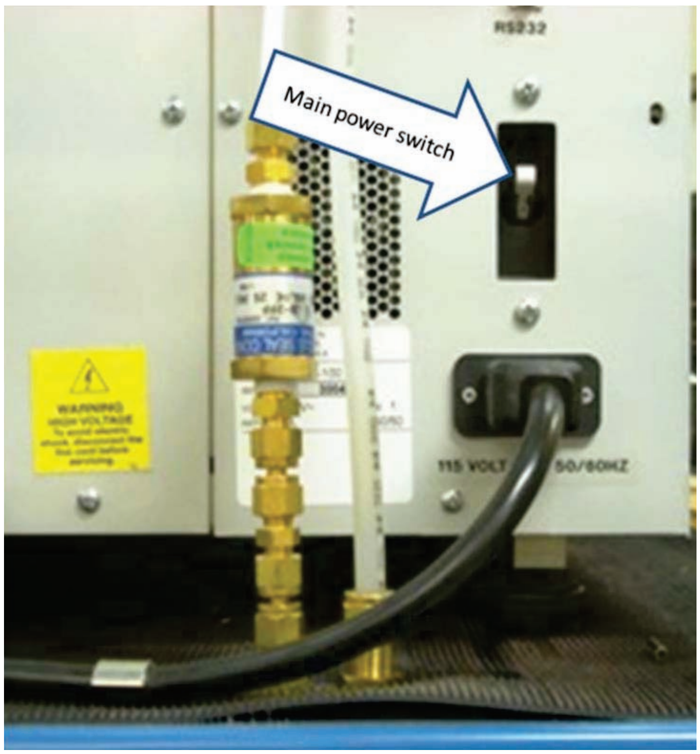
OXYGEN SAMPLE CAPTURE

29) **SLOWLY OPEN** V410
30) Pressurize cylinder to 1200psig (PI411…will take 2-3 minutes)
31) **CLOSE** V416
32) **CLOSE** V410.
33) **CLOSE** V322
34) **SLOWLY OPEN** V414 to depressurize manifold lines.
35) When PI411 is "0 psig" **CLOSE** V414
36) Unmake ¼ " Swagelok" fitting at inlet of V416.
37) Plug V416 inlet with ¼" Swagelok plug.
38) Loosen the oxygen sample cylinder ring clamp .
39) Lift and remove the oxygen sample cylinder from it's support.
40) **Replace ¼" Swagelok cap** on oxygen sample outlet pigtail.
41) Package sample cylinder per instructions for shipping.
42) **SLOWLY OPEN** V414.
43) **SLOWLY OPEN** V410.
44) Turn PCV402 counter clock until no regulator outlet pressure is on PI404.
45) **CLOSE** V410, V414

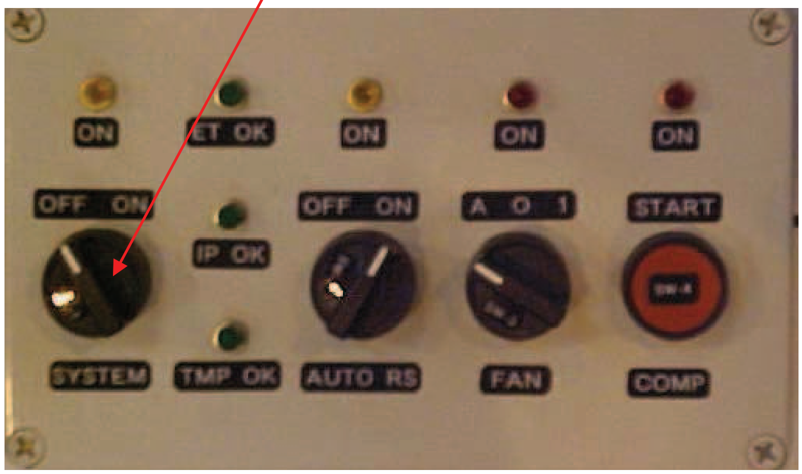
Rev Date: 17Sept09

Emergency Shutdown Procedure

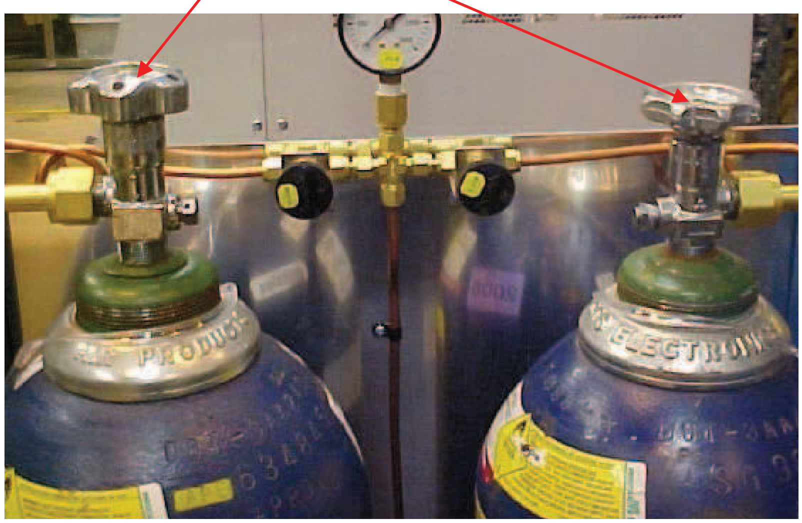
Turn OFF both (2) oxygen generators main power switches on left side of generator cabinets.

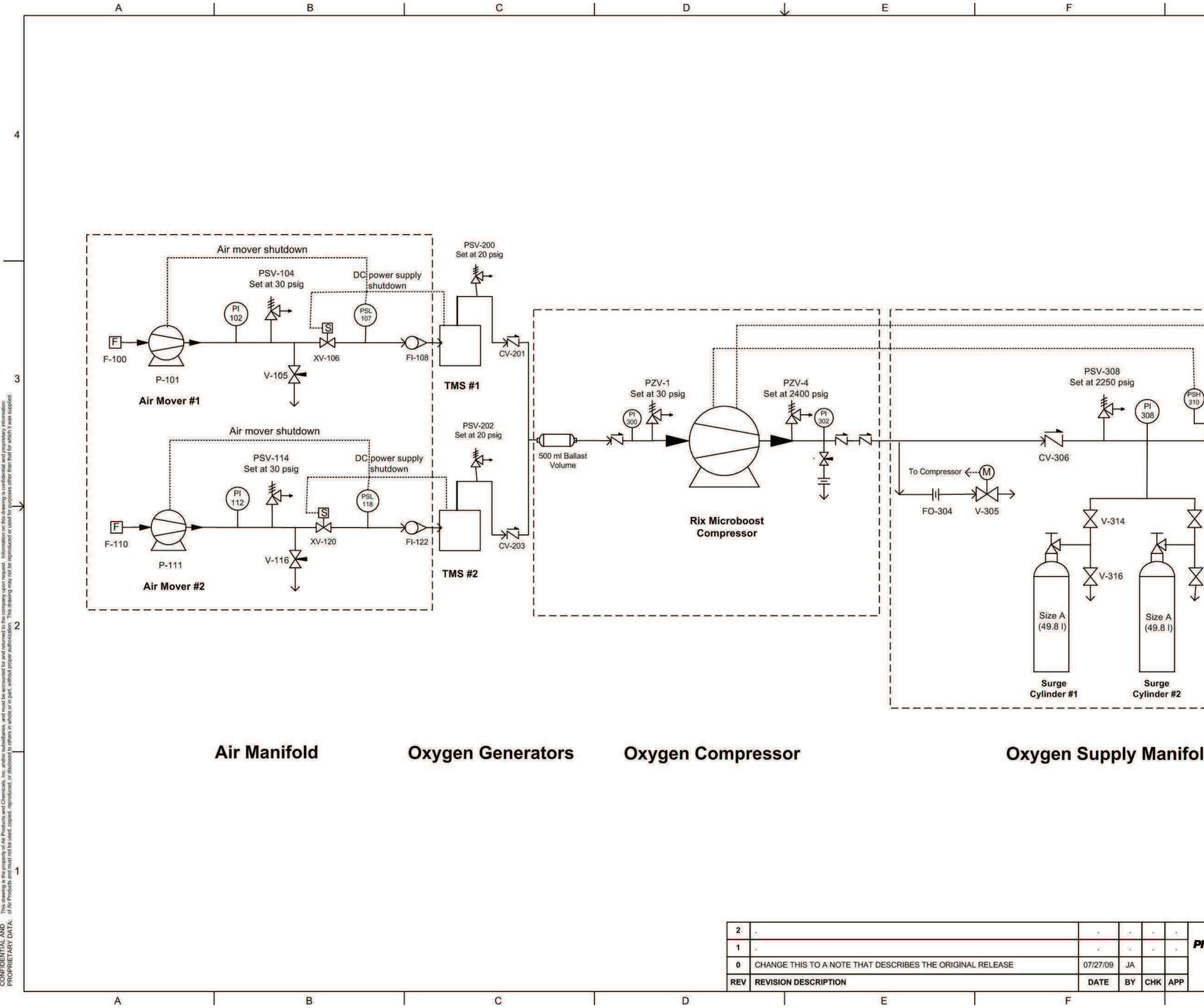


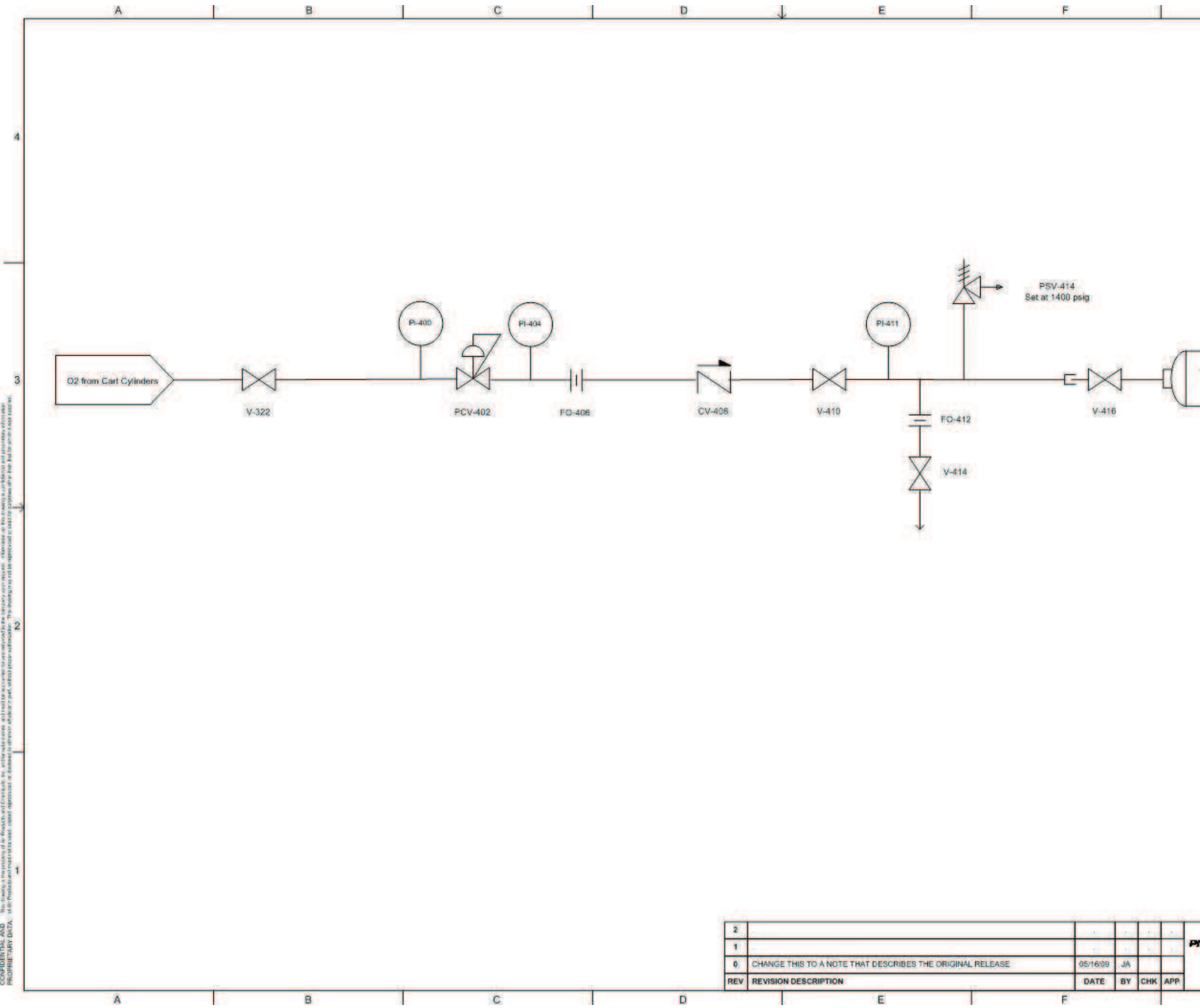
Turn the Rix Compressor <u>System Switch</u> to the <u>OFF</u> Position



<u>CLOSE</u> the Cylinders Shutoff Valve

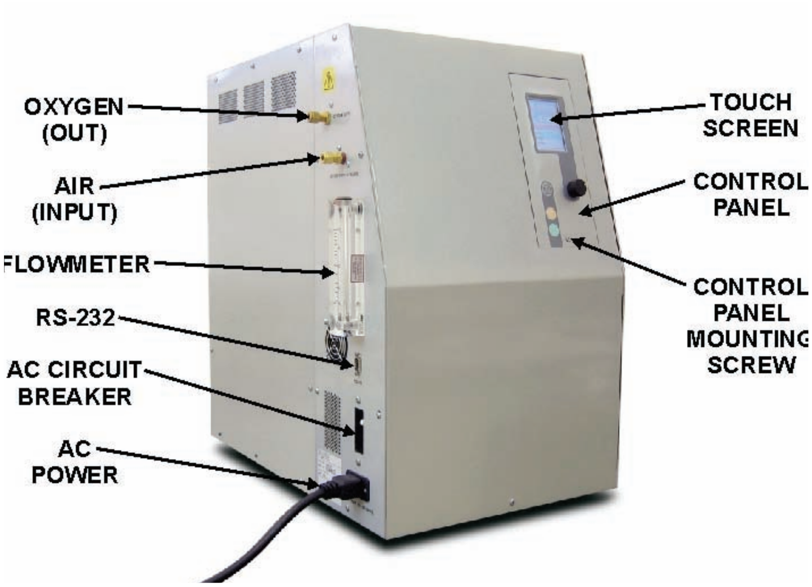



Air mover shutdown
PSV-104
Set at 30 psig
DC power supply
shutdown
PI 102
PSL 107
F
F-100
P-101
Air Mover #1
V-105
XV-106
FI-108
PSV-200
Set at 20 psig
TMS #1
CV-201
Air mover shutdown
PSV-114
Set at 30 psig
DC power supply
shutdown
PI 112
PSL 118
F-110
P-111
Air Mover #2
V-116
XV-120
FI-122
PSV-202
Set at 20 psig
TMS #2
CV-203
500 ml Ballast
Volume
PI 300
PZV-1
Set at 30 psig
PZV-4
Set at 2400 psig
PI 302
Rix Microboost
Compressor
PSV-308
Set at 2250 psig
PI 308
PSH 310
CV-306
To Compressor
M
FO-304
V-305
V-314
V-316
Size A
(49.8 l)
Size A
(49.8 l)
Surge
Cylinder #1
Surge
Cylinder #2
Air Manifold
Oxygen Generators
Oxygen Compressor
Oxygen Supply Manifol
CONFIDENTIAL AND
PROPRIETARY DATA:
2
1
0
CHANGE THIS TO A NOTE THAT DESCRIBES THE ORIGINAL RELEASE
07/27/09
JA
REV
REVISION DESCRIPTION
DATE
BY
CHK
APP


O2 from Cart Cylinders
V-322
PI-400
PCV-402
PI-404
FO-406
CV-408
V-410
PI-411
FO-412
V-414
PSV-414
Set at 1400 psig
V-416
0
CHANGE THIS TO A NOTE THAT DESCRIBES THE ORIGINAL RELEASE
05/16/09
JA
REV
REVISION DESCRIPTION
DATE
BY
CHK
APP

Oxygen Generator Instruction Manual

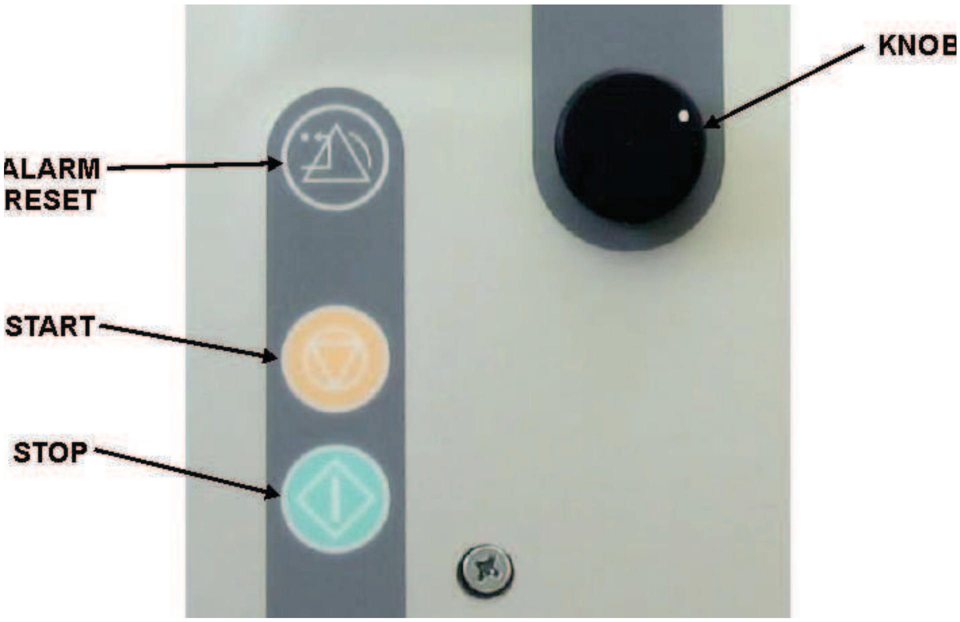
The following instruction manual provides the user with information and instruction to operate the oxygen generator.



Operation

Control Panel Functions

The Control Panel, on the right side of the front panel, consists of a Touch-Pad, three Push Buttons and a Knob.



Push Buttons below the Touch Screen

<u>The Alarm Reset button</u> is used to reset or clear an alarm. If an alarm occurs it will be displayed on the touch screen. Refer to the Alarms page for a list of alarms and possible causes.

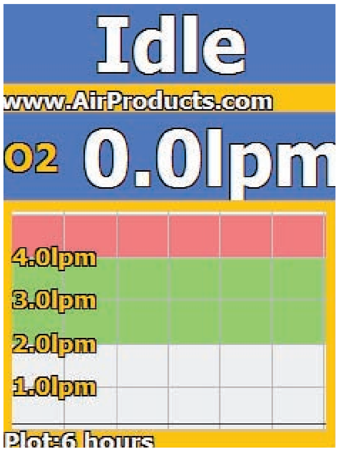
<u>The Start button</u> is used to start the oxygen generator and produce oxygen. "Heating" will appear on the top of the touch screen and the temperature displayed on the graph will increase. After the temperature stabilizes "Operate" will appear on the touch screen indicating the oxygen generator is producing oxygen.

<u>The Stop button</u> is used to stop the oxygen generator from producing oxygen. "Cooling" will appear on the touch screen and the temperature displayed on the graph will decrease. After the temperature stabilizes, "Idle" will appear on the touch screen indicating oxygen generation has stopped.

<u>The Knob</u> is used to zoom the chart and scroll through historical values. For a list of parameter abbreviations and their definitions refer to the Touch Screen Parameter Abbreviations page.

Touch Screen Operation

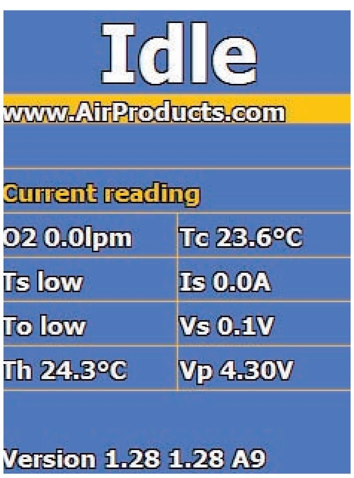
1. When the Oxygen Generator is first turned on (AC power switches on lower left side of respective TMS cabinets) the Splash screen will appear. In a short time the Main screen will appear with Idle displayed on the top line.



2. The operating parameter displayed on the graph is listed on the third line down. To select other operating parameters touch the parameter value.

3. Turn the Knob to zoom the chart. Selections are 10 minutes, 30 minutes, 1 hour, 2 hours, 6 hours, 12 hours, 24 hours and 48 hours.

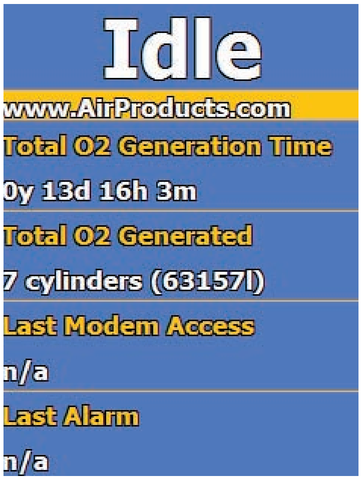
4. Touch the top line to display a table of all the operating parameters and their values.



5. The fourth line down displays the time the parameter values were recorded. By default the displayed values will be current values and the display will indicate current reading.

6. Turn the Knob counterclockwise to display a past list of operational parameter values. By turning the knob you can display past values for every minute for the past 48 hours. Touch the screen, while turning the knob, to advance in one-hour increments.

7. Touch the top line again to display the statistics.



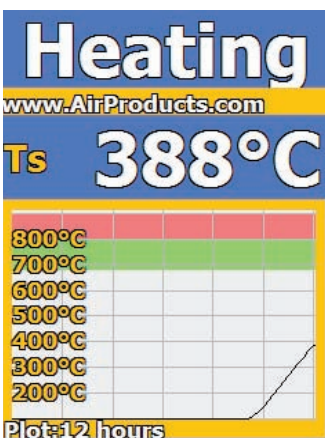
8. Touch the top line again to return to the Main screen.

Oxygen Generation

Start Oxygen Generation

1.Turn the oxygen generator on. The Main screen will appear.

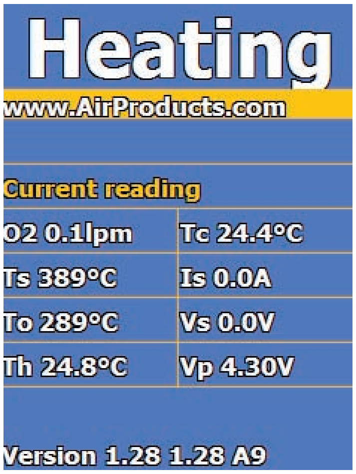
2. Press the Start button on the control panel. The touch-screen will display Heating and the oxygen generator will heat the stack to the operating temperature. This will take approximately 6 hours.



3. The operating parameter displayed on the graph is listed on the third line down. To select other operating parameters touch the parameter value.

4. Turn the knob to zoom the chart. Selections are 10 minutes, 30 minutes, 1 hour, 2 hours, 6 hours, 12 hours, 24 hours and 48 hours.

5. As the generator is heating touch Heating to display a list of operating parameters and their values.



6. The fourth line down displays the time the parameter values were recorded. By default the displayed values will be the current values and the display will indicate Current Reading.

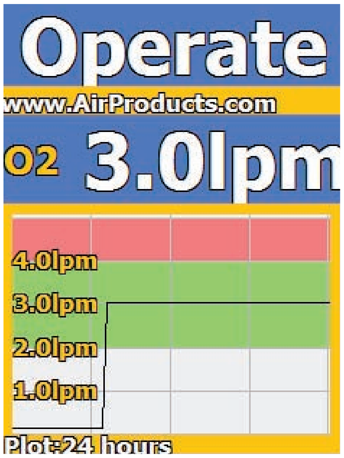
7. Turn the Knob counterclockwise to display a past list of operational parameter values. By turning the knob you can display past values for every minute for the past 48 hours. Touch the screen, while turning the knob, to advance in one-hour increments.

8. Touch the top line again to display the statistics.

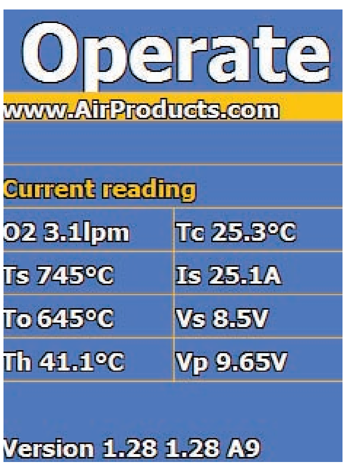
9. Touch the top line again to return to the Main screen.

Oxygen Generation

1. After reaching the operating temperature Operate will appear on the top of the screen and the generator will start producing oxygen.



2. As the generator is producing oxygen touch Operate to display a list of operating parameters and their values.



3. The fourth line down displays the time the parameter values were recorded. By default the displayed values will be the current values and the display will indicate Current Reading.

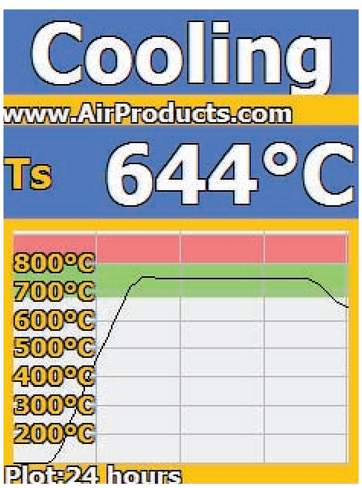
4. Turn the Knob counterclockwise to display a past list of operational parameter values. By turning the knob you can display past values for every minute for the past 48 hours. Touch the screen, while turning the knob, to advance in one-hour increments.

5. Touch the top line again to display the statistics.

6. Touch the top line again to return to the Main screen.

Stop Oxygen Generation

1. Press the Stop button on the control panel. The touch-screen will display Cooling and the oxygen generator will cool to ambient temperature. This will take a few hours.



2. The operating parameter displayed on the graph is listed on the third line down. To select other operating parameters touch the parameter value.

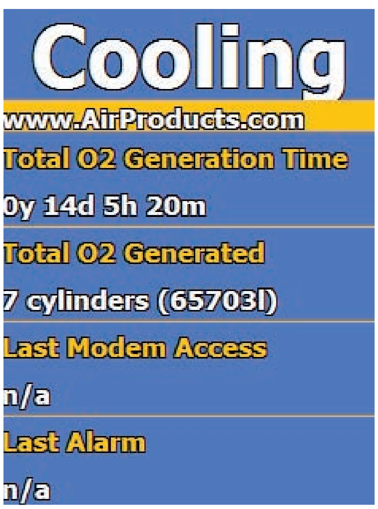
3. Turn the knob to zoom the chart. Selections are 10 minutes, 30 minutes, 1 hour, 2 hours, 6 hours, 12 hours, 24 hours and 48 hours.

4. As the generator is cooling touch Cool to display a list of operating parameters and their values.

5. The fourth line down displays the time the parameter values were recorded. By default the displayed values will be the current values and the display will indicate Current Reading.

6. Turn the Knob counterclockwise to display a past list of operational parameter values. By turning the knob you can display past values for every minute for the past 48 hours. Touch the screen, while turning the knob, to advance in one-hour increments.

7. Touch the top line again to display the statistics.



8. Touch the top line again to return to the Main screen.

Touch Screen Parameter Abbreviations

The following is a list of parameter abbreviations with their definitions. These abbreviations will appear on the touch-screen during operation.

Parameter	Definition
O2	Oxygen Flow
Tc	Cold Junction Temperature
Ts	Stack Temperature
Is	Stack Current
To	Oxygen Pipe Temperature
Vs	Stack Voltage
Th	Heat sink Temperature
Vp	DCPS Voltage

Alarms

The following alarms will be displayed on the touch screen if they occur. Press Alarm Reset, on the front panel, to clear the alarm.

TAH	Stack temperature went above the maximum limit.
OCA	Stack current went above the maximum limit.
PAL	Incoming air pressure went below the minimum limit
FAL	Outgoing oxygen flow went below the minimum limit. Normal status for FAL light depends on the operating mode of the oxygen delivery system. The FAL (Flow Alarm Low) will not be illuminated when the compressor is operating and delivering oxygen to the user. The generators will indicate a FAL however when the compressor is shut down. During normal operation the FAL light indicates that the oxygen being continuously produced by the generators is being bled off through the relief valves inside the generator cabinets. The relief valves are located upstream of the oxygen flow meter and therefore the flow meter correctly registers the lack of oxygen flow to the compressor. When the compressor restarts, the relief valves close and the flow of oxygen through the flow meter is reestablished
RAMP	Stack temperature ramp rate went above the maximum limit.
SHORT	Stack voltage dropped below minimum while stack current was above threshold.
SNK	Heat sink temperature rose above maximum limit.
THRM	Stack or oxygen pipe thermocouples may be shorted or disconnected.
CURR	Stack current went above the maximum limit.
VROR	Reference voltage went out of range.
VPOR	Power supply voltage went out of range.
V24OR V+24V	power went out of range.
V5OR V+5V	power went out of range.
COR AC	line measurement circuit went out of range.
ACFLT	The AC line voltage went below the minimum limit.
OK	No alarms indicated.

AUTOMATIC SHUTDOWN GUIDE

SEOS Oxygen Compressor

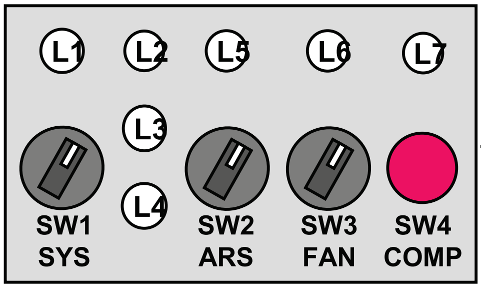
Upon recognizing the compressor as shutdown, before any control box switch adjustments are made, take note of the condition of the switches and lamps. Use this guide to find the matching control box face diagram. Comments in the adjacent dialog box list possible faults.

How to use this guide

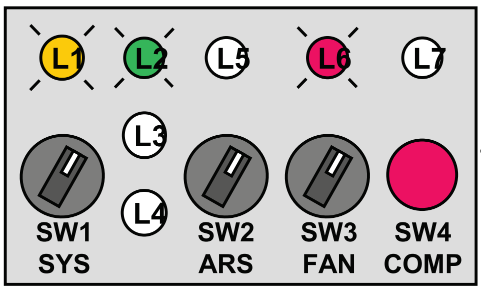
First Note the position of the switches and turn to the pages that describe that set of positions. The switch positions are noted at the top of each page.

Second Note the status of all the lamps and find the corresponding diagram. Use the trouble shooting suggestions found to the right of the matching diagram

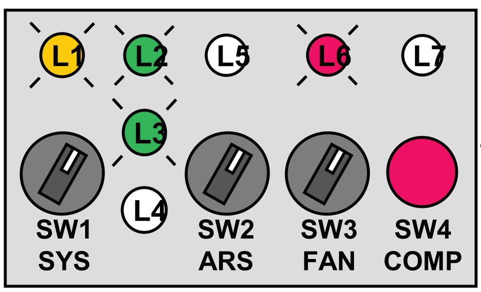
SYS = on ARS = on FAN = 1



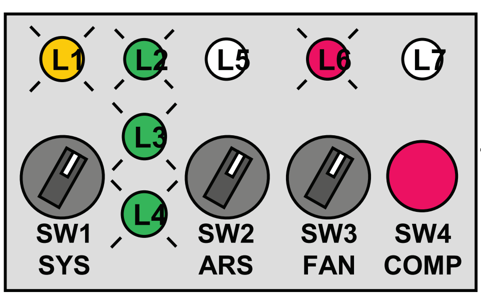
- Power unplugged
- Fuse blown
- CB-1 opened



- Insufficient inlet pressure (supply)
- XV coil opened

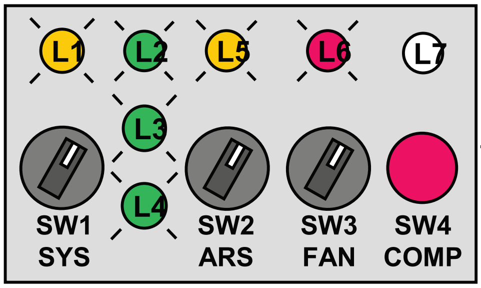


- High enclosure temp

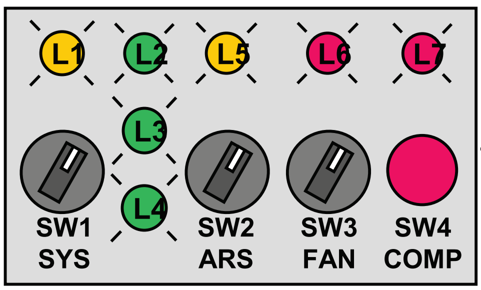


- Low inlet pressure & reset
- High enclosure temp & reset

SYS = on   ARS = on   FAN = 1

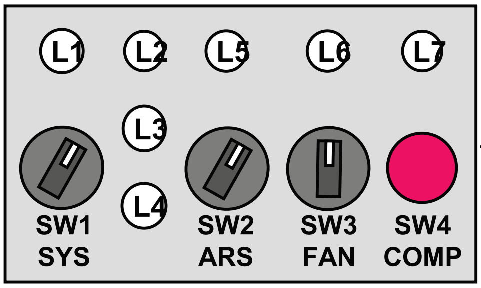


- Shutdown on high disch. press.

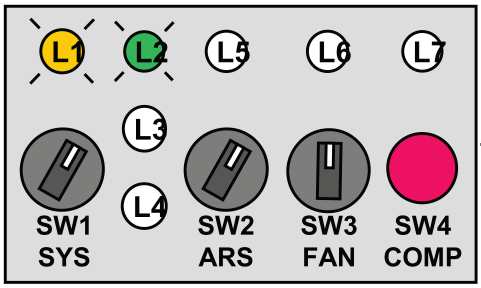


(Compressor audibly not running)
- CB-2 opened
- Rix motor contactor coil open
- Relay R1 coil open
- Rix motor thermal OL open

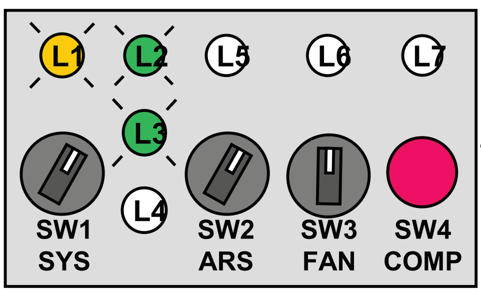
SYS = on ARS = on FAN = 0



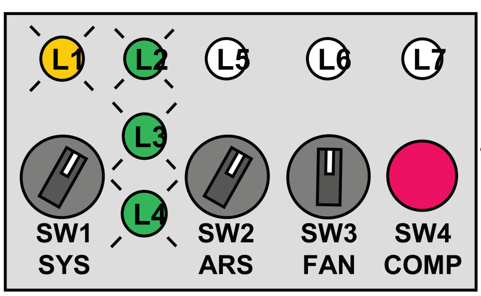
- Power unplugged
- Fuse blown
- CB-1 opened



- Insufficient inlet pressure (supply)
- XV coil opened

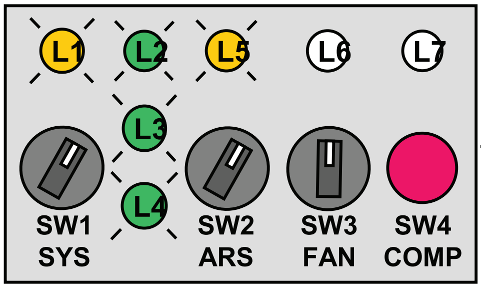


- High enclosure temp

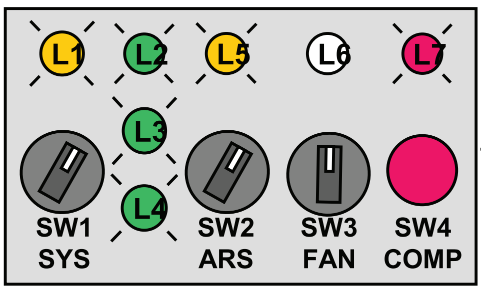


- Low inlet pressure & reset
- High enclosure temp & reset

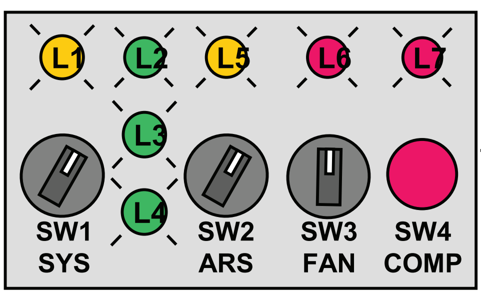
SYS = on ARS = on FAN = 0



- Shutdown on high disch. press.

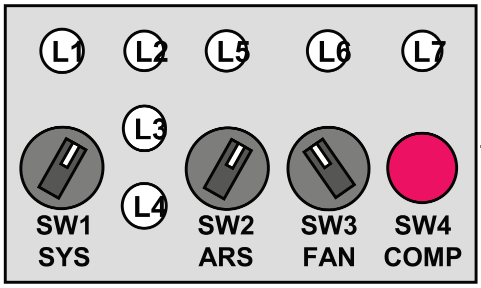


(Compressor audibly not running)
- CB-2 opened
- Relay R1 coil open
- Rix motor contactor coil open

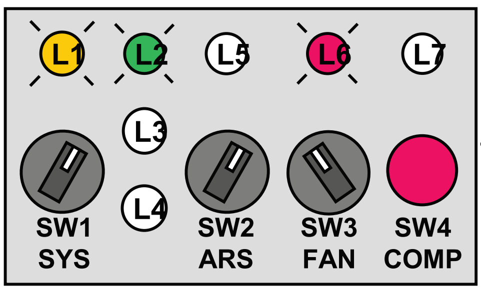


(Compressor audibly not running)
- Rix motor thermal OL open

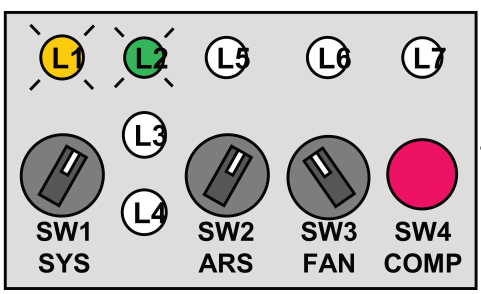
SYS = on ARS = on FAN = A



- Power unplugged
- Fuse blown
- CB-1 opened

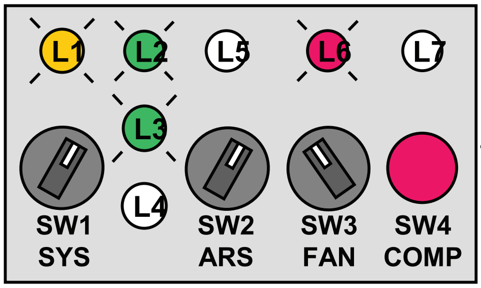


- Insufficient inlet pressure (supply)
- XV coil opened

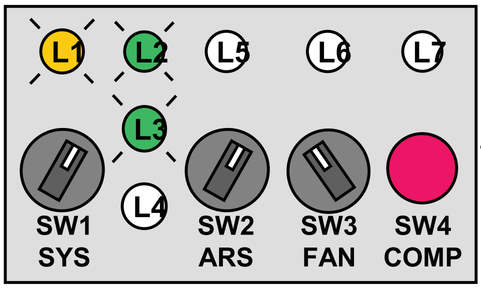


- Insufficient inlet pressure (supply)
- XV coil opened

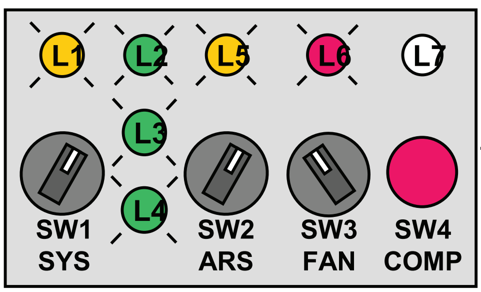
SYS = on   ARS = on   FAN = A



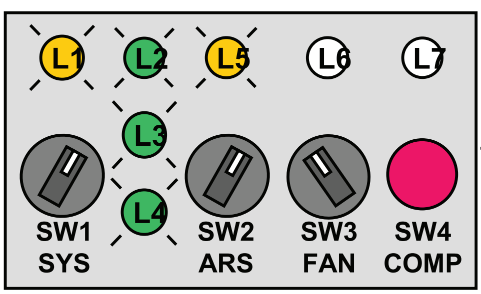
- High enclosure temp



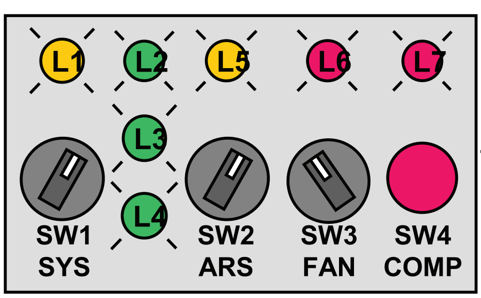
- High enclosure temp



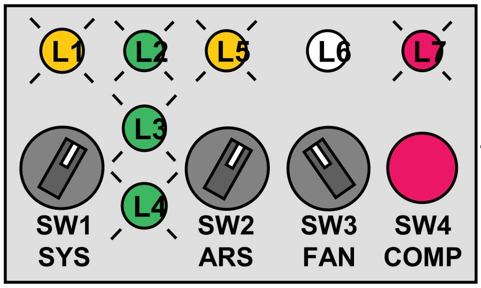
- Shutdown on high disch. press.



- Shutdown on high disch. press.

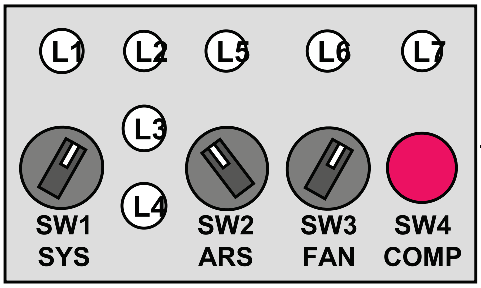


(Compressor audibly not running)
- CB-2 opened
- Relay R1 coil open
- Rix motor contactor coil open
- Rix motor thermal OL open

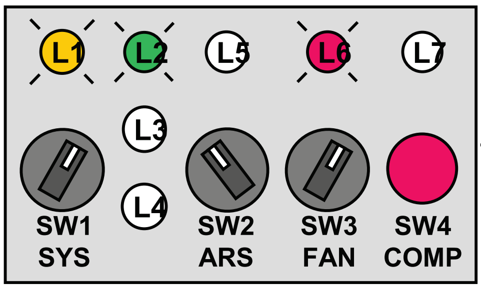


(Compressor audibly not running)
- CB-2 opened
- Relay R1 coil open
- Rix motor contactor coil open
- Rix motor thermal OL open

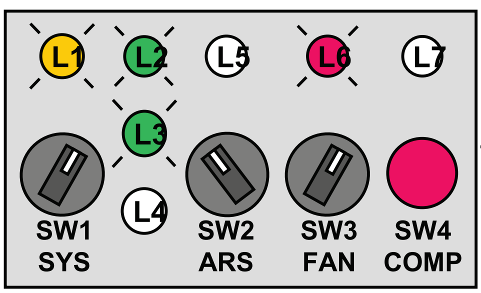
SYS = on ARS = off FAN = 1



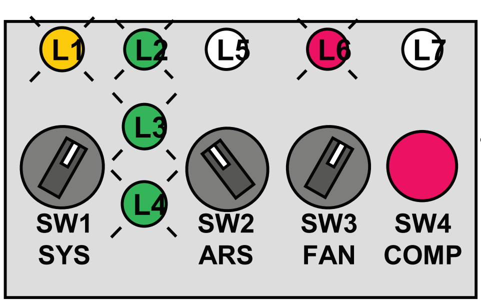
- Power unplugged
- Fuse blown
- CB-1 opened



- Insufficient inlet pressure (supply)
- XV coil opened

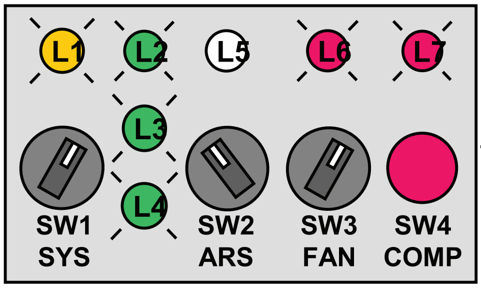


- High enclosure temp



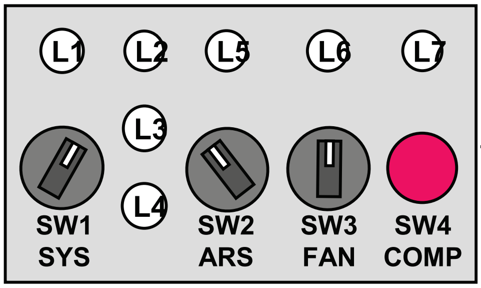
- Low inlet pressure & reset
- High enclosure temp & reset

SYS = on ARS = off FAN = 1

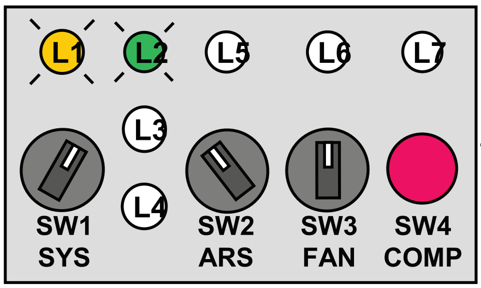


(Compressor audibly not running)
- CB-2 opened
- Relay R1 coil open
- Rix motor contactor coil open
- Rix motor thermal OL open

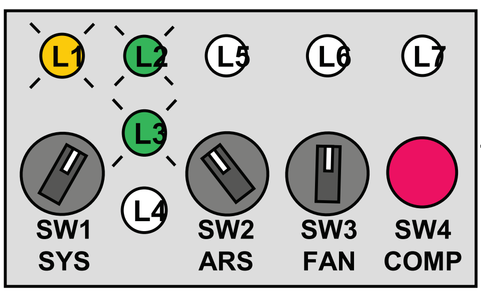
SYS = on ARS = off FAN = 0



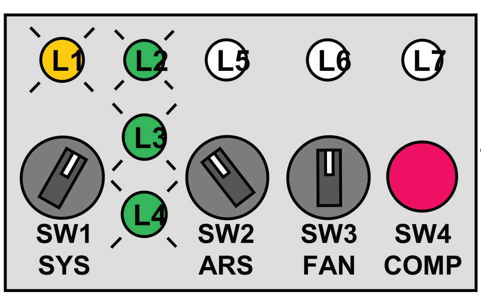
- Power unplugged
- Fuse blown
- CB-1 opened



- Insufficient inlet pressure (supply)
- XV coil opened

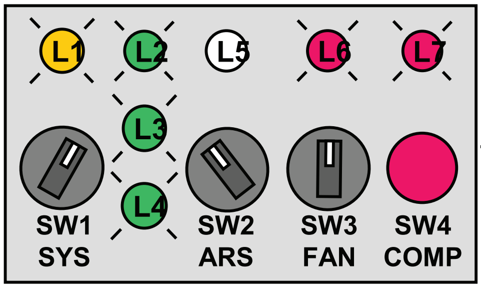


- High enclosure temp

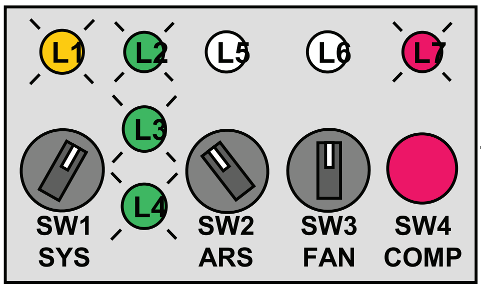


- Low inlet pressure & reset
- High enclosure temp & reset
- Shutdown on high disch. press.
- Relay R1 coil open
- Rix motor contactor coil open

SYS = on ARS = off FAN = 0

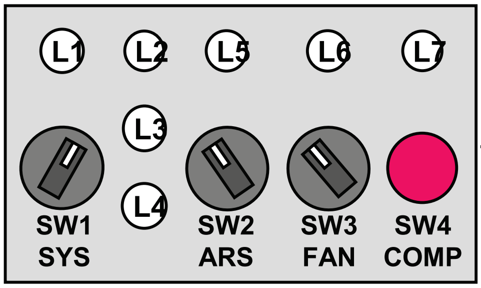


(Compressor audibly not running)
- Rix motor thermal OL open

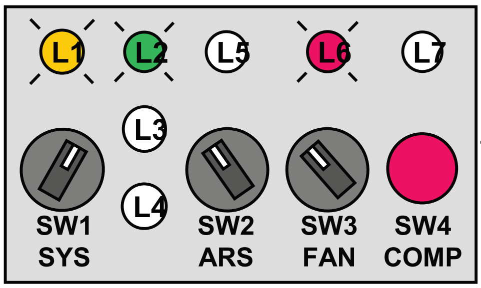


(Compressor audibly not running)
- Rix motor contactor coil open

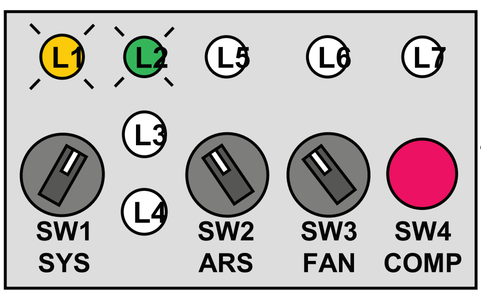
SYS = on ARS = off FAN = A



- Power unplugged
- Fuse blown
- CB-1 opened

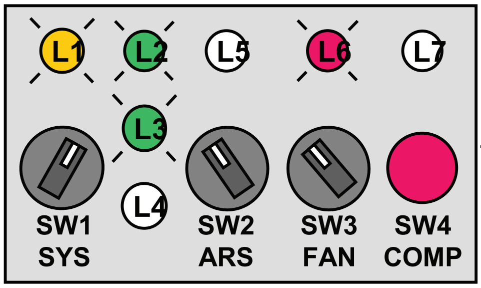


- Insufficient inlet pressure (supply)
- XV coil opened

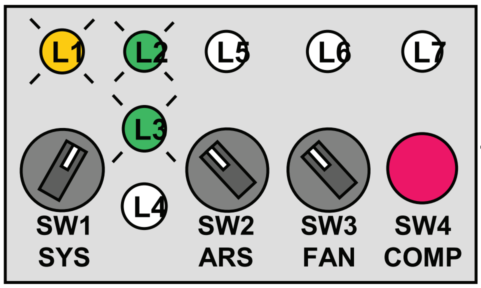


- Insufficient inlet pressure (supply)
- XV coil opened

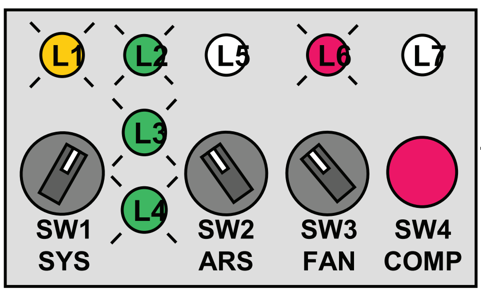
SYS = on ARS = off FAN = A



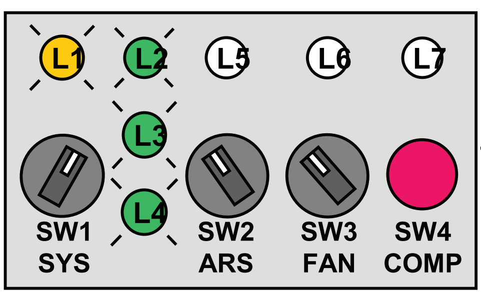
- High enclosure temp



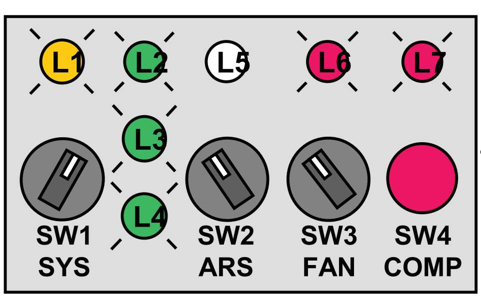
- High enclosure temp



- Low inlet pressure & reset
- High enclosure temp & reset
- Shutdown on high disch. press.
- Relay R1 coil open



- Low inlet pressure & reset
- High enclosure temp & reset
- Shutdown on high disch. press.
- Relay R1 coil open



(Compressor audibly not running)
- Rix motor thermal OL open
- Rix motor contactor coil open

APPENDIX C – Narrative Logbook

EARLY FIELD ASSESSMENT OF SOLID ELECTROLYTE OXYGEN SEPARATOR

AT OC-ALC, TINKER AFB OK

NARRATIVE LOGBOOK

Next Oxygen Sample Due: 18 Jun 10

11 Jun 10, Friday - Status: ON-LINE BUT SUPPLING OXYGEN AT REDUCED CAPACITY

Telecon minutes: Oxygen generator #1 (left side) air mover is not working. APCI will ship a new air mover to Tinker. Tinker plans to install the air mover. Oxygen generator #2 is supplying oxygen at 2.4 LPM. Compressor is OK. Compressor auto-start function appears OK. APCI maintenance trip to Tinker is currently pre-planned for sometime during the month of July, pending contract modification to extend the SEOS Tinker effort to Nov 10 and personnel availability.

04 Jun 10, Friday - Status: ON-LINE BUT SUPPLYING OXYGEN AT REDUCED CAPACITY

Telecon minutes: Tinker reported construction in the area may be causing power outages. Presently, Oxygen Generator #1 is off-line. Its air mover will not start. Oxygen Generator #2 is working but at a slightly reduced capacity (2.5 LPM). Tinker plans to troubleshoot Generator #1. Compressor is ok. Supply cylinder pressure appears adequate. A pressure of 1800 psig was noted on 04 Jun 10. Tinker plans to take an oxygen sample next week.

02 Jun 10, Wednesday - Status: OFF-LINE.

Tinker AFB reported the shop lost power over the weekend. The breadboard was restarted and is in the heating cycle. Sometime today the DC ramp will be started.

07 May 10, Friday - Status: OFF-LINE.

Telecon minutes: Tinker AFB reported the facility had a prolonged power outage. The SEOS breadboard shutdown for an estimated three hours. Stack temperature dropped to an estimated 517°C. The device was restarted and is currently in the heat-up phase. Full startup should occur today. Also, the compressor auto start function will be checked.

29 Apr 10, Thursday - Status: OK.

Tinker AFB reported compressor is not starting automatically. Manual restart works but the start button must be held down for 90 seconds. APCI/Ceramatec are investigating possible causes for the problem.

23 Apr 10, Friday - Status: OK.

Tinker AFB had to manually start the compressor but it appeared to run OK. Start button had to be depressed 90 seconds.

23 Apr 10, Friday - Status: OFF-LINE

Telecon minutes: Based on review of the data set received on 22 Apr 10, the compressor isn't cycling on. The SEOS oxygen generators appear OK. Action: APCI/Ceramatec will contact Tinker AFB personnel on 26 Apr 10 and attempt to reset the compressor control circuit.

09 Apr 10, Friday - Status: OK.

Telecon minutes: Oxygen generators, air movers, and compressor functioning OK based on review of the latest data set.

02 Apr 10, Friday - Status: OK.

Tinker AFB reported a FAL alarm occurs when the compressor isn't pumping oxygen. The FAL alarm terminates when the compressor starts pumping oxygen. APCI/Ceramatec confirmed this occurrence is normal operation, however, it isn't noted in the O&M manual. A new O&M manual page 27 (Alarms) was prepared with an updated description of the FAL alarm.

26 Mar 10, Friday - Status: OK.

Telecon minutes:

-- Lab analysis showed the oxygen samples were in compliance with the mil specs.

-- SEOS breadboard is back on-line and connected to B. 1055 high pressure oxygen manifold.

-- Air movers are running at 2.7 to 2.8 liters/minute. Compressor is cycling normally.

-- A replacement power supply arrived at APCI, Allentown PA. The item will be shipped to Tinker AFB.

24 Mar 10, Wednesday - Status: OFF-LINE/AWAITING OXYGEN SAMPLE LAB ANALYSIS REPORT

Tinker AFB reported the shop experienced a long term power outage over the weekend. Tinker AFB restarted the breadboard. Oxygen samples were taken and sent to the lab for analysis. If the samples show the oxygen still in compliance with the mil specs, the breadboard will go back on-line.

08 Mar 10, Monday - Status: OFF-LINE/AWAITING OXYGEN SAMPLE LAB ANALYSIS REPORT

Tinker AFB replaced the right side air mover and powered-up the breadboard. Voltage at the right side air mover power supply was measured at 13.9 Volts. Oxygen samples will be collected. Breadboard will go back on-line after the oxygen samples show compliance with the mil specs.

05 Mar 10, Friday - Status: OFF-LINE/AWAITING OXYGEN SAMPLE LAB ANALYSIS REPORT

Telecon minutes:

-- Tinker AFB reported left side oxygen generator OK, right side air mover shutdown, and compressor OK. Oxygen samples were collected and sent to the lab. Results should be available next week.

-- Way forward: Tinker AFB will attempt to replace the right side air mover. A spare air mover is on-site at Tinker AFB. Tinker AFB will check the voltage supplied to the right side air mover. If needed, APCI and Ceramatec plan to support Tinker AFB in these actions via telephonic communication.

02 Mar 10, Tuesday - Status: OFF-LINE - Tinker AFB reported the breadboard malfunctioned on 22 Feb 10.

19 Feb 10, Friday - Status: OFF-LINE/AWAITING OXYGEN SAMPLE LAB ANALYSIS REPORT - APCI completed breadboard preventative maintenance and repair at Tinker AFB (17-19 Feb 10). The breadboard is operating normally. Air mover #1 was replaced. Air mover #2 was rebuilt. Power supply for air mover #2 was replaced and rewired. The oxygen generators and SEOS electrochemical stacks are functioning normally. The compressor wiring and timers were modified. The compressor modifications enable the compressor to restart after extended low pressure or zero pressure conditions. A small leak was detected in the compressor outlet piping but it should have negligible impact on breadboard operations. The compressor high pressure setting remains at 2100 psig and the low pressure setting was reset to 1700 psig. An oxygen sample must be taken to show continued compliance with the military specifications.

22 Jan 10, Friday - Status: OFF-LINE - APCI breadboard maintenance trip to Tinker AFB planned for 28 and 29 Jan 10. APCI plans to send two people.

13 Jan 10, Wednesday - Status: OFF-LINE - Tinker AFB reported the oxygen generator air movers are experiencing electrical problems. The air movers supply ambient air to the SEOS electrochemical stacks. Tinker AFB isolated the SEOS breadboard and reconnected their oxygen supply manifold to the vendor oxygen bottles. The oxygen generator and compressor electrical problems will be resolved during the upcoming APCI maintenance trip. The trip is tentatively planned for the week of 25 Jan 10. Most likely APCI will need facility access for 2 days. Confirmation of the exact trip dates will be provided shortly.

12 Jan 10, Tuesday - Status: OFF-LINE

Telecon minutes:

-- Tinker AFB reported Oxygen Generator #1 is showing an alarm mode and Oxygen Generator #2 is not running. The electrochemical stack temperatures on both units are near the normal operational temperature; hence, APCI will assist Tinker AFB personnel in attempting to restart the generators.

-- Tinker AFB reported the compressor is running OK but disconnecting and reconnecting the compressor electrical connector may be causing excessive wear at the connector pins. The group noted compressor vibration might be causing the current issues. APCI will suggest an approach to mitigate compressor vibration.

-- 18 Dec 09 Action Item (Status: OPEN): Date for the APCI maintenance trip to Tinker AFB is TBD pending review of personnel availability.

23 Dec 09, Wednesday - Status: OK - Tinker AFB reported laboratory test reports for SEOS oxygen (samples N6350 and N6352) show compliance with the appropriate military standards.

18 Dec 09, Friday - Status: OK

Telecon minutes:

-- On 17 Dec 09 Tinker AFB noted the compressor was down but after reconnecting the compressor control box the problem resolved.

-- Action Item: APCI will determine if the planned February preventative maintenance trip can be scheduled earlier. Trip would be used to resolve the compressor intermittent electrical problem and conduct general preventative maintenance.

15 Dec 09, Tuesday - Status: OK - Compressor is working.

14 Dec 09, Monday - Status: OFF-LINE - Compressor is down. New control box should be installed today.

08 Dec 09, Tuesday - Status: OK - APCI shipped new compressor control box to Tinker AFB.

07 Dec 09, Monday - Status: OFF-LINE - Tinker AFB reported compressor is down. Disconnecting and reconnecting compressor control box resolved the problem.

04 Dec 09, Friday - Status: OK

Telecon minutes:

-- Tinker AFB reported when the compressor shutdown on 01 Dec 09 the troubleshooting guide was of limited value in helping to define the problem. Intermittent connections at the power cable connector most likely made troubleshooting more difficult. APCI suggested using duct tape on the power connector to help secure it.

-- Tinker AFB will retain the current oxygen manifold valves which have integral check valves. The check valves prevent SEOS from filling the manifold bottles. Presently, Tinker AFB believes the two SEOS breadboard oxygen bottles will meet their needs.

-- Tinker AFB will return the APCI tool kit. Also, Tinker AFB will ship the breadboard packaging foam to APCI.

02 Dec 09, Wednesday- Status: OK - Power cable from control box to compressor found loose. Cable retightened.

01 Dec 09, Tuesday - Status: OFF-LINE - Oxygen generators OK. Compressor shut down.

20 Nov 09, Friday - Status: OK - SEOS breadboard installed and operating properly at OC-ALC, Tinker AFB OK. Several facility personnel trained on start-up, operation, shutdown, oxygen sampling, and data logging. Tinker AFB laboratory confirmed SEOS oxygen complies with mil spec for aviator's breathing oxygen. Next oxygen sampling required in 45 days (04 Jan 10). First aircraft oxygen bottle filled with SEOS oxygen. User questionnaire and performance metrics are under development.

EARLY FIELD ASSESSMENT OF SOLID ELECTROLYTE OXYGEN SEPARATOR

AT OC-ALC, TINKER AFB OK

NARRATIVE LOGBOOK

Next Oxygen Sample Due: 18 Jun 10

11 Jun 10, Friday - Status: ON-LINE BUT SUPPLING OXYGEN AT REDUCED CAPACITY

Telecon minutes: Oxygen generator #1 (left side) air mover is not working. APCI will ship a new air mover to Tinker. Tinker plans to install the air mover. Oxygen generator #2 is supplying oxygen at 2.4 LPM. Compressor is OK. Compressor auto-start function appears OK. APCI maintenance trip to Tinker is currently pre-planned for sometime during the month of July, pending contract modification to extend the SEOS Tinker effort to Nov 10 and personnel availability.

04 Jun 10, Friday - Status: ON-LINE BUT SUPPLYING OXYGEN AT REDUCED CAPACITY

Telecon minutes: Tinker reported construction in the area may be causing power outages. Presently, Oxygen Generator #1 is off-line. Its air mover will not start. Oxygen Generator #2 is working but at a slightly reduced capacity (2.5 LPM). Tinker plans to troubleshoot Generator #1. Compressor is ok. Supply cylinder pressure appears adequate. A pressure of 1800 psig was noted on 04 Jun 10. Tinker plans to take an oxygen sample next week.

02 Jun 10, Wednesday - Status: OFF-LINE.

Tinker AFB reported the shop lost power over the weekend. The breadboard was restarted and is in the heating cycle. Sometime today the DC ramp will be started.

07 May 10, Friday - Status: OFF-LINE.

Telecon minutes: Tinker AFB reported the facility had a prolonged power outage. The SEOS breadboard shutdown for an estimated three hours. Stack temperature dropped to an estimated 517°C. The device was restarted and is currently in the heat-up phase. Full startup should occur today. Also, the compressor auto start function will be checked.

29 Apr 10, Thursday - Status: OK.

Tinker AFB reported compressor is not starting automatically. Manual restart works but the start button must be held down for 90 seconds. APCI/Ceramatec are investigating possible causes for the problem.

23 Apr 10, Friday - Status: OK.

Tinker AFB had to manually start the compressor but it appeared to run OK. Start button had to be depressed 90 seconds.

23 Apr 10, Friday - Status: OFF-LINE

Telecon minutes: Based on review of the data set received on 22 Apr 10, the compressor isn't cycling on. The SEOS oxygen generators appear OK. Action: APCI/Ceramatec will contact Tinker AFB personnel on 26 Apr 10 and attempt to reset the compressor control circuit.

09 Apr 10, Friday - Status: OK.

Telecon minutes: Oxygen generators, air movers, and compressor functioning OK based on review of the latest data set.

02 Apr 10, Friday - Status: OK.

Tinker AFB reported a FAL alarm occurs when the compressor isn't pumping oxygen. The FAL alarm terminates when the compressor starts pumping oxygen. APCI/Ceramatec confirmed this occurrence is normal operation, however, it isn't noted in the O&M manual. A new O&M manual page 27 (Alarms) was prepared with an updated description of the FAL alarm.

26 Mar 10, Friday - Status: OK.

Telecon minutes:

-- Lab analysis showed the oxygen samples were in compliance with the mil specs.

-- SEOS breadboard is back on-line and connected to B. 1055 high pressure oxygen manifold.

-- Air movers are running at 2.7 to 2.8 liters/minute. Compressor is cycling normally.

-- A replacement power supply arrived at APCI, Allentown PA. The item will be shipped to Tinker AFB.

24 Mar 10, Wednesday - Status: OFF-LINE/AWAITING OXYGEN SAMPLE LAB ANALYSIS REPORT

Tinker AFB reported the shop experienced a long term power outage over the weekend. Tinker AFB restarted the breadboard. Oxygen samples were taken and sent to the lab for analysis. If the samples show the oxygen still in compliance with the mil specs, the breadboard will go back on-line.

08 Mar 10, Monday - Status: OFF-LINE/AWAITING OXYGEN SAMPLE LAB ANALYSIS REPORT

Tinker AFB replaced the right side air mover and powered-up the breadboard. Voltage at the right side air mover power supply was measured at 13.9 Volts. Oxygen samples will be collected. Breadboard will go back on-line after the oxygen samples show compliance with the mil specs.

05 Mar 10, Friday - Status: OFF-LINE/AWAITING OXYGEN SAMPLE LAB ANALYSIS REPORT

Telecon minutes:

-- Tinker AFB reported left side oxygen generator OK, right side air mover shutdown, and compressor OK. Oxygen samples were collected and sent to the lab. Results should be available next week.

-- Way forward: Tinker AFB will attempt to replace the right side air mover. A spare air mover is on-site at Tinker AFB. Tinker AFB will check the voltage supplied to the right side air mover. If needed, APCI and Ceramatec plan to support Tinker AFB in these actions via telephonic communication.

02 Mar 10, Tuesday - Status: OFF-LINE - Tinker AFB reported the breadboard malfunctioned on 22 Feb 10.

19 Feb 10, Friday - Status: OFF-LINE/AWAITING OXYGEN SAMPLE LAB ANALYSIS REPORT - APCI completed breadboard preventative maintenance and repair at Tinker AFB (17-19 Feb 10). The breadboard is operating normally. Air mover #1 was replaced. Air mover #2 was rebuilt. Power supply for air mover #2 was replaced and rewired. The oxygen generators and SEOS electrochemical stacks are functioning normally. The compressor wiring and timers were modified. The compressor modifications enable the compressor to restart after extended low pressure or zero pressure conditions. A small leak was detected in the compressor outlet piping but it should have negligible impact on breadboard operations. The compressor high pressure setting remains at 2100 psig and the low pressure setting was reset to 1700 psig. An oxygen sample must be taken to show continued compliance with the military specifications.

22 Jan 10, Friday - Status: OFF-LINE - APCI breadboard maintenance trip to Tinker AFB planned for 28 and 29 Jan 10. APCI plans to send two people.

13 Jan 10, Wednesday - Status: OFF-LINE - Tinker AFB reported the oxygen generator air movers are experiencing electrical problems. The air movers supply ambient air to the SEOS electrochemical stacks. Tinker AFB isolated the SEOS breadboard and reconnected their oxygen supply manifold to the vendor oxygen bottles. The oxygen generator and compressor electrical problems will be resolved during the upcoming APCI maintenance trip. The trip is tentatively planned for the week of 25 Jan 10. Most likely APCI will need facility access for 2 days. Confirmation of the exact trip dates will be provided shortly.

12 Jan 10, Tuesday - Status: OFF-LINE

Telecon minutes:

-- Tinker AFB reported Oxygen Generator #1 is showing an alarm mode and Oxygen Generator #2 is not running. The electrochemical stack temperatures on both units are near the normal operational temperature; hence, APCI will assist Tinker AFB personnel in attempting to restart the generators.

-- Tinker AFB reported the compressor is running OK but disconnecting and reconnecting the compressor electrical connector may be causing excessive wear at the connector pins. The group noted compressor vibration might be causing the current issues. APCI will suggest an approach to mitigate compressor vibration.

-- 18 Dec 09 Action Item (Status: OPEN): Date for the APCI maintenance trip to Tinker AFB is TBD pending review of personnel availability.

23 Dec 09, Wednesday - Status: OK - Tinker AFB reported laboratory test reports for SEOS oxygen (samples N6350 and N6352) show compliance with the appropriate military standards.

18 Dec 09, Friday - Status: OK

Telecon minutes:

-- On 17 Dec 09 Tinker AFB noted the compressor was down but after reconnecting the compressor control box the problem resolved.

-- Action Item: APCI will determine if the planned February preventative maintenance trip can be scheduled earlier. Trip would be used to resolve the compressor intermittent electrical problem and conduct general preventative maintenance.

15 Dec 09, Tuesday - Status: OK - Compressor is working.

14 Dec 09, Monday - Status: OFF-LINE - Compressor is down. New control box should be installed today.

08 Dec 09, Tuesday - Status: OK - APCI shipped new compressor control box to Tinker AFB.

07 Dec 09, Monday - Status: OFF-LINE - Tinker AFB reported compressor is down. Disconnecting and reconnecting compressor control box resolved the problem.

04 Dec 09, Friday - Status: OK

Telecon minutes:

-- Tinker AFB reported when the compressor shutdown on 01 Dec 09 the troubleshooting guide was of limited value in helping to define the problem. Intermittent connections at the power cable connector most likely made troubleshooting more difficult. APCI suggested using duct tape on the power connector to help secure it.

-- Tinker AFB will retain the current oxygen manifold valves which have integral check valves. The check valves prevent SEOS from filling the manifold bottles. Presently, Tinker AFB believes the two SEOS breadboard oxygen bottles will meet their needs.

-- Tinker AFB will return the APCI tool kit. Also, Tinker AFB will ship the breadboard packaging foam to APCI.

02 Dec 09, Wednesday- Status: OK - Power cable from control box to compressor found loose. Cable retightened.

01 Dec 09, Tuesday - Status: OFF-LINE - Oxygen generators OK. Compressor shut down.

20 Nov 09, Friday - Status: OK - SEOS breadboard installed and operating properly at Building 1055, OC-ALC, Tinker AFB OK. Several facility personnel trained on start-up, operation, shutdown, oxygen sampling, and data logging. Tinker AFB laboratory confirmed SEOS oxygen complies with mil spec for aviator's breathing oxygen. Next oxygen sampling required in 45 days (04 Jan 10). First aircraft oxygen bottle filled with SEOS oxygen. User questionnaire and performance metrics are under development.

APPENDIX D – Laboratory Oxygen Analysis Reports

AFPET LABORATORY REPORT
HQ AFPET/PTPLA

Lab Report No: 2008LA14694001 | Protocol: GA-OXY-0003 | Cust Sample No: 06046-011-B-1030 08

Date Sampled: 10/30/2008 | Date Received: 11/05/2008 | Date Reported: 11/06/2008

Contract No: NOT INDICATED

Sample Submitter:
HQ AFPET/PTPT 2430

Prime Contractor:
Air Products & Chemicals
7201 Hamilton Boulevard
Allentown, PA 18195-1501

Reason for Submission: Preproduction (Commercial)
Product: Oxygen, Aviator's Breathing, Gaseous

Specification: MIL-PRF-27210G(1) Type:I

Sample Eq Ser No: CG1080 Tank Pressure:1,200 psi

Method	Test	Min	Max	Result
CGA G-4.3-2000	Odor			None
CGA G-4.3-2000	Purity (% vol)	99.5		100.0
CGA G-4.3-2000	Moisture (ppmv)		7	1
MIL-STD-1564A	Minor Constituents (By IR)			
	Carbon Dioxide (ppmv)		10	0
	Methane (ppmv)		50	0
	Acetylene (ppmv)		0.1	0.0
	Ethylene (ppmv)		0.4	0.0
	Ethane + Ethane Equivalents (ppmv)		6	0
	Nitrous Oxide (ppmv)		4	0
	Refrigerants (Freons) (ppmv)		2	0
	Halogenated Solvents (ppmv)		0.2	0.0
	Others (ppmv)		0.2	0.0

Dispositions:
For information purposes only.

Approved By **Date**

LABORATORY TEST REPORT

Customer:

Report Date: 19 November 2009
Product: Oxygen (gas)
Specification: T.O. 42B6-1-1 Procurement

Base Sample No. : N6238

SAMPLE INFORMATION:

Lab Sample No. :	N6238	**Sample Origin:**	Oxygen Convert Shop
			na
Date Received:	18 Nov 09	**Date Last Added:**	na
Sampler Pressure (psi):	1000	**Date Last Purged:**	Other(1)
Sampler No. :	2	**Manufacturer:**	
Date Sampled:	18 Nov 09	**Reason For Analysis:**	

LABORATORY TEST RESULTS

METHOD	TEST	MIN	MAX	RESULTS
T.O.\GC-TCD\ SOP-P-002	**Oxygen, % vol**	99.5		99.9
Mil-STD-1564\ SOP-P-001	**Trace Contaminant Gases, IR**		5	0.4
	Carbon Dioxide, ppmv		1	0
	Refrigerants, ppmv		25	0
	Methane, ppmv		0.1	0
	Halogenated Solvents, ppmv		2	0
	Nitrous Oxide, ppmv		3	0
	C2+ Hydrocarbon as Ethane, ppmv		0.2	0
	Ethylene, ppmv		0.05	0
	Acetylene, ppmv		0.1	None DET
	Other, ppmv		None	None
T.O.	**Odor**		7	6
Mil-STD-1564\ SOP-P-001	**Moisture, ppmv**			

REMARKS:

Sample complies with specified T.O. limits for tests performed.

Copy to: AFTT

Reported by:

Approved by:

LABORATORY TEST REPORT

Customer:

Report Date: 23 December 2009
Product: Liquid Oxygen
Specification: T.O. 42B6-1-1 Procurement

Base Sample No. : N6352

SAMPLE INFORMATION:

Lab Sample No. : N6352
Date Received: 22 Dec 09
Sampler Pressure (psi):
Sampler No. : B
Date Sampled: 22 Dec 09

Sample Origin:
Date Last Added:
Date Last Purged:
Manufacturer: N/A
Reason For Analysis: other

LABORATORY TEST RESULTS

METHOD	TEST	MIN	MAX	RESULTS
-T.O.\GC-TCD\ SOP-P-002	Oxygen, % vol	99.5		99.9
Mil.STD.1564\ SOP.P.001	Trace Contaminant Gases, IR			
	Carbon Dioxide, ppmv			0.2
	Refrigerants, ppmv		1	0 0
	Methane, ppmv		25	0 0
	Halogenated Solvents, ppmv Nitrous		0.1	0 0
	Oxide, ppmv		2	0
	C2+ Hydrocarbon as Ethane, ppmv		3	
	Ethylene, ppmv		0.2	
	Acetylene, ppmv		0.05	
	Other, ppmv		0.1	None DET
T.O.	Odor		None	None
Mil-STD-1564\SOP-P-001	Moisture, ppmv		7	5

REMARKS:

Sample complies with specified T.O. limits for tests performed.

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Approved by:

LABORATORY TEST REPORT

Customer:		Report Date:	8 March 2010
		Product:	Compressed Oxygen
		Specification:	T.O. 42B6-1-1 Procurement
Base Sample No. : NA			

SAMPLE INFORMATION:

Lab Sample No. :	N6508	Sample Origin:	
Date Received:	4 Mar 10	Date Last Added:	
Sampler Pressure (psi):	NA	Date Last Purged:	
Sampler No. :	B	Manufacturer:	NA
Date Sampled:	3 Mar 10	Reason For Analysis:	Periodic

LABORATORY TEST RESULTS

METHOD	TEST	MIN	MAX	RESULTS
T.O.\GC-TCD\ SOP-P-002	Oxygen, % vol	99.5		99.9
Mil-STD-1564\ SOP-P-001	Trace Contaminant Gases, IR			
	Carbon Dioxide, ppmv		5	0.53
	Refrigerants, ppmv		1	0
	Methane, ppmv		25	0
	Halogenated Solvents, ppmv		0.1	0
	Nitrous Oxide, ppmv		2	0
	C2+ Hydrocarbon as Ethane, ppmv		3	0
	Ethylene, ppmv		0.2	0
	Acetylene, ppmv		0.05	0
	Other, ppmv		0.2	None DET
T.O.	Odor		None	None
Mil-STD-1564\ SOP-P-001	Moisture, ppmv		7	6

REMARKS:

Sample does comply with specified T.O for tests performed.

LABORATORY TEST REPORT

Customer:

Report Date: 22 March 2010
Product: Liquid Oxygen
Specification: T.O. 42B6-1-1 Procurement

Base Sample No. : NA

SAMPLE INFORMATION:

Lab Sample No. : N6523
Date Received: 22 Mar 10
Sampler Pressure (psi): NA
Sampler No. :
Date Sampled: NA

Sample Origin:
Date Last Added:
Date Last Purged: NA
Manufacturer: Periodic
Reason For Analysis:

LABORATORY TEST

RESULTS METHOD	**TEST**	**MIN**	**MAX**	**RESULTS**
T.O.\GC-TCD SOP-P-002	**Oxygen, % vol**	99.5		99.9
Mil-STD-1564\ SOP-P-001	**Trace Contaminant Gases, IR**			

Carbon Dioxide, ppmv
Refrigerants, ppmv Methane,
ppmv Halogenated Solvents,
ppmv
Nitrous Oxide, ppmv
C2+ Hydrocarbon as Ethane, ppmv
Ethylene, ppmv
Acetylene, ppmv
Other, ppmv

MAX: 5, 1, 25, 0.1, 2, 3, 0.2, 0.05, 0.1, None

RESULTS: 0, 0, None DET, None

RESULTS METHOD	**TEST**	**MAX**	**RESULTS**
T.O.	**Odor**		
Mil-STD-1564\ SOP-P-001	**Moisture, ppmv**	7 MAX	7

REMARKS:

Sample does comply for tests performed.

Approved by:

LABORATORY TEST REPORT

Customer:

Report Date: ... 24 March 2010
Product: Liquid Oxygen
Specification: T.O. 42B6-1-1 Procurement

Base Sample No. : NA

SAMPLE INFORMATION:

Lab Sample No. :	N65311-	**Sample Origin:**	
Date Received:	24 Mar 10	**Date Last Added:**	NA NA
Sampler Pressure (psi):	NA	**Date Last Purged:**	NA
Sampler No. :	B	**Manufacturer:**	Periodic
Date Sampled:	23 Mar **10**	**Reason For Analysis:**	

LABORATORY TEST RESULTS

METHOD	TEST	MIN	MAX	RESULTS
T.O.\GC-TCD SOP-P-002	**Oxygen, % vol**	99.5		99.9
Mil-STD-1564\ SOP-P-001	**Trace Contaminant Gases, IR**			
	Carbon Dioxide, ppmv		5	0.15
	Refrigerants, ppmv		1	0
	Methane, ppmv		25	0
	Halogenated Solvents, ppmv		0.1	0
	Nitrous Oxide, ppmv		2	0
	C2+ Hydrocarbon as Ethane, ppmv		3	0
	Ethylene, ppmv		0.2	0
	Acetylene, ppmv		0.05	0
	Other, ppmv		0.1	None DET
T.O.	**Odor**		None	None
Mil-STD-1564\ SOP-P-001	**Moisture, ppmv**		7 MAX	5

REMARKS:

Sample complies with specified T.O. limits for tests performed.

Copy to: AFTT

Reported by:

APPENDIX E – Questionnaire

SEOS Questionnaire and Performance Metrics
(Frequency: On or About the 1st of Each Month)

Name: Organization: Date:

1. SEOS is user friendly.	N/A	Strongly Disagree	Disagree	Agree	Strongly Agree
	0	1	2	3	(4)

Comments: PDA interface is very easy to navigate, all valves clearly labeled, user instructions very thorough. Shop comment: All info for data log easy to access.

2. The controls are adequate to operate system.	N/A	Strongly Disagree	Disagree	Agree	Strongly Agree
	0	1	2	3	(4)

Comments: Touch interface on PDA very easy to use.

3. Displays are sufficient.	N/A	Strongly Disagree	Disagree	Agree	Strongly Agree
	0	1	2	3	(4)

Comments: All necessary information for data sheet easy to find and read. Information on PDA all in one place.

4. System checklists are sufficient.	N/A	Strongly Disagree	Disagree	Agree	Strongly Agree
	0	1	2	3	(4)

Comments: Checklists are very thorough and easy to follow.

5. System emergency shutdown procedures are adequate.	N/A	Strongly Disagree	Disagree	Agree	Strongly Agree
	(0)	1	2	3	4

Comments: Have not had to shut down system. If shut down is necessary, it should be easy to accomplish.

SEOS Questionnaire (Page 2 of 3)					
6. Markings and labels are adequate.	N/A 0	Strongly Disagree 1	Disagree 2	Agree 3	Strongly Agree (4)
Comments:					
7. System noise level is acceptable.	N/A 0	Strongly Disagree 1	Disagree 2	Agree (3)	Strongly Agree 4
Comments: System is more quiet than current equipment.					
8. System size is acceptable.	N/A 0	Strongly Disagree 1	Disagree 2	Agree (3)	Strongly Agree 4
Comments: System requires less space than cylinder pallets.					
9.	N/A 0	Strongly Disagree 1	Disagree 2	Agree 3	Strongly Agree 4
Comments:					
10.	N/A 0	Strongly Disagree 1	Disagree 2	Agree 3	Strongly Agree 4
Comments:					
11.	N/A 0	Strongly Disagree 1	Disagree 2	Agree 3	Strongly Agree 4
Comments:					

SEOS Performance Metrics (3 of 3)					
1. Estimated system up-time/on-line percentage/month.	<50%	50-79%	80-89%	90-95%	>95%
Comments:					
2. Estimated facility cost savings/month based on not using vendor supplied oxygen cylinders.	None	$1-$99	$100-$499	$500-$1,000	>$1,000
Comments:					
3. Estimated man-hours saved/month based on not using vendor supplied oxygen cylinders.	None	1-9 hrs	10-19 hrs	20-50 hrs	>50 hrs
Comments:					
4. Estimated reduction in safety risk due to reduced handling of vendor supplied oxygen cylinders.	None	Somewhat	Moderate	Significant	
Comments:					
5.					
Comments:					