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U.S. NAVY MOLECULAR SIEVE ON-BOARD OXYGEN GENERATION SYSTEM - AN UPDATE

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Naval Air Development Center has been conducting a development program to explore the On-Board Oxygen Generation (OBOG) concept for application aboard tactical Naval aircraft. The objective of the program is to eliminate hazardous and logistically burdensome LOX (liquid oxygen) installations on ships, as well as forward basing areas, by generation of oxygen on board the aircraft.

Program progress includes: (1) Major reduction in values of weight and resource requirements to acceptable levels; (2) Development of hardware proto-

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) types of the proposed systems suitable for flight test; (3) Aircraft/OBOG systems integration studies; (4) Laboratory T&E of the prototype systems; (5) Physiological assessment (man rating) of the prototype systems; (6) Flight testing to date.

The purpose of this paper is to report current progress including: Laboratory qualification testing and Technical Evaluation. In addition, program direction and milestones up to and including Approval for Service Use will be discussed.

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INTRODUCTION

Operational and combat missions are routinely conducted by military aircraft at altitudes where the partial pressure of oxygen in the atmosphere is insufficient to meet physiological requirements of aircrewmembers. The required source of breathing oxygen is presently supplied by either gaseous or liquid (LOX) systems. These systems require generation of oxygen aboard the carrier and servicing of the aircraft prior to each flight, which imposes a major logistic burden on the ship or shore base.

The Navy decision to deploy aircraft aboard non-avaiacion ships and forward bases further complicates the problem since these ships cannot provide the necessary space required for the generation, transfer, and storage of LOX. It is also unacceptable to make these ships dependent upon carriers and other ships for LOX and limit their operational employment.

Introduction of OBOG systems as an alternative to the present method of oxygen supply both reduces present burdens and makes the VSTOL/non-aviation ship concept practical. The OBOG system is designed as a "one for one" replacement of the liquid oxygen system. OBOGs will be required to meet physiological requirements of breathing gas throughout the performance envelope of the aircraft with a minimum impact on aircraft resources. OBOGs provide a maximum of 95% oxygen and 5% argon as breathing gas in place of the 100% oxygen generated by the LOX system. Current diluter regulators mix air with oxygen in accordance with a predetermined schedule based on altitude and physiological requirements. Under certain conditions, OBOGs will provide less than 95% oxygen but, under all conditions, the physiological requirements will be met and the percentage of oxygen supplied under a dilution schedule will be exceeded.

SYSTEM DESCRIPTION

Development of a molecular sieve OBOG system was reported (Reference (1)) including successful DT-IIC flight testing in an EA-6B of an Advanced Development Model prototype system. The molecular sieve OBOG system consists of three major components: oxygen concentrator, breathing regulator, and performance monitor.

OXYGEN CONCENTRATOR

A detailed description of the development of the concentrator can be found in reference (1). The concentrator, Figure 1, processes engine bleed air concentrating all gases except oxygen and argon. The processed air, or oxygen enriched air, is then provided as a breathing gas to the aircrewmember. Due to the similarity of the oxygen and argon molecule, both are spearated from the bleed air and concentrated together with a maximum of 95% oxygen and 5% argon. The composition of the breathing gas is a function of mass flow rate through the concentrator (Reference (2)) which is determined by bleed air pressure, breathing (flow) rate, cabin altitude, and aircraft altitude, which governs exhaust pressure.

BREATHING REGULATOR

The regulator is designed to replace the chest mounted "mini" regulator and be compatible with the low operating pressure range of breathing gas delivered by the oxygen concentrator (5 psi). The regulator is an automatic pressure breathing type which provides on demand, breathing gas (concentrated oxygen) under normal operating conditions. See Figure 2.

PERFORMANCE MONITOR

The oxygen performance monitor utilizes a polarographic partial pressure oxygen sensor and electronics module within a pressure controlled sensing chamber. The sensor, electronics, and compensating aneroid are shown in Figure 3. The elctronic module with its sensor exposed to the OEAS product gas provides an output signal whenever oxygen partial pressure falls below 220 mm Hg which is greater than the physiological limits for Harrier pressurized cabin conditions. The compensating aneroid/valve mechanism serves to maintain a constant absolute pressure equivalent to 28,000 feet in the sensor cavity to prevent a false warning signal in the event of loss of cabin pressure above 28,000 feet. In addition, there is a manual system status check capability (push to test) which vents the sensor to ambient and illuminates a warning light.

A I R C R A F T   I N T E G R A T I O N

PROGRAM OBJECTIVE

The objective of the OBOG development program at its current stage is to integrate the OBOG system, described above, into the AV-8A, "Harrier", which has been designated for the initial application. The AV-8A is the first in the VSTOL generation of aircraft currently operational.

AIRFRAME MODIFICATIONS

Incorporation of the OBOGs in the AV-8A, Figure 4, requires removal of the LOX Converter Unit from the oxygen bay together with the associated Oscillator Bridge Unit. The Oxygen Pressure Gauge, Oxygen Quantity Gauge, Flow Indicator, Flow Transmitter, and Oxygen Low Pressure Warming Switch are removed from the cockpit. Eighth stage bleed air for OBOGs operation is taken from an existing port on the high pressure delivery casing of the engine and piped to a new heat exchanger for cooling. The OBOGs unit will be installed onto an existing mounting plate in the oxygen bay. The Performance Monitor and a new Oxygen Plenum will be installed in the cockpit. Modifications to the aircraft electrical system will be made to interface the Performance Monitor with the Central Warning System and to provide power to the Oxygen Concentrator unit. New plumbing will be installed to route the engine bleed air to the OBOGs unit. Changes will be made to the oxygen delivery line: 1) in the oxygen bay, to accommodate the concentrator unit, and 2) in the cockpit, to provide for the monitor and plenum installations.

PERSONAL EQUIPMENT

The following changes were initially required for the pilots personal gear. Replace chest mounted "mini" regulator with OBOG chest mounted regulator. However, excessive pressure drops through the aircraft system caused unsatisfactory performance at engine low RPM (idle speed). This had been predicted and was verified during the first flight of the prototype installation of the OBOG system at McDonnell-Douglas in A/C 159255 which took place at St. Louis on 29 January 1980. There deficiencies were overcome by utilization of the alternate 2A installation. Figure 5, of the pilots personal equipment recommended by McDonnell-Douglas (Reference (3)). This involved: (1) Moving the oxygen regulator from the pilot's chest to a cockpit right hand side mounting location. (2) Addition of a CRU-60 connector to the cockpit installation. (3) Addition of a connector retainer (CRU-60) on the pilots torso harness and/or the SV-2 survival vest to hold the CRU-60. (4) Modification of the RALSA to add an O_2 regulator and rearrange associated hardware to permit right hand attachment of the B/O hose assy. (5) Provide double hose leads from the two regulator outlets to the CRU-60 connector. (6) Provide 17 inch soft, flexible hose in place of standard A-13/A rigid hose. A complete T&E program was then conducted to insure functional integration of the hardware had been obtained.

LABORATORY TEST AND EVALUATION

PURPOSE

The purpose of the test program was to establish the performance of the system in the environment anticipated during developmental (TECHEVAL) flight test. The program will also meet the requirements of qualification. MIL-STD-810C, "Environmental Test Methods", will be utilized to establish qualification test requirements.

The test program will: (a) Verify throughout the operating envelope of the aircraft that design criteria has been met. (b) Verify that the design will meet the qualification requirements of MIL-STD-810C. (c) Establish a baseline for the system throughout the operating envelope of the aircraft. (d) Provide data, where applicable, to support reliability predictions for the system. The test program is being conducted in two phases, performance and qualification. The performance phase will establish a baseline of data throughout the operational envelope AV-8A and verify that the design criteria of the OBOG system has been attained. Data points will be taken in an excursion around the performance envelope with all resources varied throughout the operating range. Should any deviations from anticipated performance occur, further investigation at the point of deviation will be initiated. The performance phase will also investigate performance of the unit under remote off-design conditions encountered during transient flight conditions. The qualification phase will verify that the unit is in compliance with the requirements of MIL-STD-810C for all naval aircraft.

OXYGEN CONCENTRATOR

The concentrator was tested throughout the operating range of bleed air (8 to 250 psi, 0° to 250°), from ambient temperatures of -65°F to 160°F, and from sea level up to and including 50,000 ft. In addition the following environmental stress (MIL-STD-810C) tests were performed: High temperature, Low Temperature, Temperature Shock, Temperature-Altitude, Humidity, Acceleration, and Vibration.

Due to the nature and location of the concentrator, the following tests are not currently scheduled: EMI, Salt Fog, Dust, Rain. Due to the following reasons, Shock testing, although included in the test plan, was not performed: (1) Magnitude and duration of random vibration test levels. (2) Unavailability of spare concentrator for destructive (no further use) test. (3) Compressed milestone schedules and hardware availability requirements. During various portions of the test program, particularly vibration testing, equipment failure occured. Redesign and retest efforts were conducted until the concentrator successfully completed the test requirements. At that time, the design was frozen and all concentrators updated to the final configuration. All testing had been considered successful.

BREATHING REGULATOR

The Regulator was tested to the requirements of MIL-R-81553 with the exception of ozone resistance and disassembly, and inspection. The testing included: Visual/Dimensional, high temperature, low temperature, Leakage, Acceleration Vibration, Noise, Underwater Breathing, Endurance, Overpressure (overload) and, Outlet pressure (altitude). To date, all tests are considered successful.

PERFORMANCE MONITOR

The Monitor was tested in accordance with the requirements of MIL-STD-810C with the following two exceptions: (1) Minimum operating temperature is 40°F (An ECP is being processed for a design change to lower the operating temperature to -65°F). (2) EMI requirements in accordance with MIL-STD-461A were relaxed from 200 volts/meter to 5 volts/meter.

Testing included: Low Pressure (altitude), High Temperature, Low Temperature, Temperature Shock, Temperature Altitude, Humidity, Acceleration, Vibration, Temperature-Humidity-Altitude. In addition, Visual/Dimensional checks, Performance, Overpressure (overload). All tests of the monitor were considered successful.

TECHNICAL EVALUATION (TecEval)

The purpose of TecEval was to test and evaluate the molecular sieve OBOG system in an AV-8A aircraft under conditions simulating the operational environment. TecEval also has the purpose of certifying that the design has met specified requirements and is ready for OpEval.

TecEval was initiated in May 1980 and completed July 1980 by the Naval Air Test Center utilizing an AV-8A integrated with OBOG system by McDonnell-Douglas. Two ground tests and twenty-three flight tests were conducted. As reported (Reference (4)), the AV-8A/OBOGs demonstrated acceptable performance throughout the scope of the test program.

OPERATIONAL TEST & EVALUATION (OT&E)

Operational Test & Evaluation of the AV-8A OBOGs system will be condcuted under the auspices of COMOPTEVFOR. It will be divided into three phases, described below.

OT&E (OT-IIA)

Initial Operational Test & Evaluation has commenced at the Marine Corps Air Station, Yuma Arizona. To date, six aircraft have been delivered and are being utilized.

DEPLOYMENT (OT-IIB)

IOT&E will be followed by a shipboard deployment of VMA-513, the evaluating squadron, currently scheduled to commence November 1980.

OpEval (OT-IIC)

Deployment will be followed by formal Operational Evaluation, scheduled to also be conducted at Yuma Arizona, and commence October 1981.

APPROVAL FOR SERVICE USE

Based upon successful completion of the above Approval for Service Use is anticipated by 3 QTR FY82.

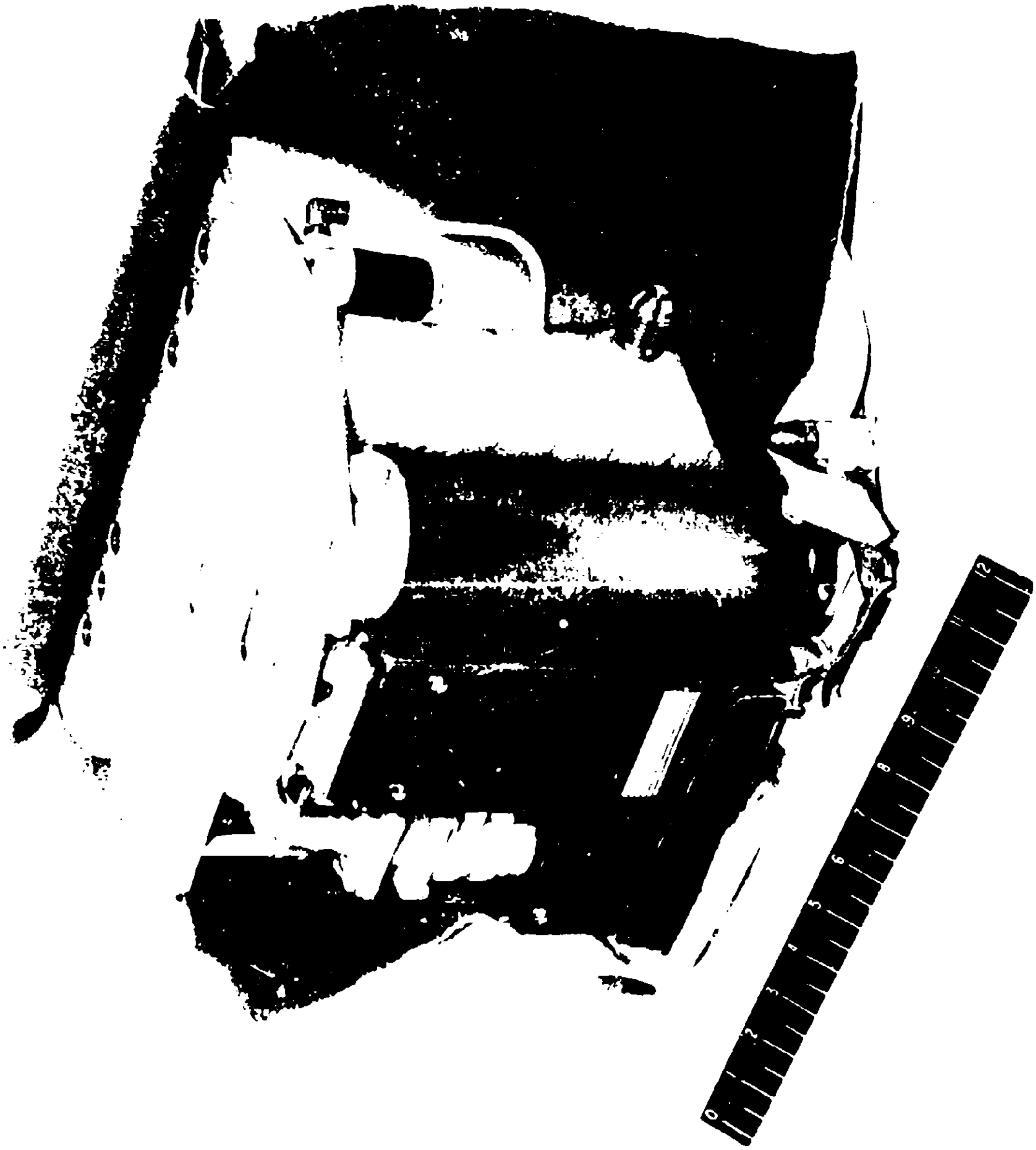

Figure 1 - Oxygen Concentrator

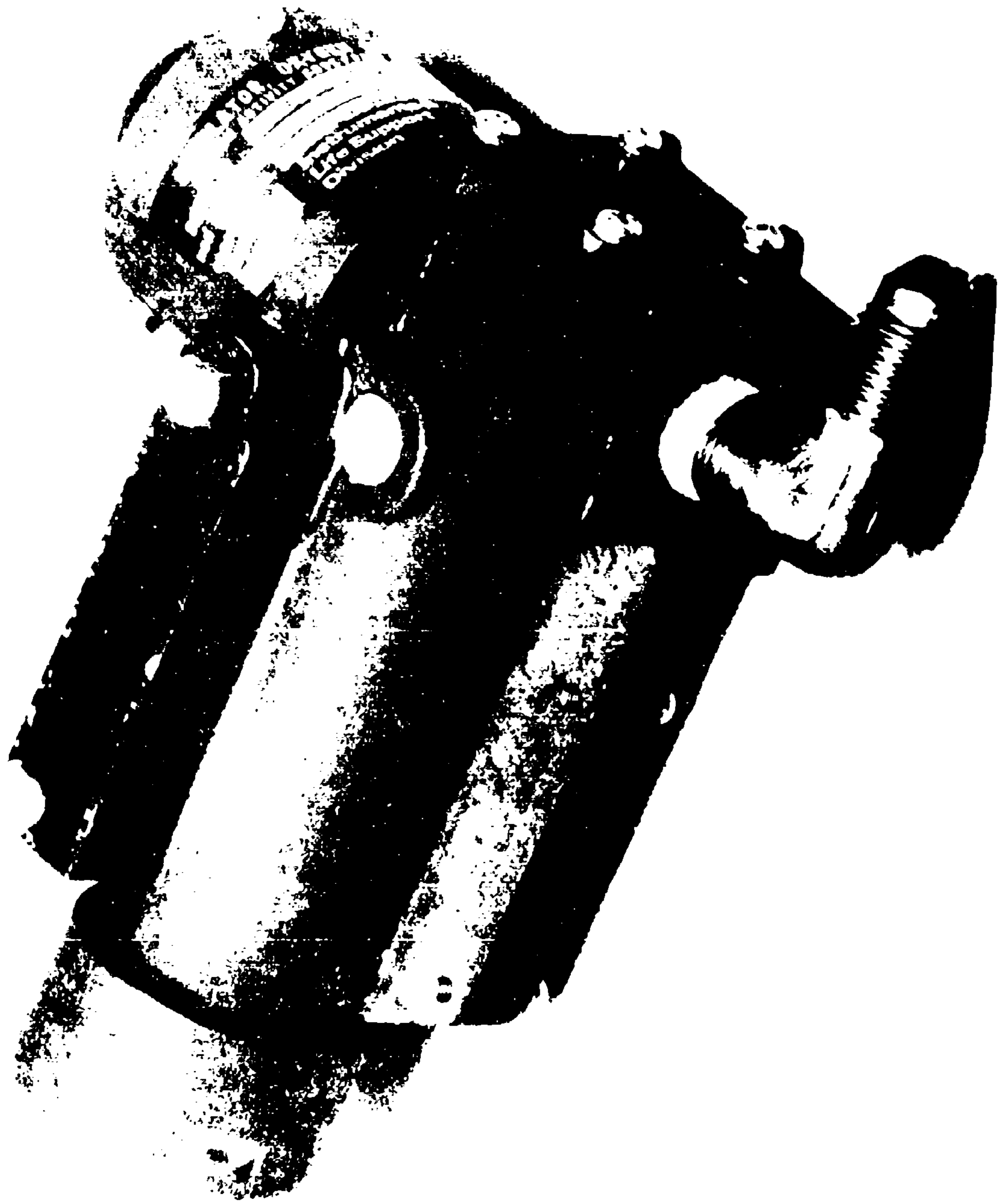

Figure 2 - Breathing Regulator

Figure 3 - Performance Monitor

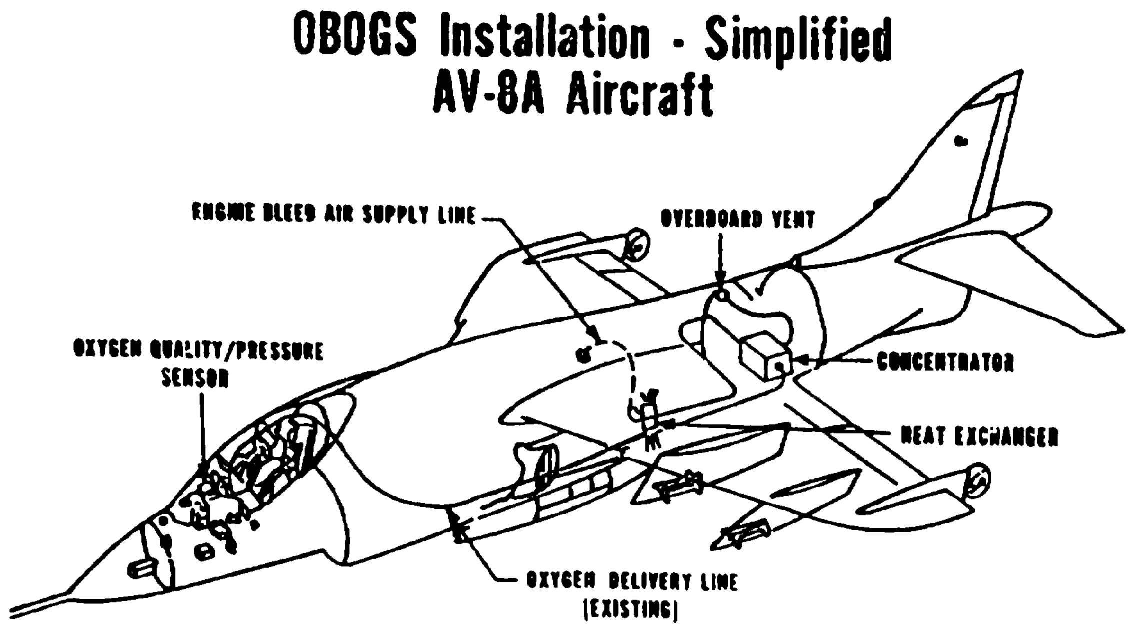

Figure [illegible] - OBOGs Installation-Simplified, AV-8A Aircraft

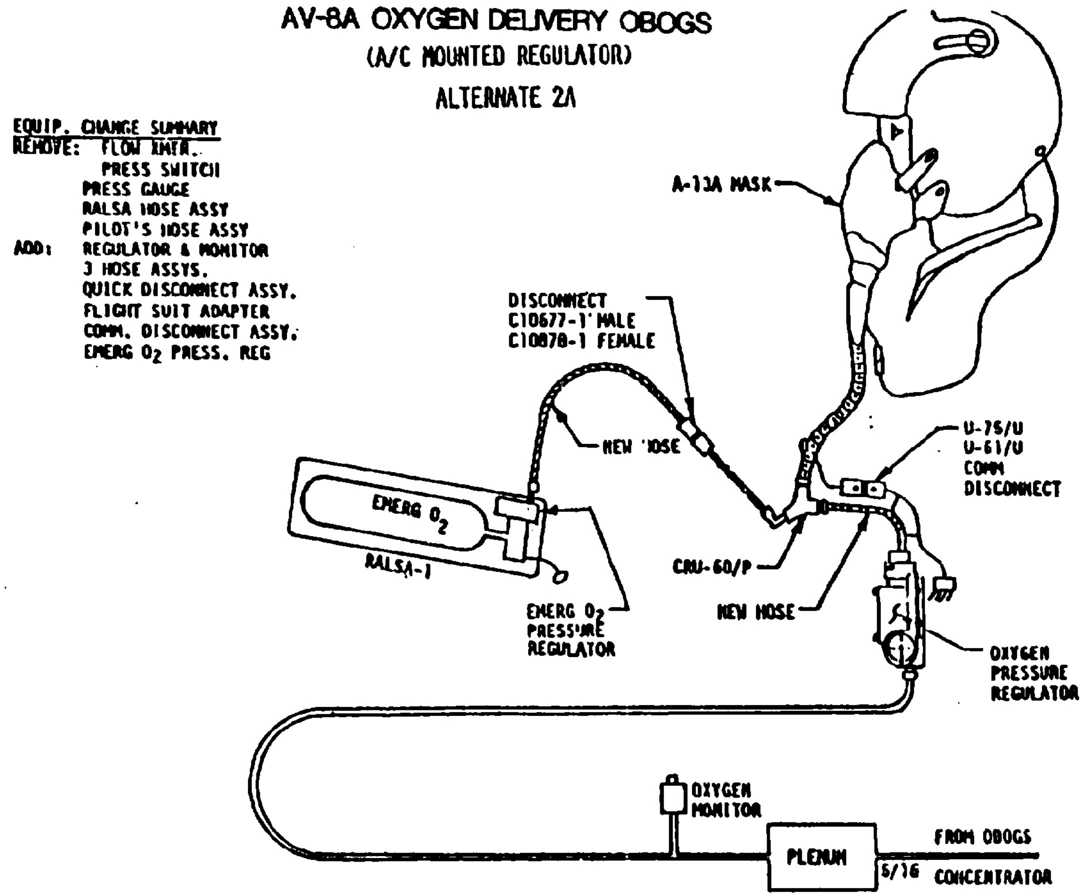

Figure 5 - AV-8A Oxygen Delivery OBOGs, Alternate 2A

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