Attachment 2: Liquid Oxygen Production and Storage System Performance Specification

PERFORMANCE SPECIFICATION

LIQUID OXYGEN PRODUCTION AND STORAGE SYSTEM

This specification is approved for use by the Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 **Scope.** This specification covers a shipboard Liquid Oxygen (LOX) Producer and Storage System that employs Pressure/Vacuum Swing Adsorption (PSA/VSA) technology to separate oxygen from ambient air, a liquefier based on the Reverse Brayton Cycle and a cryogenic storage tank.

2. APPLICABLE DOCUMENTS

2.1 **General.** The documents listed in this section are specified in sections 3 and 4 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of the list, document users are cautioned that they must meet all specified requirements documents cited in sections 3 and 4 of this specification, whether or not they are listed.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document, should be addressed to: Code 9212, Naval Surface Warfare Center, Carderock Division, Bldg. 4 2nd Floor, Philadelphia, PA 19112 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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2.2 **Government documents.**

2.2.1 **Specifications, standards and handbooks.** The following specifications, standards and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation (see 6.2).

Department Of Defense Specifications

MIL-S-16032	Switches and Detectors, Shipboard alarm systems
MIL-S-901	Shock test, H.I. (High Impact) shipboard machinery, and systems, requirements for
MIL-G-18997	Gauge, pressure, dial indicating (Naval shipboard use)
MIL-S-27626	Sampler, cryogenic liquid
MIL-C-104	Crates, Wood: lumber and plywood sheathed, nailed, and bolted
MIL-DTL-15090	Enamel, Equipment light gray, (Navy formula no.111)
MIL-PRF-27210	Oxygen, aviator's breathing, liquid and gas
MIL-DTL-24784/7B	Technical repair standards (TRS) for hull, mechanical, and electrical (HM&E) equipment, electronic equipment, and ordnance equipment
MIL-M-24784	Manual, technical, equipments and systems content, requirements for

Department of Defense Standards

MIL-STD –1472	Human Engineering
MIL-STD-777	Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships
MIL-STD-889	Dissimilar Metals
MIL-STD-167	Mechanical Vibrations of Shipboard Equipment (Type I – Environmental and Type II Internally Excited)
MIL-STD-461E	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-1330	Standard Practice for Precision Cleaning and Testing of Shipboard Oxygen, Helium, Helium-Oxygen, Nitrogen and Hydrogen Systems
MIL-STD-38784	Standard Practice for Manuals, Technical: General Style and Format Requirements

Department of Defense Handbooks

S9074-AR-GIB-010/278	Requirements for Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping and Pressure Vessels
S9074-AQ-GIB-010/248	Requirements for Welding and Brazing Procedure and Performance Qualification
T9074-AS-GIB-010/271	Requirements for Nondestructive Testing Methods
0900-LP-001-7000	Fabrication and Inspection of Brazed Piping Systems

MIL-HDBK-470	Designing and Developing Maintainable Products and Systems
MIL-HDBK-2036	Preparation of Electronic Equipment Specifications
MIL-HDBK-454	General Guidelines for Electronic Equipment
MIL-STD-740B	Airborne and Structureborne Noise Measurements and Acceptance Criteria of Shipboard Equipment
MIL-HDBK-781	Reliability Test Methods, Plans, and Environments for Engineering, Development Qualification, and Production

(Unless otherwise indicated, copies of the above specifications, standards and handbooks are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.3 **Non-Government Publications**: The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents, which are DoD adopted, are those listed in the issue of the DoDISS cited in the solicitation. Unless otherwise specified, the issues of the documents not listed in the DoDISS are the issues of the documents cited in the solicitation (see paragraph 8.2).

National Electrical Manufacturers Association

NEMA 250 - Enclosures for Electrical Equipment (1000 Volts Max)

(Application for copies should be addressed to the National Electrical Manufacturers Association 1300 North 17th Street suite 1847 Rosslyn, VA 22209)

American Society of Mechanical Engineers (ASME)

Boiler and Pressure Vessel Code, Section VIII, Rules of Construction of Pressure Vessels

(Application for copies should be addressed to the American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017)

American Society for Testing and Materials (ASTM)

ASTM F1716 - Standard Guide for Transition and performance of marine Software systems maintenance

ASTM Manual 36 - Safe Use of Oxygen System Design, Material Selection, Operation, Storage and Transportation.

ASTM G4.05 - Design Guidelines for High Pressure Oxygen Systems and Fire Hazards in Oxygen Systems

ASTM G63 - Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service

(Application for copies should be addressed to the American Society for testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pa 19428-2959.)

Institute of Electrical and Electronics Engineers (IEEE)

IEEE 45 Recommended Practice for Electrical Installations on Shipboard
IEEE 12207 Industry Implementation of International Standard ISO/IEC 12207: 1995 (ISO/IEC 12207) Standard for Information Technology

(Application for copies should be addressed to the Institute of Electrical and Electronics Engineers, IEEE, P.O. Box 6804, Piscataway, NJ 08854-6804)

Society of Automotive Engineers (SAE International)

SAE J 1739 - Potential Failure Mode and Effects Analysis in Design (Design FMEA) Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA) and Potential Failure mode and Effects Analysis for Machinery (Machinery FMEA)

(Application for copies should be addressed to the SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001)

3. REQUIREMENTS

3.1 General.

3.1.1 **Requirements.** The production and storage system shall be configured for installation in a shipboard compartment and be capable of automatically producing and storing liquid oxygen meeting the flow rate, purity and quality levels specified herein. The system shall produce gaseous oxygen using pressure/vacuum swing adsorption (PSA/VSA) technology, liquefy the produced gas in a Reverse Brayton Cycle liquefier and store the liquid produced in a super-insulated cryogenic storage tank. The generating and storage system equipment shall be a complete unit process, including adsorbent beds, adsorbent material, oxygen receiver, nitrogen compressor, cycling valves, heat exchangers, storage vessel, controller, etc. as required to provide a complete and operational LOX generating and storage system. The system shall be capable of performing its function safely in a shipboard environment, undergoing ship motion (pitch, roll, list), and induced shocks, vibrations and Electro-magnetic Interference (EMI). The generation and storage system shall contain a Programmable Logic Controller (PLC) or a similar device that monitors and processes various system parameters, i.e. pressures, temperatures, liquid levels and oxygen purity. The control system shall automatically operate the various components necessary to safely generate and store LOX product at the specified temperature, pressure, capacity and purity. Once the tank is completely filled, the control system shall safely place the system in a shutdown/idle mode.

3.1.2 **Characteristics.** The production and storage system equipment, components, subcomponents, assemblies, and subassemblies shall be constructed for maximum reliability, automatic operation and from materials of construction suitable for a marine environment and the fluid being processed. The production and storage system shall be designed for ease of maintenance by shipboard personnel with minimum training in cryogenics. The production and storage system

shall be designed so that any component or equipment failure will not cause operator injury or damage to adjacent components. The control system shall automatically detect out-of-specification conditions, record conditions, and secure the plant safely, at which time personnel actions would reestablish proper parameters. The production and storage system shall incorporate manual override features to permit operation in event of controller failures. The production and storage system shall be constructed in such a manner to minimize airborne noise and EMI emissions.

3.2 **First article.** When specified (see paragraph 8.2), a sample shall be subjected to first article inspection in accordance with 4.4.

3.3 **Performance Requirements.** The liquid oxygen (LOX) production and storage system shall satisfy the following performance requirements.

3.3.1 **Producer and Storage Tank System Capacity.**

3.3.1.1 **Generator Capacity.** The producer shall be capable of producing liquid oxygen at a rate of 5 gallons per hour minimum.

3.3.1.2 **Storage Tank Capacity.** The liquid oxygen storage vessel shall have a 250-gallon capacity plus 10% vapor space at a minimum.

3.3.1.3 **Drain.** The storage vessel shall have a drain capable of draining the contents of a full tank in ten minutes or less.

3.3.1.4 **End User Liquid Supply.** The storage vessel shall be capable of delivering liquid oxygen to the end user i.e. LOX cart at a rate of 20 gallons per minute when the storage tank pressure is not greater than 25 psig.

3.3.1.5 **Gaseous Supply.** High-pressure gaseous oxygen shall be provided at a rate of 575 – 600 scfh and 3000 psig.

3.3.1.6 **Cryogenic liquid loss.** The rate of vaporization losses from the storage tank shall not exceed 0.05 % per day in a compartment with an ambient temperature of 80 degrees Fahrenheit.

3.3.2 **Purity and Quality.** The liquid oxygen purity shall be 94 %. The maximum level of minor constituents shall not exceed those currently specified in MIL-PRF-27210. The other constituents not indicated in Table 1 in paragraph 3.6.2, resulting from the lower purity requirement, shall be inert (nitrogen and argon).

3.3.3 **Airborne noise.** Continuously produced airborne noise levels shall not exceed 80 Decibels (dB) at any frequency.

3.4 **Utilities.**

3.4.1 **Electrical power.** The integrated production and storage system shall require only one source of electrical power. The source power shall be 440 volts, 3 phase, and 60 hertz (Hz)

with a maximum voltage variation of plus 10%, minus 20% of rated voltage at 122 degrees Fahrenheit. The maximum power demand shall not exceed 100 Kilowatts (kW). The average power demand shall not exceed 75 kW. One circuit breaker or overload protection will be provided by the installing activity. All electrical components necessary to ensure proper LOX plant operation shall be supplied and integrally mounted within the equipment space. Each component making up the production and storage system shall be completely wired and interconnected at the factory. All required breakers and overload protection shall be supplied with the producer and storage system and integrally mounted. All control power shall be obtained from the main input power. The electrical insulation resistance of each independent electric circuit shall have a resistance to ground and to other independent circuits greater than 5 mega ohms. Electrical and thermocouple wire shall be clearly labeled and run through wire harnesses or conduits.

3.4.2 **Air/Ventilation supply.** Air will be supplied to the production and storage system from a shipboard independent ventilation supply source, which supplies ambient air from outside the ship to the compartment. If air is required for operation of pneumatic systems or other equipment within the LOX production and storage system, the air shall be taken from within the processing system itself.

3.4.3 **Purge gas.** The reverse Brayton cycle liquefier cold box shall be pressurized to at least 2 inches of water, minimum. The maximum purge gas flow to maintain pressure shall be 40 SCFH. The nitrogen required will be supplied from the ship's nitrogen distribution system.

3.4.4 **Water.** If any component or subassembly of the LOX production and storage system requires a shipboard-cooling medium, then that component or subassembly shall be capable of being cooled adequately by seawater at a temperature of 97 degrees Fahrenheit maximum.

3.5 **Physical Characteristics.**

3.5.1 **Dimensions and weight.** The production and storage system envelope dimensions shall not exceed the following: height: 90 inches, width (across front): 147 inches and depth (front to back): 96 inches. The height restriction includes the total height of the system component and the height gained by using resilient mounts including anticipated shock excursions. The clearance necessary for maintenance or removal of any system component shall be within the system envelope dimensions cited above. Total LOX production and storage system weight shall not exceed 11 tons (22,000 pounds).

3.5.2 **Operational life.** The producer shall be operated in the shipboard environment specified herein for a period of 25 years with no limit on the number of operating cycles. Minimum time between overhauls shall be 30,000 operating hours.

3.5.3 **Hatchable.** The production and storage system, PSA/VSA and liquefier unit, shall be capable of fitting through a hatch opening measuring 66 x 26 inches, once disassembled. The storage tank assembly shall be capable of being installed in its designated compartment using temporary enlarged opening around existing compartment hatch opening.

3.6 **Environmental.**

3.6.1 **Pitch, roll and list.** The production and storage system shall operate at rated capacity and purity under the following specified pitch, roll and list conditions:

Pitch - 4 degrees for an 11 second period
Roll - 15 degrees for a 15 second period
List - 5 degrees continuous

The producer shall not lose fluids or be damaged under the following conditions:

Operating at a fixed incline of up 15 degrees in any direction.
Operating while pitching at a maximum of 10 degrees up or down from its normal horizontal plane.
Operating while rolling a maximum of 30 degrees to either side of vertical.

3.6.2 **Intake air contaminants.** The production and storage system shall produce oxygen that will meet the purity requirements as set forth in paragraph 3.3.2 at the rate specified in paragraph 3.3.1.1 when the influent air contains contaminants in the concentrations listed below:

Contaminants	Concentration maximum by volume
Carbon Dioxide (CO2)	1000 p/ml
Water vapor (H2O)	Saturated
Nitrous Oxide (N2O)	5 ppm
Carbon Monoxide (CO)	20 ppm
Methane (CH4)	1 ppm
Sulfur dioxide (SO2)	1 ppm
Acetaldehyde (C2H4O)	1 ppm
Acetylene (C2H2)	2 ppm

Table 1

3.6.3 **Intake air temperature.** The production and storage system shall produce oxygen that will meet the purity requirements as set forth in paragraph 3.3.2 at the rate specified in paragraph 3.3.1.1 when operating in any ambient temperature between 40 - 122 degrees Fahrenheit.

3.6.4 **Intake air pressure.** The production and storage system shall produce oxygen that will meet the purity requirements as set forth in paragraph 3.3.2 at the rate specified in paragraph 3.3.1.1 when operating at any ambient sea level pressure between 14.0 to 15.0 psia.

3.6.5 **Intake Air Humidity.** The production and storage system shall produce oxygen that will meet the purity requirements as set forth in paragraph 3.3.2 at the rate specified in paragraph 3.3.1.1 when processing air at atmospheric temperatures between 40 -122 degrees Fahrenheit and relative humidity between 0-100% RH.

3.6.6 **Shock.** The production and storage system shall meet grade A, class I and Class II, deck mounted equipment shock requirements in accordance with MIL-S-901. The use of previous shock tests extensions shall be used to the maximum extent practical. The use of resilient mounts requires the use of flexible interface connections for all shipboard interfaces. These interfaces

shall be provided with the production and storage system. The shock mathematical model analysis report shall be submitted in accordance to DD Form 1423-1, Sequence No. A014.

3.6.7 **Vibration.** The production and storage system shall meet the requirements of MIL-STD-167–1, Type I and Type II.

3.6.8 **Electromagnetic interference (EMI).** The production and storage system shall meet and demonstrate compliance with the requirements of MIL-STD-461 Rev E (dated 20 Aug 1999) for Surface Ship, Below Deck, Metallic Hull installations.

3.7 **Materials.** The material used shall meet the requirements specified herein. The materials used in the production and storage system shall be ignition resistant and suitable for use in a marine environment and the pressure and temperatures specified. The selected material shall conform to the requirements of MIL-STD-777. Where no specific material requirements are identified, consult the following publications:

- ASTM MANUAL 36, Safe Use of Oxygen System Design, Material Selection, Operation, Storage and Transportation.
- ASTM G4.05, Design Guidelines for High Pressure Oxygen Systems and Fire Hazards in Oxygen Systems.
- ASTM G63 American Society of Testing and Materials, Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service material.

Safety and reliability shall be of paramount importance in the selection of material, design, and installation of oxygen system components. During selection of piping and component materials, the minimization of fire hazard shall be an important consideration because oxygen promotes ignition and supports combustion. Materials for liquid oxygen service shall consider strength retention at cryogenic temperatures and arrangement for expansion and contraction. Incompatible oil or grease shall not be used. Pipe threaded (tapered threads) materials are not approved. Materials used shall be limited to 300 series corrosion resistant steels, aluminum and aluminum alloys, copper and copper alloys, silicon-bronze, 70/30 Cu-Ni, Brass or Monel. Carbon steel alloys may be used for structural supports, which are not subjected to low temperatures from cryogenic vessels or piping. Materials selected shall be treated to prevent corrosion and provide a corrosion allowance for a 25-year life. Cast iron shall not be used.

3.7.1 **Dissimilar materials.** The use of dissimilar metals shall be minimized to preclude galvanic corrosion and shall be in accordance with MIL-STD-889 requirements for selection and protection of dissimilar materials. Where dissimilar metal joints are used, the joint construction shall preclude metal-to-metal contact and moisture entrapment at the gasket. Dissimilar metal joints shall not use pipe threads/NPT, tapered pipe threads, explosion bonded or inertia welded (silver containing interlayer between the metals) joints.

3.7.2 **Metal in contact with cryogenic liquid.** Unless otherwise specified herein, stainless steel type 304, 304L or 316L, silicon-bronze, Cu-Ni, Bronze and aluminum alloys shall be used for parts in contact with liquid cryogen or subject to liquid cryogen temperatures.

3.7.3 **Aluminum.** When aluminum is used, it shall be hard anodized after all welding and forming are completed on the component or piping assembly.

3.7.4 **Nonmetallic materials.** Nylon, combustible materials, or nonmetallic materials adversely affected or deteriorated by continued use with gaseous or liquid oxygen shall not be used. All factors associated with their use, such as temperature, pressure and oxygen compatibility must be considered in deciding if a material can be used without decreasing the safety integrity of oxygen systems. Materials, including gaskets and valve packing, insulation and greases, shall be compatible with cleaning solvents as specified in MIL-STD-1330.

3.7.5 **Cold Box.** Within the cold box insulation jacket, each pipe shall be separated by a minimum of 4 inches (measured radially from the piping surface) from any item of dissimilar material. The cold box shall include removable panels to permit access for maintenance. The entire jacket shall have sufficient insulation to prevent the formation of frost spots when operating at temperature and humidity conditions specified in paragraph 3.6.5. The jacket shall be constructed to prevent leakage in excess of 40 SCFH maximum at 2 inches of water pressure.

3.7.6 **Compressor heat exchangers.** Material in all heat exchanger tube bundles that contact seawater shall be of titanium or 70-30 Cu-Ni. Heat exchanger shells and compression cylinders contacting seawater can be made of non-corrosion resistant material if Zinc anodes are provided in the design. Heat exchangers shall be constructed to be suitable for the specified operating environment. Aluminum in the heat exchange shall be anodized after completion of all forming. Painted or coated carbon steel pipe and fittings shall not be used.

3.7.7 **Toxic chemicals, hazardous substances, or Ozone Depleting Chemicals (ODC's).** The use of toxic chemicals, hazardous substances or ODCs shall be avoided where feasible. Materials used in the construction of the producer shall have no effect on the health of personnel when the materials are used for their intended purpose. Regardless of other requirements, materials and parts containing asbestos, cadmium, lithium, mercury or radioactive materials shall not be used.

3.7.8 **Recycled, recovered, or environmentally preferable materials.** Recycled, recovered or environmentally preferable materials should be used to the maximum extent possible provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

3.8 **Compressors.** All compressors shall be an oil free design. The compressor shall be capable of operating continuously at the maximum delivery pressure under an ambient temperature of 122 degrees Fahrenheit without having to stop for cooldown. The lubricants used shall be of an approved type listed in NAVSEA Technical Manual S9086-H7-STM-010/CH-262.

3.9 **Pressure/Vacuum Swing Adsorption unit.** The adsorbent used in the oxygen generator shall be nitrogen selective, capable of operating under environmental conditions specified herein. Through its adsorption characteristics, oxygen gas is produced at the required flow rate and 94% purity minimum for feed to a Reverse Brayton Cycle Liquefier.

3.10 **Reverse Brayton cycle liquefier.** The liquefier shall employ an oil free turboexpander to provide all the required refrigeration for liquefaction of the supplied high purity oxygen gas. The liquefier shall then direct the liquid oxygen to the storage tank at a minimum flow rate of 5 gph. The working fluid used in the liquefier's closed loop shall be nitrogen gas, which will be supplied from

the ship's nitrogen distribution system. The system shall have a means to provide a sample of liquid oxygen for infrared analysis.

3.11 **Super insulated storage tank.** The storage system shall be designed, fabricated and tested in accordance with the ASME Boiler and Pressure Vessel code, section VIII for unfired vessels. The tank shall be fitted with a means to sample its contents and to enable distribution of liquid to the LOX cart fill room at the rate specified in paragraph 3.3.1.4. The storage tank shall have a method for withdrawing the stored liquid oxygen from the tank, pumping the liquid, converting the liquid to a gas and delivering the gas to an external system at a rate 575 – 600 SCFH and 3000 psig pressure. The conversion from liquid to gas shall be accomplished using an electrically heated and thermostatically controlled vaporizer that shall be capable of vaporizing the entire output of oxygen from the pump and heating the gas to a temperature of 100 degrees Fahrenheit. All control and indicators shall be located at one end of the storage system and be readily visible.

3.12 **Piping, valves and fittings.** Unless otherwise specified, all piping, valves and fittings shall be in accordance with MIL-STD-777. Glass Reinforced Pipe (GRP) shall not be used. Pipe or tube made from Bessemer steel shall not be used. Piping, valves and fittings containing tapered pipe threads and or brazed bosses shall not be approved. Transition fittings containing a silver interlayer between aluminum and stainless steel piping are not approved to prevent failures of these joints in service.

3.13 **Cryogenic liquid transfer line.** The cryogenic transfer line from the producer to the storage tank shall be a vacuum-jacketed pipe, incorporating low boil-off features to minimize the quantity of product boil-off. It shall be sized to allow cryogenic liquid to flow at the rate specified herein.

3.14 **Vessels.** Pressure-containing vessels shall be in accordance with the ASME boiler Pressure Vessel Code Section VIII for unfired pressure vessels.

3.15 **Pressure Gauges.** If used to manually operate the system, pressure gauges shall be of simplex type. Only pressure gauges utilizing a C-type bourdon tube as the elastic element shall be used for oxygen service. The bore diameter throughout the element shall be not less than .025 inch. The gauge shall have a circular scale and the dial face shall be in accordance with ANSI B40.1. Gauges used for Oxygen services shall have the words "OXYGEN SERVICE" printed in red on the gauge face.

3.16 **Pressure transmitters.** Pressure transmitters shall be 4-20 mA, two-wire, loop powered type. Dedicated pressure transmitters with adequate sensors shall be provided to measure critical pressures within the production and storage system.

3.17 **Flow meters.** If used, flow meters shall be two-wire differential transmitter type, employing a rupture-proof bellows design. Flow meters shall have a LCD indicator and shall generate a 4-20 mA output. Meters will read in standard cubic feet, inches of water or pounds per hour and shall be accurate to within plus or minus 4 percent of actual flow measurements. Normal operating readings shall be indicated within the middle one-third range of the indicator. The indicator shall be installed on a common instrumentation panel and/or the PLC display and measure, as a minimum, the production and storage system critical flows.

3.18 **Liquid level gauge.** Liquid level gages shall read in gallons. Liquid level indicators employing a rupture-proof bellows design shall be provided to measure the process fluid levels. Liquid level indicators shall display the process fluid level on an LCD indicator and shall generate a 4-20 mA output. If mechanical gauges are used, the level gauge should employ a rupture-proof bellows design. The scale of each level gauge shall be supplied with a zero adjustment and shall be graduated in increments of volume. Normal operating readings should be indicated within the middle one-third range of the indicators.

3.19 **Temperature indicating system.** A temperature-indicating system measuring critical temperatures within the production and storage system shall be provided for manual operation. The system shall consist of individually installed resistance temperature detectors (RTDs) which are connected to one common temperature indicating unit mounted on the front of the generator components and to the PLC input /output modules.

3.20 **Product filter.** A 10-micron product filter shall be used to prevent particulate matter from reaching the storage tank. The filter shall contain a removable and cleanable CRES 300 series filter element.

3.21 **Product purity analyzer.** One oxygen product purity analyzer shall be provided. The analyzer shall be of a paramagnetic type and shall be mounted on the generator. Analyzers based on other technology will be considered, provided the contractor supplies adequate trade-off analysis ensuring that the proposed analyzer contains features similar to or better than those of the paramagnetic analyzers. Product oxygen sample lines shall be provided to the analyzer. Sample gases are to be at room temperature before being sent to the analyzer. The electronic analyzer shall provide continuous readout of the purities. The electronic analyzer shall be accurate to within +/- 0.5 percent of the actual sample gas purity. The producer shall have sample gas tubing, calibration gas tubing, gas flow manifolds, and electrical wiring so that the purity of the sampled process stream can be easily and accurately determined. The electronic analyzer warm-up period shall not exceed 2 hours. The electronic analyzer shall not require calibration more than once per 24 hours, and shall not require consumables except for calibration gas. If calibration gas is required for the electronic analyzer operation, the analyzer shall operate as specified herein using either military gas or gas for which certified composition analysis is not necessary. The analyzer shall not require calibration gas purity of greater than 99.99 percent. The analyzer shall be capable of communicating with the controller. The controller shall recognize, communicate and monitor normal and alarm conditions associated with the analyzer.

3.22 **Programmable Logic Controller (PLC).** A PLC or similar device programmed for complete, safe and reliable operation shall be contained within the oxygen generation and storage system. The PLC shall automatically sense control system parameters (temperature, pressure, bulk purity, etc.) and energize the system to produce and store oxygen product in accordance with the capacity and purity requirements of this specification. The PLC shall be designed so that installation, operation, inspection, maintenance and adjustments can be accomplished without causing injury or damage to equipment. It shall be designed so that one failure will not cause or produce an unsafe condition nor shall it cause a ripple effect. The PLC's electrical system shall provide built-in safety features comprised of both hardware and software to guarantee safe system operation. The controller shall incorporate safety features for out of tolerance electrical voltages and current. The PLC shall automatically detect out-of-specification conditions, record conditions, and

secure the plant safely, at which time personnel actions would reestablish proper parameters. All software executables (PLC and PC), PLC ladder logic and PC source code; software tools (and/or licenses if applicable) and other software support information shall be provided with the producer. If PLC is password protected those passwords shall be supplied with the producer.

3.22.1 **Program requirements.** The PLC shall be programmed to include functionality for Controlling, Alarming, Data Storage (alarms and data). Data values shall be scaled in standard U.S. engineering units (PSI, Deg F, Gallons, Pounds, Feet/Inches etc.) in the PLC throughout the program, and made available to the operator interface and network as such. The PLC shall detect and record alarm conditions and shutdown data (i.e. overpressure conditions, controller memory faults, controller execution faults, TBX over speed, thaw heater over temperature and out of specification product purity levels) in the central processing unit for failure analysis. The failure data (time and date of system failure/shutdown as well as vital information on temperature, pressure, flow, liquid levels and valve position) shall be available for downloading.

3.22.2 **Inputs/Outputs (I/O).** The controller shall have sufficient I/O capability to input all process variables required for safe operation and output all manipulated variables required to completely and safely control the oxygen production and storage system. In addition, inputs for the following process variables are required to be input into the controller for monitoring and remote data acquisition purposes. The PLC and its enclosure shall be designed with future expansion capability (and space) for at least two additional I/O modules of the same design as the base PLC without requiring modification to original enclosure or PLC rack. The oxygen production and storage system shall be provided with all necessary analog and digital interfaces to enable controlling safely the liquid oxygen production and storage system at the specified purity and rates. Provisions shall also be made to accept the analog/digital interface necessary as follows:

3.22.2.1 A remote emergency stop (kill) switch located just outside of the oxygen producer compartment.

3.22.2.2 Signal interface from and to Damage Control Central to alert personnel staffing this space of an abnormal operational condition.

3.22.2.3 Ventilation failure alarm.

3.22.3 **Network.** The PLC shall be provided with network interfaces for both Ethernet and Serial interfaces. The Ethernet interface must support both TCP/IP and UDP/IP protocols. The serial interface must support IEEE 1174 standard which adds interface functionality to serial communication links. This communication port shall allow temporary installation of a portable laptop to enable displaying information in the event of display failures.

3.22.4 **Memory.** The PLC shall be equipped with sufficient memory to perform all of the above functions and have at least 50 % excess capacity. The PLC microprocessor shall operate the producer, store pertinent data and transmit data to a graphical display via the computer.

3.22.5 **Programming interface.** The PLC shall be equipped with a local programming interface for a standard laptop computer using programming software. Software shall conform to requirements detailed in paragraph 3.22.8. Controller software shall not be used as a final safety check for over temperature and over pressure fault detection. The controller shall be programmed for data acquisition from pressure and temperature transducers, differential pressure

transducers, analog inputs and outputs and any other pertinent data points. The PLC shall input system parameters and shall use this data to provide operator prompting for system start up, operation, shutdown, emergency start up, ambient thaw, thaw and shutdown via a PC computer interface.

3.22.6 **Power supply.** The power to the controller, computer and graphics display shall be obtained from the main input power of the oxygen generation and storage system. Their power supply shall be able to withstand/tolerate a 10% to 15% variation in line voltage and frequency change. When the voltage or frequency exceeds 1 to 3 AC cycles in duration, the power supply shall issue a shutdown command to the processor. A local and remote safety shutdown switch shall be hard wired in series with the power to the O2 production and storage system.

3.22.7 **Operator Interface (OI).** The PLC shall be equipped with a direct interface to a programmable OI display. The OI shall be a flat panel color touch screen display with programmable screen views. The OI shall contain graphical (programmable) pushbuttons and data displays as required for an operator to start, stop, manually control and view all processes required for safe O2 producer operation, such as failure messages and diagnostic information to assist in operation and trouble-shooting. The OI shall have separate screen views for alarming, trending, operator control and process monitoring of the O2 producer. The following OI are required: Power ON/OFF, Auto/Manual, Start, Stop, and as a minimum four lights to indicate Power ON, Warm-up Mode, Running, Stand By, etc. The PLC shall be capable of accepting input from the operator to allow for emergency operation. The operator shall be able to monitor and modify maintenance requirement messages, access troubleshooting test functions, and monitor alarm set points and incident histories. The controller shall also be capable of interfacing with a computer and a touch screen display to enable transmission of real time data when prompted. The data recorder shall be able to download and record information from the controller processor via a suitable and portable communication interface (i.e. an RS-232 port).

3.22.7.1 **Operator Screen View.** The operator screen view shall provide a means for the operator to control the O2 Producer. It shall have the ability to start and stop the producer via soft pushbuttons, and to manually take control of the following processes: start up, cold plant start up, shut down, cold plant shutdown, thaw, etc.

3.22.7.2 **Alarm Screen View.** The alarm screen view shall provide a display of all relevant alarm conditions associated with the O2 producer. The alarm screen shall provide a means for the operator to acknowledge and clear alarm conditions as appropriate.

3.22.7.3 **Trend Screen View.** The Trend screen view shall provide a means to graphically view several processes in real-time.

3.22.7.4 **Process Monitoring Screen View.** The process monitoring screen view shall provide a graphical view of the most relevant process variable to provide the operator a quick view of the O2 Producer operation. It shall contain only the most relevant parameters (levels, pressures, temperatures, flows) needed to assess operation. Secondary level graphical views may be provided for display of additional detailed data parameters.

3.22.8 **PLC/PC software development and documentation.** All software (PLC and PC) shall be developed in compliance with IEEE/EIS 12207. If commercially available

software meets all requirements specified herein, compliance to IEEE/EIS 12207 is not required. This would only be allowed if the commercially available software is utilized "as is" and NO software changes are required. Compliance to IEEE 12207 requires that all software development shall be planned, managed and documented appropriately throughout the software development lifecycle. Those requirements of IEEE/EIS 12207 that are to be adhered to during the software development lifecycle shall be identified in the Statement Of Work (SOW) Contract Deliverable Requirements Lists (CDRLs) and the associated Data Information Descriptions (DIDs). Submittals shall be in accordance to DD Form 1423-1, Sequence No. A025, S002, S003, and S007. All developed software must have defined software requirements that are traceable from design to code and test. All software requirements must be consistent, feasible and verifiable. All developed software executables, source code, and documentation shall be the property of the US Navy. The software shall NOT be considered proprietary. If passwords or other security measures are employed, those passwords, security measures and codes shall be delivered with the producer. Commercially available software for PC and PLC communication can be used to enable the prompts/interactions stated herein. If this option is pursued, the government shall be supplied with all rights and licensing agreements for use said software. All embedded software shall not be susceptible to potential viruses when using communication ports specified herein.

3.23 **Hour meters.** A cumulative hour meter capable of recording up to a minimum of 999,999 hours shall be provided.

3.24 **Master switch shutdown.** The production and generation system shall be provided with a master switch to shutdown all production equipment in the event of an emergency.

3.25 **Sampler connection.** To ensure sampler connectivity, the sample interface connection must be a 37-degree flare-fitting interface. The system shall include a minimum of two liquid sample connections, one on the liquefier and the other on the storage tank. A gas sample connection shall be supplied to the bulk purity analyzer. The design of the sample connection shall include all parts and accessories for connecting to a cryogenic vessel or analyzer and obtaining a representative sample of the liquid or gas. The connection interface shall match the sampler connections, which consist of the following major components: liquid sampling assembly (dwg 270271); shipping cylinder (dwg. 2702704); case (dwg. 2702715); hose (dwg. 2702476); adapter (dwg. 2702439).

3.26 **Motors and controllers.** Motors and controllers shall be in accordance with paragraph 33.6 of IEEE 45. Electrical equipment in hazardous locations should be of a type suitable for such locations (Class, Division, or Zone and Group) and be type tested and certified or listed to a specific American National Product Standard by an independent testing laboratory acceptable to the regulatory authority (authority having jurisdiction)".

3.27 **Enclosures.** Enclosures shall be NEMA 3 as defined by NEMA 250.

3.28 **Automatic shut off and safety valves.** Electrically operated Automatic shut-off valves shall be furnished with pneumatic actuators at the oxygen producer compressor air inlet and at the turboexpander inlet for emergency shutdowns. The generation process shall be protected from abnormal pressures by safety valves. To facilitate inspection, safety valves shall be located in one region and shall be equipped with flanged or union type outlets connected to a single vent header. Safety valves shall conform to MIL-S-16032 or be approved by NAVSEA.

3.29 **Control valves.** Valves shall be in accordance with MIL-STD -777 and as specified herein. Gate valves shall not be used in any throttling service. Valves shall have replaceable seats and discs. All control valves shall be equipped with an actuator-positioner assembly for automatic operation.

3.30 **Welding/brazing.** Welding shall be in accordance with NAVSEA S9074-AR-GIB-010/278. All welding procedures and personnel shall be qualified in accordance with S9074-AQ-GIB-010/248. All brazing shall be performed in accordance with NAVSEA 0900-LP-001-7000. No component or piping system shall be soldered. Submittal of procedures shall be in accordance with DD Form 1423-1, Sequence No. A004.

3.31 **Thermal insulation.** Surfaces, including the insulation jacket but excluding the outer end of sample lines and sample vaporizers, shall be insulated so the surfaces will neither collect frost nor sweat when exposed to an atmosphere with a dry bulb temperature of 90°F (32.2°C) and a wet bulb temperature of 80°F (26.7°C). Small frost or sweat spots that form after extended operation due to thermal conductivity through structural members are not considered significant. Hydraulic setting types of insulation material shall not be used. Producer cold box insulation shall be mineral wool. The use of Perlite insulation shall be limited to those inaccessible areas within the producer where packing of mineral wool cannot be done at the required density. The hydrocarbon oil content of the insulation shall not exceed 0.175 percent by weight.

3.32 **Paint.** The color shall match color number 26307 of FED-STD-595.

3.33 **Flexibility.** When tested in accordance with MIL-DTL-15090, the enamel shall show no evidence of cracking or flaking.

3.34 **Ergonomics.** A human engineering design approach utilizing guidelines provided in MIL-STD-1472 and those provided in this section shall be submitted prior to implementation. Submittal shall also be in accordance with DD Form 1423-1, Sequence No. A009. MIL-STD-1472 takes precedence for ergonomics requirements not provided in this section.

3.34.1 **Access.** Adequate space shall be provided for personnel, their equipment, and free volume for the movements and activities that are required during operation and maintenance tasks under normal and emergency conditions.

3.34.2 **Fail-safe.** A fail-safe design shall be provided to eliminate the possibility of catastrophic damage to equipment, injury to personnel, or inadvertent operation of critical equipment.

3.34.3 **Simplicity of design.** The equipment shall represent the simplest design consistent with functional requirements and expected service conditions. It shall be capable of being operated, maintained and repaired in the specified environment by personnel with a minimum of training.

3.34.4 **Functional use of colors.** Where not in conflict with color codes specified herein, colors used for functional purposes (e.g., visual displays, controls, workspaces, equipment connections), shall accommodate users with color deficient vision.

3.34.5 **Hazard protection.** Personnel protection from thermal, toxicological, radiological, mechanical, electrical, electromagnetic, pyrotechnic, visual and other hazards shall be provided.

3.35 **Reliability and Maintainability.** The Mean Time Between Failure (MTBF) shall not be less than 10,000 hours and a Mean Time to Repair (MTTR) of not greater than 4 hours. The contractor shall submit a Program Plan to demonstrate fulfillment of the MTBF and MTTR. Submittal shall be in accordance with DD Form 1423-1, Sequence No. A005.

3.36 **Operating Cycle.** The producer shall produce at rated capacity within 4-6 hours of start-up from ambient temperature, and within 1 hour after a shutdown of less than 2 hours. Upon starting, the producer shall be capable of operating continuously and in a steady state mode of operation for a minimum of 10 out of every 11 days. After this period of time, the producer shall be defrosted to remove any accumulated ice from the liquefier. The defrost cycle shall not take more than 6 hours. Immediately after the completion of the defrost cycle, the producer shall be capable of operating for another 10 consecutive days.

3.37 **Identification plates and placards.** Identification plates and placards shall be provided for the identification of all piping, valves, vessels and subcomponents in the system, for emergency shutdown and start-up operating procedures and flow schematic of the process components. The placards are to be installed on the generating system panels.

3.38 **Logistics.** The logistic data shall be provided in electronic formats as follows:

3.38.1 **Drawings.** System drawings shall be provided in Auto Cad format. Other formats may be acceptable with NAVSEA written approval. Submittal should be in accordance with DD Form 1423-1, Sequence No. L004.

3.38.2 **Provisioning list.** A detailed list of maintenance and repair parts shall be provided in electronic format, including all the drawings required to catalog parts in the US Navy supply system. Submittal shall be in accordance with DD Form 1423-1, Sequence No. L009.

3.38.3 **Technical manual.** The technical manual shall include information for installation, operation, troubleshooting, lubrication, outline drawings showing overall dimensions and motor and controller drawings. Also included shall be exploded views, list of repair parts down to the lowest level, electrical data and diagrams, repair procedures, maintenance procedures and programmable controller program sequence. Installation instruction shall also be provided. The manual shall be in digital format. It shall contain links to the various sections in the technical manual for illustration purposes or for increased understanding of the matter being discussed. In order to demonstrate complicated maintenance items, a video link shall be included. The manual shall be in accordance with MIL-STD-38784 and MIL-M-24784. (See paragraph 8.5) Submittal shall also be in accordance with DD Form 1423-1, Sequence No. A021 and A022.

4. VERIFICATION

4.1 **Purpose.** The purpose of the testing specified herein is to verify that the generation and storage system delivered to the US Navy conforms to all requirements specified.

4.2 **General Inspection Requirements.**

4.2.1 **General provisions for inspection.** Inspection, as used herein, shall be understood to mean the examination and applicable testing of materials, fabricated components, the manufacturing processes and the completed assemblies to determine and ensure conformance to the specifications set forth in the contract or purchase order.

4.2.2 **Responsibility for inspection.** Unless otherwise specified in the contract or purchase order, the contractor shall be responsible for the performance of all inspection requirements (examinations and tests) specified herein. The contractor shall provide and maintain a written inspection system, which will assure that all supplies and services submitted to the Government for acceptance conform to contract requirements whether manufactured or processed by the contractor, or procured from subcontractors or contractors. The contractor shall perform or have performed the inspections and tests required to substantiate product conformance to drawings, specifications and contract requirements and shall also perform or have performed all inspections and tests otherwise required by the contract. The contractor's inspection system shall be documented and shall be available for review by the Naval Surface Warfare Center Carderock Division - Philadelphia Site, Naval Business Center, Bldg. 4, Philadelphia, PA 19112-1409, Attn: Code 9212, via the DCMC, fifteen (15) days after award of contract and throughout the life of the contract. The contractor shall notify the Naval Surface Warfare Center, Carderock Division - Philadelphia Site Code 9212 in writing of any change to the inspection system. The inspection system shall be subject to disapproval if changes thereto would result in nonconforming product. Contractors currently operating under ANSI/ISO/ASQ Q9001-2000 or MIL-I-45208 quality system will be deemed acceptable under this provision. Software quality assurance shall be developed, reviewed, tested and controlled in accordance with tailored requirements of IEEE/EIS 12207. The contractor may use their own or any other facilities, including available Government laboratories, suitable for the performance of the tests and inspection requirements specified herein unless objected to by the Government. The contractor shall maintain the system throughout all tests, which includes providing repair parts and consumables, as required. The government reserves the right to perform any of the inspections set forth in this specification, where such inspections are deemed necessary to ensure supplies and services conform to the prescribed requirements.

4.2.3 **Responsibilities for compliance.** All items shall meet all requirements of section 3. The inspection set forth in this specification shall become part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract or purchase order. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of defective material, either indicated or actual, nor does it commit the Government to accept defective material. Request for waivers or deviations shall be submitted using form DD 1694 and MIL-STD-973, as a guide. A request for waiver shall be used for government acceptance of Type I and Type II nonconformance.

4.2.4 **Government participation.** The contractor shall notify the procuring activity regarding the starting date of tests and examinations as soon as it is determined.

4.2.5 **Inspection system/design verification test plan.** A test and inspection system program plan shall be prepared and approved by the procuring agency prior to commencement of all tests and examinations required herein. The test plan shall address all required test procedures for verification of performance and functional compliance with the stated requirements of the complete system. The test plan shall also include all instrumentation, electrical hookups, test sequences, facilities, etc., which the contractor intends to use. All special test equipment shall be fully identified and provided to the government upon request as an accessory of the system. All special tools shall be identified and recommended as a requirement for the maintenance of the system. The use of special tools shall be kept to a minimum. In addition, the contractor shall perform a Failure Mode and Effects Criticality Analysis (FMECA), which shall be reviewed during the critical design review phase. The FMECA shall be performed in accordance with MIL-STD-1629 or SAE J 1739. The analysis shall indicate clearly the design approach to mitigate all risk areas found during the FMECA.

4.3 **Classification of inspections.** The Inspection requirements specified herein are classified as follows:

a. First article inspection (see paragraph 4.4)
b. Capacity conformance inspection (see paragraph 4.5)

4.4 **First article inspection.** First article testing shall be performed by the contractor to validate conformance with this specification. The first article inspection shall consist of examinations and tests specified in paragraph 4.6.1 through 4.6.24 (see paragraph 8.2). Submittal of First Article Test procedures and reports shall be in accordance with DD Form 1423-1, Sequence No. A012 and A013.

4.5 **Capacity conformance inspection.** All oxygen production and storage systems shall be subjected to conformance inspection, and shall consist of examinations and tests specified in paragraphs 4.6.2, through 4.6.5, 4.6.7, 4.6.9, 4.6.10 through 4.6.13, 4.6.16 through 4.6.21, 4.6.23 and 4.6.24. Software quality assurance shall be developed, reviewed, tested and controlled in accordance with tailored requirements of IEEE/EIS 12207. Nonconformance to one or more requirements of this specification or failure of any one or more tests shall be cause for rejection.

4.6 **Testing.** Testing shall be conducted as specified herein. Upon completion of each test, all parts damaged by that test shall be replaced. A test plan outlining procedures for all tests included herein shall be submitted to the government prior to commencement of any test. Submittals shall be in accordance with attached DD Forms 1423.

4.6.1 **Adsorbent material testing.** The adsorbent material used in the system shall be tested separately to verify conformance with the shipboard environment, as specified in paragraph 3.9. This test shall be performed before the system manufacturing process begins. In a separate breadboard test-setup, the adsorbent material shall be tested for conformance with the shock and vibration requirements (MIL-S-901 and MIL-STD-167), that the system shall be exposed to when installed shipboard. This testing shall be performed prior to and in addition to MIL-S-901D full system shock test and cannot be utilized to satisfy subsidiary component shock qualification. Failure to meet this requirement constitutes grounds for rejection. Pulverization of the adsorbent material under these environmental conditions, which can cause the material to flow downstream or become ineffective, resulting in potential system efficiency losses, shall constitute grounds for

rejection and authorization to proceed with manufacturing will be rejected. Submittal of test plan and test report shall be in accordance with DD Form 1423-1, Sequence No. A010 and A011.

4.6.2 **Welded and silver brazed joint inspections.** All nondestructive test inspections shall be performed in accordance with T9074-AS-GIB-010/271. Inspection procedures and personnel shall be certified in accordance with T9074-AS-GIB-010/271. Silver brazed joints shall be tested in accordance with NAVSEA 0900-LP-001-7000.

4.6.3 **ASME BPVC section VIII vessels.** Presence of ASME Official Code U-Symbol stamped or marked and a copy of ASME data sheet (Form U-1) will be accepted as evidence that pressure vessels and connections conform to ASME rules for construction of pressure vessels. This will be verified in accordance with paragraph 3.11 and 3.14.

4.6.4 **Leak testing.** No leakage is permitted. Leak testing to ensure the integrity of the assembled components shall be accomplished during fabrication, assembly, and on the complete assembled units. At the time of assembly, all vessels, piping components and subassemblies shall be pressure tested with dry oil-free air or nitrogen and examined for leaks using a leak detector solution. The completed assembled unit shall be leak tested to expose all leaks that are detrimental to the operation of the system, including leaks through the seat of valves, through the body of valves and through other piping components. All leaks shall be repaired prior to further testing. After final assembly, each producer and liquefier shall be leak tested at normal operating pressure for a minimum of 8 hours. The pressure drop compensated for any temperature change shall not exceed 2 percent of the test pressure after compensating for ambient pressure and temperature changes.

4.6.4.1 **Cold box leak test.** When fully assembled, the liquefier cold box shall be tested to ensure that its leakage rate does not exceed 40 cu.ft./hr at 2 inches water column pressure. A piping network shall be installed to ensure that the entire producer is properly purged.

4.6.5 **Hydrostatic testing/cleaning for oxygen service.** The production and storage system shall be hydrostatically tested to 150 percent of design pressure and held for a minimum of 30 minutes. Because of the differing component design pressures, the producer may be segregated as necessary to facilitate testing. Hydrostatic testing may be accomplished immediately prior to cleaning using the cleaning fluid in accordance with MIL-STD-1330. The test shall demonstrate the isolation capabilities and integrity of the components as a whole. After completion of the hydrostatic test, the generation and storage system shall be cleaned for oxygen service and purged in accordance with the requirements of MIL-STD-1330. All consumables incompatible with the authorize solvent used shall be replaced after cleaning operations.

4.6.6 **Endurance testing.** The first article production and storage system shall be tested as follows to determine its capabilities to meet capacity and purity requirements under the specified environmental conditions. During this test, the producer shall be operated in the manner outlined in the technical manual. The system shall be operationally tested for a minimum of 720 hours to determine conformance to the capacity, purity, duty cycle, start up time and defrost time specified in paragraphs 3.3.1, 3.32, and 3.35. During this time, the producer shall be operated for a minimum of 4 hours under each of the conditions listed in paragraphs 4.6.6.1 through 4.6.6.6 to demonstrate conformance to the required capacity and purity. The capacity of the producer shall be determined by measuring the liquefied oxygen accumulated in the storage tank using the tank's liquid level gage. The product purity shall be tested at least once every 8 hours to ensure that the

liquid oxygen purity is in accordance with paragraph 3.3.4. Additionally, the producer shall be subjected to the combine contaminant levels noted in paragraph 3.6.2 to determine its conformance with paragraph 3.3.4.

4.6.6.1 **Pitch, roll, and list.** The production and storage tank system shall demonstrate its capacity to meet the pitch, roll and list conditions specified in paragraph 3.6.1. Failure to meet the capacity and purity shall be ground for rejection.

4.6.6.2 **Intake air contaminants.** The production and storage system shall meet the requirements of paragraphs 3.3.1 and 3.3.2, verified by chemical analysis of a liquid oxygen sample taken prior to discharge into the storage vessel. The sample shall be taken after the producer has been operating for 1 hour while being subjected continuously to the maximum intake contaminants, as listed in paragraph 3.6.2.

4.6.6.3 **Intake air temperature/PLC thermal testing.** The requirements of paragraph 3.6.3 shall be demonstrated. The production and storage system shall clearly demonstrate its ability to operate continuously in the temperature range specified in paragraph 3.6.3. The PLC, PC, graphical display and all interface cards/modules shall be subjected to thermal test as specified in MIL-HDBK-2036. Temperature measuring instruments shall be place at critical points throughout the endurance test. Failure criteria are defined in MIL-HDBK-454.

4.6.6.4 **Intake air pressure.** The requirements of paragraph 3.6.4 shall be demonstrated. The production and storage system shall clearly demonstrate its ability to operate continuously in the pressure range specified in paragraph 3.6.4.

4.6.6.5 **Cooling medium.** The requirements of paragraph 3.4.4 shall be demonstrated. The production and storage system shall clearly demonstrate its ability to operate continuously using cooling water set at the maximum temperature specified in paragraph 3.4.4.

4.6.6.6 **Operational cycle/demonstration.** The production and storage system shall be operated as specified in paragraph 3.35 to demonstrate its capabilities to meet the minimum operating duty cycle requirements. This demonstration shall include defrost and regeneration cycles. The demonstration shall meet the requirements of paragraphs 3.3.1, 3.3.2 and 3.35.

4.6.7 **Quality conformance operational demonstration test.** Each subsequent production and storage system built after the first article tested system shall be tested as follows to determine its capability to meet all capacity and purity requirements, under the specified normal atmospheric conditions while undergoing pitch, roll and list. The operational cycle shall demonstrate the production and storage system capability to meet duty cycle, start up and defrost time. The test shall be accomplished for a period of 240 hrs. These demonstrations can be accomplished, as outlined above in paragraph 4.6.6, but operating for a shorter amount of time as approved by the government. The capacity of the producer shall be determined by measuring the liquefied oxygen accumulated in the storage tank using the tanks liquid level gauge. The product purity shall be tested at least once every 8 hours to ensure that the liquid oxygen purity is in accordance with paragraph 3.3.2. Additionally, during this time the producer shall be subjected to the combined contaminant levels noted in paragraph 3.6.2 to determine its conformance with paragraph 3.3.2.

4.6.8 **Storage tank emergency draining.** The liquid oxygen storage vessel shall be measured and shall have a minimum of 36.75 cubic feet of storage volume. The tank shall be full (250 gallons) of liquid oxygen, the drain valve completely opened, and the tank drained and timed to ensure compliance with paragraph 3.3.1.3.

4.6.9 **Delivery rate.** An operational test shall be performed to demonstrate delivery rates for both liquid and gaseous oxygen in accordance with paragraphs 3.3.1.4 and 3.3.1.5. The liquid pump and vaporizer may be tested concurrently. The test shall demonstrate the capacity of both the pump and vaporizer and that controls and safety devices perform as required ensuring safe operation of the system. The liquid delivery test shall demonstrate the capacity of the pressure build-up coil to maintain the required pressure while filling another container at the flow rate specified in paragraphs 3.3.1.4 and 3.3.1.5.

4.6.10 **Cryogenic liquid loss/vaporization losses.** With the tank filled to not less than 60% of its capacity, the internal temperature shall be allowed to stabilize at atmospheric pressure. The evaporation losses shall then be determined by passing all vented gas from the inner container through a gas flow measuring apparatus attached to the system vent line for a period of not less than 72 hours. Throughout the temperature stabilization period and the 72-hour test period, the ambient temperature at the test location shall remain at not less than 80 degrees Fahrenheit. Throughout the test, the inner container vapor phase pressure shall remain as close to atmospheric as permitted by the necessary pressure drop through the flow measuring apparatus. Evaporation loss exceeding an average rate of 0.6 scfh for the 72 hr test shall constitute failure of this test. This test could be performed by a weight method, as well. Other methods to determine qualification to paragraph 3.3.1.6 will be considered by the Government.

4.6.11 **Airborne noise.** Each production and storage system shall be tested in accordance with the requirements of MIL-STD-740 to determine conformance to paragraph 3.3.3. Testing shall include all modes of operation. Exceeding the specified noise level at any frequency will constitute failure to pass this demonstration.

4.6.12 **Electric power.** The production and storage system shall be operationally demonstrated to conform to the requirements in paragraph 3.4.1. The power consumption requirement of the system shall be measured in kW to demonstrate the specification requirement.

4.6.12.1 **Electrical insulation resistance test.** To determine conformance to paragraph 3.4.1, an insulation resistance test shall be performed for the production and storage tank using a resistance function of a standard multimeter with current calibration. The test shall be conducted at 40 and 122 degree Fahrenheit. The system shall be divided into independent circuits. Each circuit shall have resistance to ground and to other independent circuits greater than 5-mega ohms.

4.6.13 **Dimensions and weight.** The dimensions and weight of the oxygen production and storage system, including all accessories, shall be as described in paragraph 3.5.1. This will be verified by review of drawings and final assembly measurements.

4.6.14 **Shock.** The system shall meet the requirements of paragraph 3.6.6 and be verified to be in accordance with MIL-S-901. Shock test extensions, in accordance with MIL-S-901,

shall be allowed where possible. Submittal of test procedures and report shall be in accordance with DD Form 1423-1, Sequence No. A015 and A016.

4.6.15 **Vibration.** The system shall meet Type I (environmental) test requirements of MIL-STD-167-1. Vibration test requirement of up to a 25 hertz (Hz) shall be conducted. Submittal of test plan and report shall be in accordance with DD Form 1423-1, Sequence No. A017.

4.6.16 **EMI.** The production and storage system shall demonstrate compliance with the requirements of MIL-STD-461 Rev E (dated 20 Aug 1999) for Surface Ship, Below Deck, Metallic Hull installations. This includes the following methods:

CE-102, CS-101, CS-114, CS-116, RE-101, RE-102, RS-101, RS-103.
All documentation shall be in accordance with the respective Data Item Description cited in 461E Section 6:
Electromagnetic Interference Control Procedures (EMICP) DI-EMCS-80199B,
Electromagnetic Interference Test Procedures (EMITP) DI- EMCS-80201B and
Electromagnetic Interference Test Report (EMITR) DI-EMCS-80200B

Submittal of EMI test procedures and report shall be in accordance with DD Form 1423-1, Sequence No. A019 and A020.

4.6.17 **Materials.** Materials used in the producer shall meet the requirements of paragraph 3.7. The materials shall be verified by drawing, specification and record reviews.

4.6.18 **Piping, valves and fittings.** The production and storage system shall meet the requirements of paragraph 3.12 and shall be verified visually and by drawing, specification and record reviews. Use of unauthorized fittings (pipe threads or explosion bonded, inertial welded or any other dissimilar metal fitting using a silver interlayer) constitutes failure to meet the requirements of paragraph 3.12. The integrity of the assembled components will be verified through hydrostatic testing in accordance with paragraphs 4.6.4 and 4.6.5.

4.6.19 **System component verification.** The production and storage system component listed below will be verified through visual inspection and where applicable through review of detail or source control drawings.

4.6.19.1 **Cold box.**
4.6.19.2 **Instrumentation.**
4.6.19.3 **Product filter.**
4.6.19.4 **Product purity analyzer.** The producer analyzer shall meet the requirements of paragraph 3.21 and all shock, vibration and EMI requirements specified herein. The requirements of paragraph 3.21 shall be demonstrated and may be demonstrated in conjunction with paragraph 4.6.7.
4.6.19.5 **Programmable Logic Controller.** The PLC shall meet the requirements of paragraph 3.22 and be tested as specified in paragraph 4.6.20.

4.6.19.6 **Hour meter.** The hour meter shall be verified visually to meet the requirements of paragraph 3.23.

4.6.19.7 **Master switch shutdown.** Operational demonstration of the switch, and the ability of the plant to respond to emergency, shall be tested during endurance testing. The switch shall shut down the system without causing any damage to components, subassemblies or the entire system.

4.6.19.8 **Sampler connection.** The suitability of the connection to match the interface of the sampler shall be verified during sampling for infrared analysis.

4.6.19.9 **The cryogenic transfer line.** The transfer line shall also be tested to determine compliance with the flow rate and pressure drop requirements. The engineering analysis used in sizing and selection of the transferred line shall be provided to the government for review and analysis.

4.6.19.10 **Motors and enclosures.** Motor and enclosures shall meet the requirements of paragraphs 3.26 and 3.27 and be verified in accordance with IEEE 45 and NEMA 250 respectively

4.6.19.11 **Automatic shut off and safety relief valves.** Automatic shut off and safety relief valves shall meet the requirements of paragraph 3.28. Relief valves shall be set at the desired relief pressure on a test stand and the setting recorded prior to installation. Minimum recorded data shall be valve identification, desired relief set point, actual relief set point, desired reset point, actual reset point, test medium used, person performing tests, pressure gauge range and scale increments, Pressure gauge serial numbers, and pressure gauge calibration date.

4.6.19.12 **Control Valves.**

4.6.19.13 **Thermal insulation.**

4.6.20 **Software Verification and documentation.** The production and storage system shall meet the requirements of paragraph 3.22, verified by means of document reviews, unit testing (testing of the controller and PC software separately) and system testing (integrated into the entire system) via formal approved test procedures. Test procedures must identify the applicable software requirements. All passwords and security codes shall be demonstrated. All software documents and software test results shall be delivered with the producer. Submittal of test plan, test description and test report shall be in accordance to DD Form 1423-1, Sequence No. S004, S005, S006.

4.6.21 **Paint.** The producer shall meet the requirements of paragraph 3.32 and be verified in accordance with MIL-DTL-15090.

4.6.22 **Reliability and Maintainability.** To verify compliance with the requirements of paragraph 3.35 the contractor shall perform a Reliability, Availability, Maintainability Allocation, Assessments, and Analysis (RMAA), and Failure Mode and Effects Criticality Analysis (FMECA) in accordance with MIL-STD-1629 or SAE J 1739 as approved by NAVSEA and documented by a report provided to the government. Submittal shall be in accordance to DD Form 1423-1, Sequence No. A006. To verify maintainability, a demonstration shall be conducted in accordance with MIL-HDBK-470. The Government will select 15-20 maintenance items to be performed to verify the actual repair time. Submittal of procedures and report shall be in accordance with DD Form 1423-1, Sequence No. A007 and A008.

4.6.23 **Identification plates and placards.** The producer shall meet the requirements of paragraph 3.37, verified visually. Operating instructions shall be validated during operational test.

4.6.24 **Logistics.** Drawings, provisioning list and technical manuals shall meet the requirements of paragraph 3.38 and shall be physically validated. This shall include hand over hand comparisons between system drawings and the producer. Technical manual validation shall be performed by actual operation of the producer in accordance with the technical manual. All preventive and corrective maintenance tasks listed in the technical manual shall be performed in accordance with the technical manual. Any discrepancies discovered during validation shall be corrected before delivery.

5. INSTALLATION SUPPORT SERVICES

As specified in the contract, the contractor shall provide personnel with the necessary knowledge and expertise to assist with the onsite installation start up, and performance testing for each liquid oxygen production and storage system.

6. FIELD TRAINING SERVICES.

As specified in the contract, the contractor shall provide personnel with the necessary knowledge and expertise to perform on-the-job training instructions to Navy personnel on-site. One class with approximately 16 students will be held for each liquid oxygen production and storage unit installed. The contractor shall develop training aids and handouts for training, and provide a certificate of award for all students who complete the training. Submittal of preliminary handouts shall be in accordance to DD-Form 1423-1, Sequence No. A028.

7. PACKAGING AND CLEANING

7.1 **Packaging.** Packaging requirements shall be as specified in the in Section D of this contract.

7.2 **Cleaning.** The production and storage system shall be cleaned per the requirements of MIL-STD-1330. The procedure shall be included in the test plan and submitted for review and approval. The system shall be shipped with a nitrogen pressure to prevent contamination of the system during shipping.

8. NOTES

(This section contains information of a general or explanatory nature that maybe helpful, but is not mandatory)

8.1 **Intended use.** The liquid oxygen producer and storage tank covered by this specification is intended for shipboard use to supply aviator-quality breathing oxygen. The producer built to this specification is intended to replace the existing producer built to MIL-P-24344 (cancelled) or new acquisitions.

8.2 **Acquisition requirements.** Acquisition documents should specify the following:

8.2.1 Title, number, and date of this specification

8.2.2 Issue of DoDISS to be cited in the solicitation and if required, the specific issue of individual documents referenced (see paragraphs 2.2 and 2.3)

8.2.3 When first article is required. (See paragraph 3.2)

8.2.4 Supercession data. This specification does not supersede any other specification (see paragraph8.1)

8.2.5 Specify required DFAR for the acquisition of all rights and data for all software and PLC codes developed under this specification.

8.2.6 The contractor shall submit to the government for review and approval an analysis of the proposed PLC interface. This report shall include a detailed description of each function, mode of operation and interaction between these modes. The report shall also describe the proposed operator interface for each of these functions and what will occur if the interface is used improperly or fails. For interactive interface, the report shall detail the conditions under which the operator can initiate actions.

8.2.7 The contractor shall provide a detailed test plan including test procedures intended to prove its design complies with the requirement of this specification

8.2.8 The procurement activity shall required design reviews for the selection of hardware and software

8.3 Subject term (key word) listing

Aviator's breathing oxygen
Cryogenic storage
Liquefier
Turbo expander
Pressure Swing Adsorption
PSA
Vacuum Swing Adsorption
VSA

8.4 **General information.** The equipment should be constructed for maximum reliability and operated, maintained and repaired by personnel with a minimum of training. The producer shall be hatchable and have as small a footprint as practical in accordance with the requirements of paragraphs 3.5.1 and 3.5.3.

8.5 **Technical manuals.** If technical manuals are required, specifications and standards that have been cleared and listed in DOD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be listed on a separate Contract Data Requirements List (DD Form 1423), which is included as an exhibit to the contract. Submittal must be in accordance to DD Form 1423-1, Sequence No. A021 and A022.

8.5.1 Unless otherwise specified in the contract or order (see paragraph 8.2), technical manuals shall be prepared in accordance with MIL-M-24784. Preliminary manuals shall be submitted to the design review agency for approval and shall include all proposed sections completed. Unless otherwise specified in the contract or order, manuals shall include system components, assemblies, subassemblies and applicable drawings. Performance curves shall be furnished with the final manuscript.

8.5.2 Manuals shall include master drawings and certification data covering the complete operation, maintenance and calibration instructions of all electrical equipment, and instrumentation, including the controller/PLC, software instructions, etc.

8.5.3 Each manual shall include not less than the following illustrations covering the IMP:

8.5.3.1 Sectional assembly drawing.
8.5.3.2 Outline drawing.
8.5.3.3 Complete list of material corresponding to the sectional assembly drawing.
8.5.3.4 Certification data.

8.5.4 A minimum of two drawings of the complete system, taken 180 degrees apart on a horizontal plane shall be provided.

8.5.5 The calibration and alignment procedure instructions shall describe in complete detail the means by which the required calibration and alignment are to be established. Exceptions to any part of the those requirements in any specific area may be granted only by providing a written technical justification for the said exception to the design review agency for approval.

8.5.6 The quantity and distribution of the technical manuals shall be as specified in the contract.

8.6 **Technical Repair Standard (TRS).** A TRS shall be provided upon initial introduction of new equipment. When configuration changes to in-production equipment are approved that would affect the adequacy of the TRS for repairs, a new TRS shall be provided. Submittal shall be in accordance with DD Form 1423-1, Sequence No. A023.

8.6.1 TRS technical content shall include sufficient technical details to enable a repair, maintenance, or overhaul activity to restore the equipment's dimensions, clearances and tolerances, such that the equipment is capable of performing its function as originally specified and is capable of being logistically supported by the DOD logistics support system.

8.6.2 The TRS format and content shall conform to MIL-DTL-24784/7B and shall be approved and validated in accordance with this standard.

Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.