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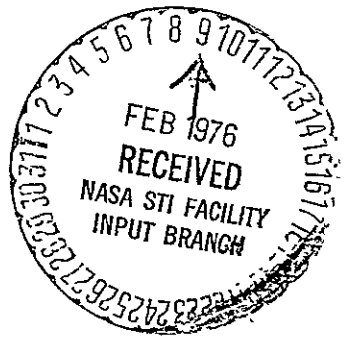
NAS 9—14458
DRL T—1043
LINE ITEM NO. 4
DRD NO. MA—183T

FINAL REPORT

For The

PORTABLE OXYGEN SUBSYSTEM



December 1975

HAMILTON STANDARD Division of UNITED TECHNOLOGIES
Windsor Locks, Connecticut 06096

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For The

PORTABLE OXYGEN SUBSYSTEM

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December 1975

HAMILTON STANDARD Division of UNITED TECHNOLOGIES
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ABSTRACT

This report presents the results of a Portable Oxygen Subsystem development program. The report discusses the concept design study and the design of the prototype hardware and presents the prototype hardware fabrication and test programs.

FOREWORD

This is the Final Report for the Portable Oxygen Subsystem program. This effort was conducted by Hamilton Standard under NASA Contract NAS 9-14458 for the Lyndon B. Johnson Space Center of the National Aeronautics and Space Administration from January 1975 to November 1975.

Special thanks are due to the Contract Technical Monitor, Mr. Roger Tanner, Crew Systems Division of the NASA Lyndon B. Johnson Space Center, for his advice and guidance.

1.0 SUMMARY

Hamilton Standard has developed a Portable Oxygen Subsystem (POS) for use in the Space Shuttle Orbiter System. This development effort was conducted under Contract NAS 9-14458 to NASA's Johnson Space Center. The scope of this program included the selection, design, fabrication, and test of a POS which meets the Shuttle objectives of long life, low cost and minimum maintenance.

The POS is a rebreather type system which provides a revitalized breathing gas supply to a crewman for denitrogenization, emergency IV activity, and/or emergency rescue.

The program effort included selection and optimization of the POS concept; detail design of a prototype system; fabrication and acceptance testing; and manned and unmanned performance testing of the prototype system.

The concept selection effort consisted of evaluation of a NASA baseline system, identification of any deficiencies in the baseline concept, definition of system concepts which eliminate the deficiencies, evaluation and selection of the optimum concept based on weight, volume, and cost. This was followed by optimization of the selected concept on the basis of weight, volume, cost, operability, and safety. The selected concept is shown schematically in Figure 1-1.

The selected system consists of a breathing circuit and an oxygen supply circuit. In operation, the crewman's exhaled CO_2 laden gas passes through the regenerative heat exchanger where it picks up heat and moisture and then passes through a check valve to a breathing bag. When the breathing bag is fully extended, the exhalation relief valve opens allowing some of the hot, moist, CO_2 laden gas to escape. Upon inhalation, the gas in the breathing bag is directed by the check valves to pass through a LiOH bed in the cartridge canister assembly where the CO_2 is removed and moisture and heat are added to the gas. The gas then passes through the regenerative heat exchanger where the gas temperature and moisture level are reduced to approximately the levels previously exhaled by the crewman. Makeup oxygen is supplied continuously either from the self contained O_2 supply or from a vehicle umbilical connected to the fill fitting. The pressure of the incoming gas is reduced to a constant level by the pressure reducer. From the pressure reducer, the gas enters the breathing circuit either through the demand regulator which only opens if the crewman should collapse the breathing bag or through a flow limiting orifice. During the inhalation phase, the makeup gas flows to the mask at the top of the visor and flows across the

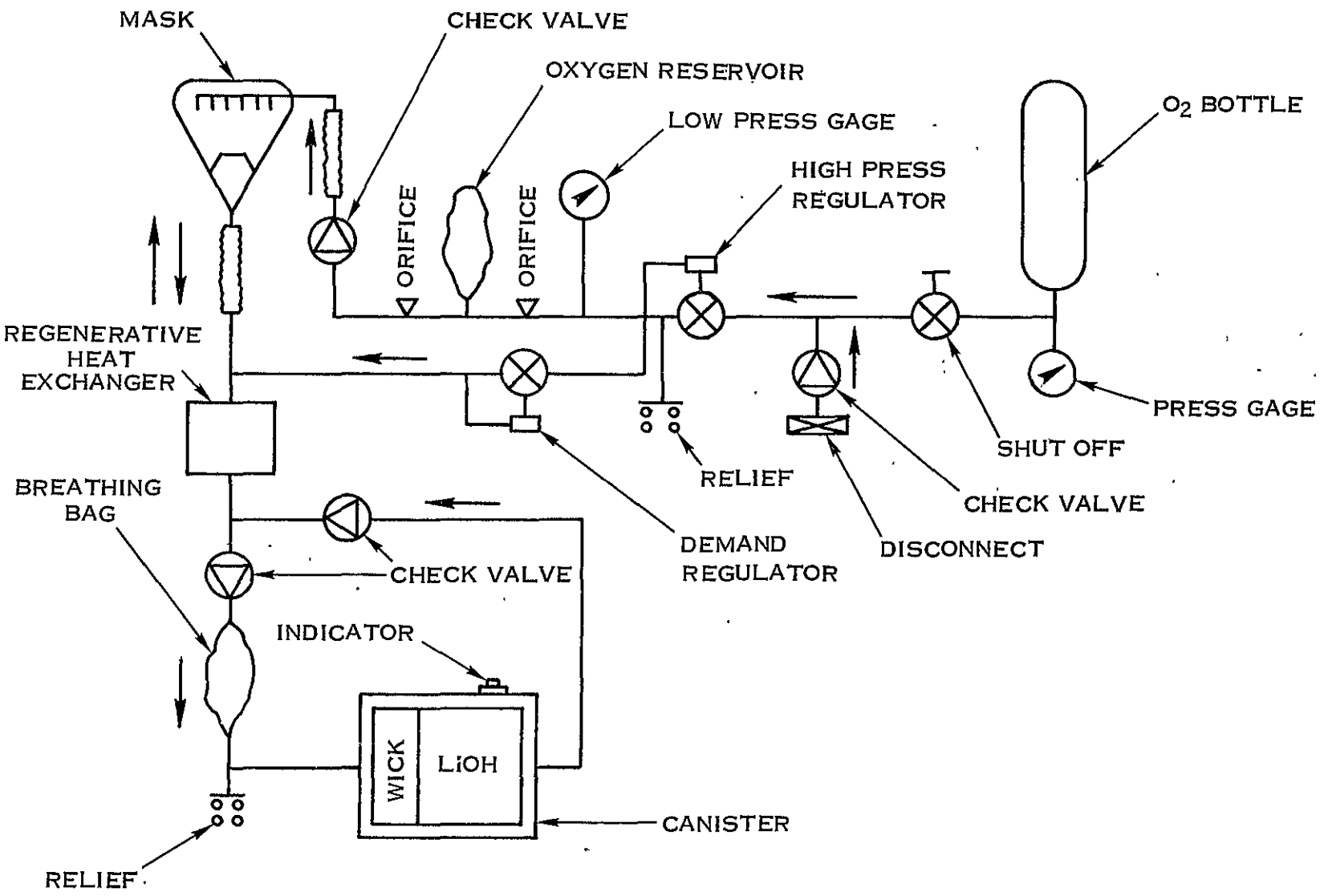


FIGURE 1-1 POS SCHEMATIC

1.0 (Continued)

visor to the crewman's oral nasal area. During the exhalation phase, the pressure in the mask increases above ambient, and the makeup flow is diverted to the O_2 reservoir which is a small breathing bag. During inhalation, the gas is drawn from the O_2 reservoir through the flow compensating orifice which is used to match the flow from the reservoir with the flow from the breathing bag. The pressure gages are used to provide status monitoring, and the high pressure relief valve is used to prevent overpressurization of the breathing circuit should the pressure reducer fail open.

The cartridge canister assembly, which is a replaceable item, contains a status indicator to assure that the LiOH has not been exposed to degrading environments.

Detail design drawings were prepared for the selected concept, and the prototype system, shown in Figure 1-2, was fabricated. The system was acceptance tested to verify proper performance of all components and was then subjected to an unmanned and manned development test program which demonstrated that the system complies with the Work Statement requirements.

Upon completion of the test program, the prototype Portable Oxygen Subsystem was delivered to NASA.

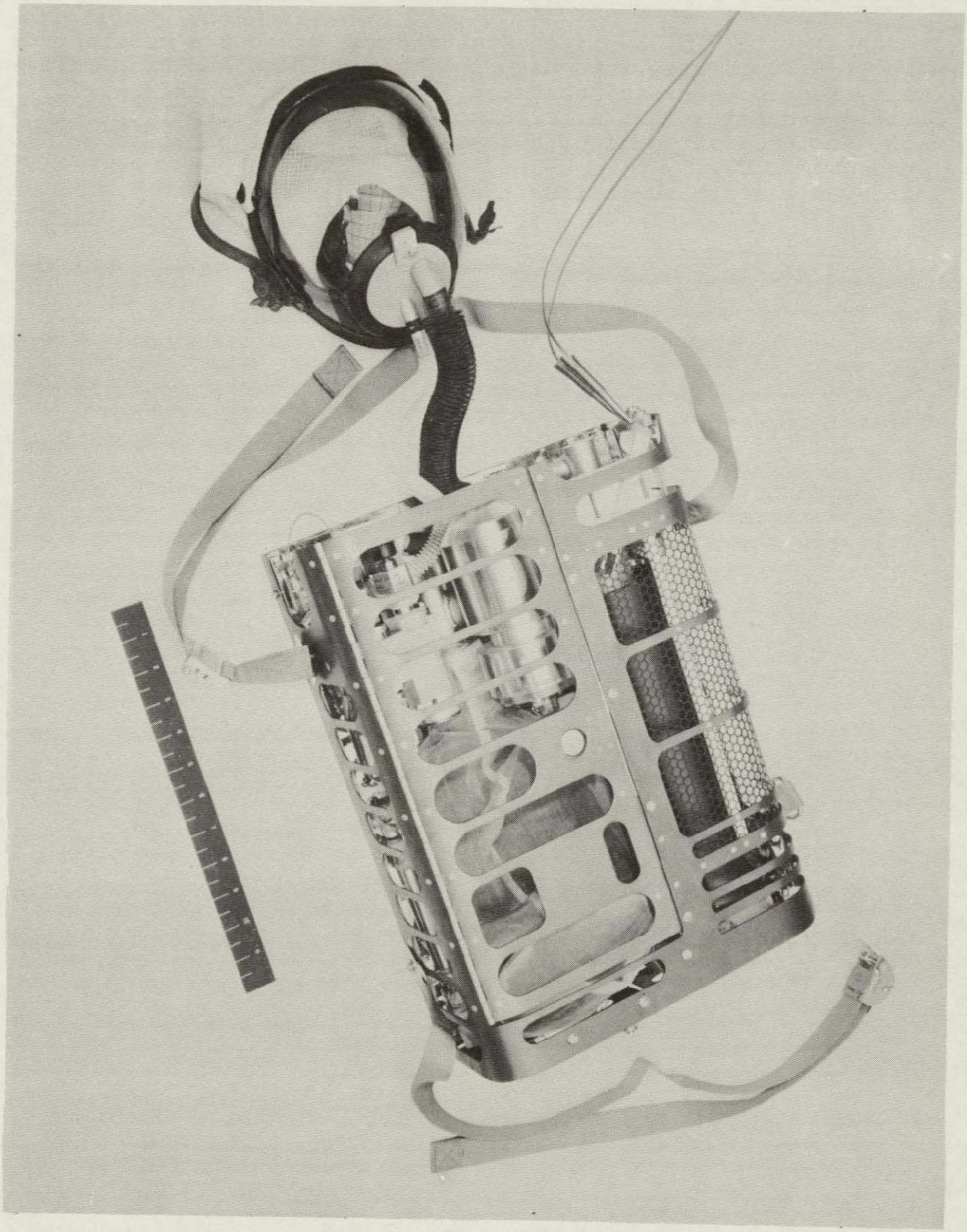


FIGURE 1-2 PORTABLE OXYGEN SUBSYSTEM

2.0 INTRODUCTION

In January of 1975, Hamilton Standard was awarded a contract to develop a long life, low cost, low maintenance, and high reliability Portable Oxygen Subsystem (POS) for use in the Space Shuttle Program. This effort included the selection, optimization, design, fabrication, and test of a prototype POS.

This Final Report summarizes the program effort.

3.0 OBJECTIVES

The objectives of this program were:

a) Establish by detail evaluation the best Portable Oxygen Subsystem (POS) for use in the Space Shuttle Program.

b) Prepare detail drawings suitable for fabrication of a prototype POS.

c) Fabricate the prototype POS.

d) Conduct sufficient development tests to verify compliance with Work Statement requirements and to verify that the unit is acceptable for further manned testing at reduced ambient pressure.

4.0 DISCUSSION

4.1 Background and Requirements

The Portable Oxygen Subsystem (POS) program was conducted to select, design, fabricate, and test a portable, regenerative breathing system for use on the Space Shuttle Oribiter. The program was conducted in accordance with the program logic shown in Figure 4-1-1.

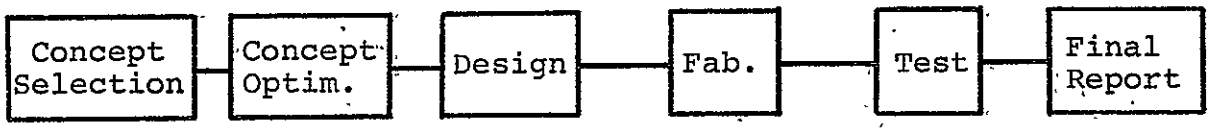


Figure 4-1-1
Portable Oxygen Subsystem Program Logic

This report section is divided into the following subsections representing the major elements of the program work breakdown structure.

- Concept Selection Study
- Concept Optimization
- Design
- Fabrication
- Test

The Portable Oxygen Subsystem (POS) is capable of performing during any one of the following mission modes.

- Denitrogenization
- Emergency Intravheicular (IV) Operation
- Emergency Extravehicular (EV) Operation

In the denitrogenization mode the POS provides a recycled, revitalized gas supply to a crewman for three hours of operation. A small quantity of gas is expelled from the system during each exhalation thus lowering the nitrogen level in the crewman to a safe level for EVA activity at 27.6 KPa (4.0 psia). During this mode of operation, makeup oxygen is supplied by the vehicle oxygen system.

In the emergency EV mode the system provides a crewman with a safe breathing supply for up to three hours while coupled to the vehicle O_2 supply for use in the event the cabin atmosphere becomes unsafe to breath. The system contains an oxygen bottle capable of providing a minimum of 10 minutes of operation independent of the vehicle O_2 supply.

4.1 (Continued)

In the emergency EV rescue mode the system operates for two hours coupled to the vehicle O_2 supply and then provides a minimum of one hour of independent operation in a rescue enclosure used for emergency EV transfer.

Table 4-1-1 summarizes the POS requirements.

4.2 Concept Selection Study

The concept selection study was initiated by defining the operating conditions, establishing trade-off criteria, and by reviewing the NASA baseline POS. The system operating conditions used in the study are included in Table 4-2-1. The trade-off criteria consisted of unit weight, unit volume, and relative cost with each element being equally important in selection of the concept. The unit weight and volume were established on the basis of a complete POS. The relative cost was based on the estimated cost to fabricate only those items which differed from concept to concept and a vehicle weight penalty of $22,000/Kg ($10,000/lb) based on 8 units per flight.

Figure 4-2-1 represents the NASA Portable Oxygen Subsystem baselined in the statement of work. It utilizes a high pressure oxygen system and a breath powered breathing circuit to furnish the astronaut with a dehumidified CO_2 free supply of oxygen. The high pressure oxygen system consists of an oxygen bottle, a vehicle oxygen connector, and a flow controller. The breathing circuit consists of a full face mask, a breathing bag, a relief valve, check valves, and a LiOH canister.

The oxygen bottle is sized for purge flow to allow independent operation for a 10 minute IV emergency or a one hour EV rescue mission.

The vehicle oxygen connector permits subsystem operation utilizing the vehicle 6,205 KPa (900 psia) O_2 supply for normal or emergency EV denitrogenization missions or for emergency IV operation. For this review, a purge flow rate of 0.51 Kg/hr (1.125 lb/hr) of O_2 dumped into the Shuttle cabin was assumed because it would not impose a penalty on the vehicle and would minimize the LiOH required for CO_2 control. This flow rate would not crack the Shuttle cabin dump valve if two astronauts purge this amount of O_2 into the cabin during three hours of POS normal or emergency IV operation. Assuming a 102.7 KPa (14.9 psia) maximum regulated pressure and a 56.6 m^3 (2,000 ft^3) Shuttle cabin volume, the vehicle pressure will not exceed 106.9 KPa (15.5 psia) at the end of three hours of operation. This approach represented maximum practical POS O_2 purge and maximum O_2 conservation for the total Shuttle system as nearly all of the O_2 used for prebreathing is ultimately consumed and not lost overboard.

TABLE 4-1-1
POS REQUIREMENTS

- Denitrogenization Mission Metabolic Profile

  2 hours and 42 minutes at 844 KJ/hr (800 Btu/hr) ambient 101.3 KPa (14.7 psia)
  15 minutes at 1,160 KJ/hr (1,100 Btu/hr) ambient 101.3 KPa (14.7 psia)
  3 minutes at 1,582 KJ/hr (1,500 Btu/hr) ambient 101.3 KPA (14.7 psia)

- Emergency IV Mission Profile

  2 hours and 42 minutes at 844 KJ/hr (800 Btu/hr) ambient 101.3 KPa (14.7 psia)
  15 minutes at 1,160 KJ/hr (1,100 Btu/hr) ambient 101.3 KPa (14.7 psia)
  3 minutes at 1,582 KJ/hr (1,500 Btu/hr) ambient 101.3 KPa (14.7 psia)
  10 minutes at 1,160 KJ/hr (1,100 Btu/hr) on bottle ambient 101.3 KPa (14.7 psia)

- Emergency EV Rescue Profile

  2 hours at 633 KJ/hr (600 Btu/hr) ambient 101.3 KPA (14.7 psia)
  1 hour at 844 KJ/hr (800 Btu/hr) ambient 34.5 KPa (5 psia)

- Maximum Inlet Temperature 43.3°C (110°F)

- Maximum Inlet Dew Point 37.8°C (100°F)

- Maximum Inlet CO_2 Partial Pressure at Work Rates up to 844 KJ/hr (800 Btu/hr) 1.0 KPa (7.6 mm Hg)

- Maximum Inlet CO_2 Partial Pressure at Work Rates Above 844 KJ/hr (800 Btu/hr) 1.99 KPa (15 mm Hg)

- Maximum Touch Temperature 45°C (113°F)

TABLE 4-2-1
SYSTEM OPERATING CONDITIONS

Cabin Pressure	101.3 ± 1.4 KPa (14.77 ± .2 psia)
Cabin Temperature	18.33 - 26.7°C (65 - 80°F)
Rescue Enclosure Pressure During Transfer	34.5 KPa (5 psia)
Rescue Enclosure Temperature During Transfer	21.1 - 46.1°C (70 - 115°F)
Vehicle O_2 Supply Pressure	6,205 KPa (900 psia) Nominal
Vehicle O_2 Supply Temperature	18.3°C (65°F) Nominal
Oxygen Allocation	0.23 Kg/Hr/POS (0.5 Lb/Hr/POS)
Cabin Relief Valve Setting	106.9 KPa (15.5 psid)
Design Respiratory Quotient	0.9

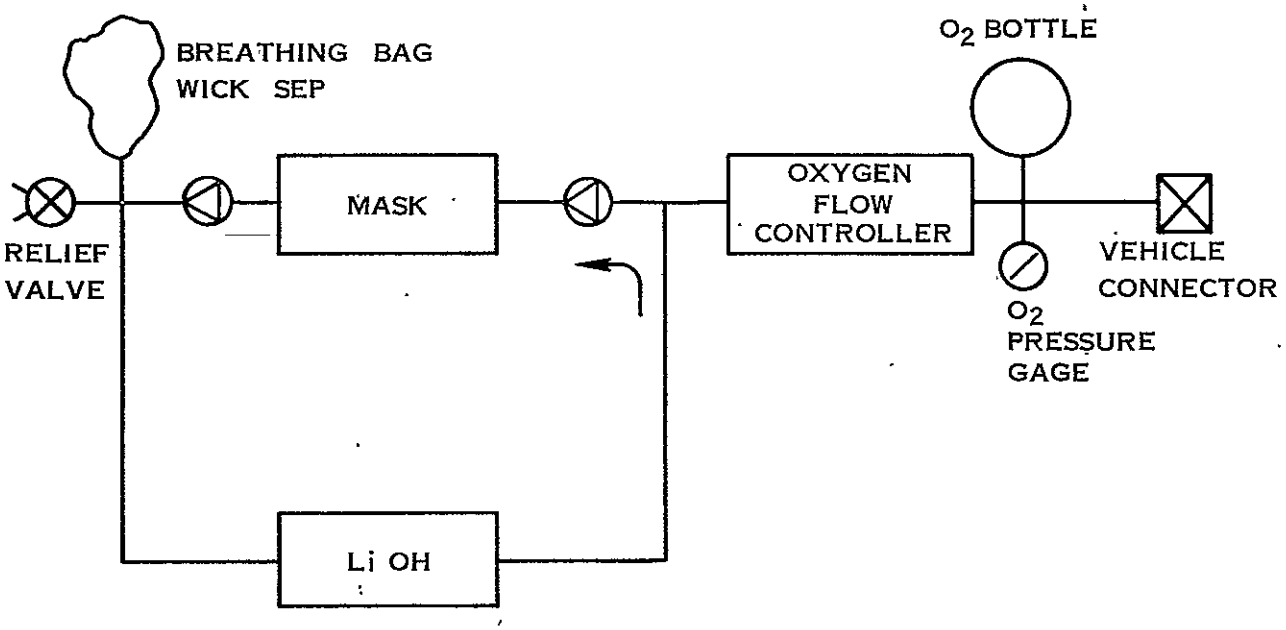


FIGURE 4-2-1 NASA BASELINE POS

4.2 (Continued)

The oxygen controller contains a shutoff valve, a pressure gage to monitor O_2 bottle pressure, a demand regulator to supply O_2 to the face mask in the event that the breathing bag bottoms out and a flow control circuit which supplies a constant flow of 0.51 Kg/hr (1.125 lb/hr) of O_2.

The breathing bag contains a wick separator and flow distribution channels to direct the inhaled and exhaled breath over the internal face of the bag to promote heat transfer with the ambient environment by radiation. The wick immobilizes any condensate that may be generated in the bag.

A relief valve is utilized to vent the purge gas to the cabin, and the ventilation loop check valves ensure that the flow of gas is only in one direction.

The lithium hydroxide canister contains lithium hydroxide to chemi-sorb CO_2 from the breathing circuit. The reaction generates heat, which is dissipated by radiation through the canister wall and by heating the breathing circuit gas stream, and generates water thus raising the humidity level of the gas circuit.

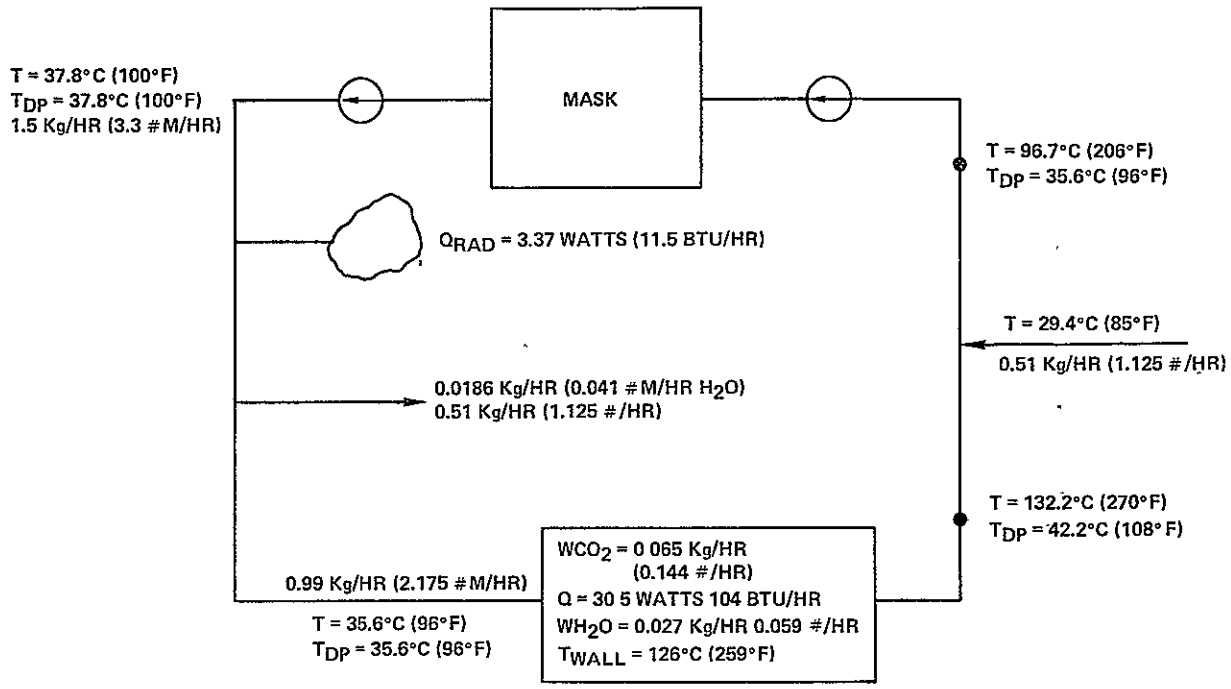
This concept, when subjected to the high metabolic rates at zero "g" conditions, results in the face mask inlet temperature of 96.7°C (206°F). This is caused by the high heat of reaction of CO_2 and the generation of water vapor by the LiOH.

Figure 4-2-2 is a flow chart of the baseline system at this operating condition.

The LTV Shuttle EVA Rescue Study Report (T-215-RP01) indicates that operation of this POS concept at a high gas purge rate will result in acceptable temperature control. This is not practically achievable because the effective radiating surface area of the LiOH canister is approximately one-half of the assumed LTV value. This radiation area has a significant affect on the heat rejection capability of the LiOH canister. Compensating for the reduced effective area by increasing the canister source temperatures drives up the LiOH canister carrier gas outlet temperature to the higher temperatures. Design of a subsystem package that provides a canister view factor higher than 0.5 is a possible method of increasing the effective radiation area. However, this approach is impractical since the POS must be worn on the astronaut's person, thus shielding about 50% of the actual projected area from effective radiation.

The mask temperature could be reduced by increasing the size of the breathing bag, however, the bag would require a radiant heat transfer area in excess of 0.84 m^2 (9 ft^2).

FLOW SCHEMATIC - NASA RECOMMENDED SYSTEM



Q_{MET} = 322.4 WATTS (1100 BTU/HR) 101.4 KPA (14.7 PSIA)

VENTILATION RATE = 1.19 m^3/HR (42 FT^3/HR) = 1.5 Kg/HR (3.3 #M/HR) @ ρ = 1.26 Kg/m^3 (0.0785 #M/FT^3)

CO_2 PRODUCTION RATE = 0.10 Kg/HR (0.219 #/HR)

LiOH CAN RADIATING AREA = 0.039m^2 (60 IN^2) ≅ 0.039m^2 (0.42 FT^2)

BREATHER BAG RADIATING AREA = 0.07m^2 (0.75 FT^2)

NOTE: INSTANTANEOUS FLOWRATES ARE DOUBLE THE TIME AVERAGED VALVES SHOWN.

$$Q = 0.51 \frac{Kg}{HR} \times 0.277 \frac{WATT - HR}{Kg - °C} \times 8.33°C + 1.5 \frac{Kg}{HR} \times 0.277 \frac{WATT - HR}{Kg - °C} \times 8.33°C = 4.7 \text{ WATTS}$$

(1.125 X 0.24 X 15 + 3.3 X 0.24 X 15 = 16 BTU/HR)
(VENT FLOW) (MAN)

FIGURE 4-2-2 PERFORMANCE CHART - NASA BASELINE

4.2 (Continued)

The remainder of the system selection study consisted primarily of evaluating various means of modifying the baseline system to provide the required thermal control and selecting the most promising candidate.

Two basic approaches for providing inlet gas thermal and humidity control were considered. These were use of a fusible heat sink and use of a regenerative heat exchanger.

Figure 4-2-3 is a function schematic of a fusible heat sink. At normal ambient temperature the heat sink material is a solid. When hot gas enters the unit, the heat sink material melts, removing heat from the gas stream. As the gas cools, moisture in the gas condenses and is trapped in the wick material.

Table 4-2-2 lists the phase change materials considered for use in the fusible heat sink.

Compound	Melting Point °C (°F)	Heat Fusion KJ/Kg (Btu/lb)
$C_{17}H_{34}O_2$	28.9 (84)	42.2 (88)
$C_{26}H_{54}$	28.9 (84)	40.3 (84)
$CaCl_2 \cdot 6H_2O$	29.4 (84.9)	35 (73.1)
$LiNO_3 \cdot 3H_2O$	29.8 (85.6)	61.4 (128)
$Na_2SO_4 \cdot 10H_2O$	32.4 (90.3)	52.3 (109)
$C_{19}H_4O$	32.2 (90)	45.6 (95)
$C_{24}H_{50}$	35 (95)	40.8 (85)
$(C_{13}H_{27}COO)_3C_3H_3$	32.8-57.2 (91-135)	41.8-43.7 (87-91)
NH_2OH	32.9 (91.4)	75.8 (158 (Est.))

Table 4-2-2
Candidate Heat Sink Materials

All of these chemicals have a melting point above or close to the maximum cabin ambient to permit resolidification after usage by stowing the sink in the cabin. The $LiNO_3 \cdot 3H_2O$ chemical was selected for the POS fusible heat sink, as the combination of its high thermal conductivity of 0.711 W/m °C (0.406 Btu/hr ft °F) as opposed to 0.14 W/m °C (0.08 Btu/hr ft °F) for the other chemicals and its Cp of 0.17 KJ/Kg °C (0.65 Btu/lb °F) provides the lightest weight, smallest volume heat sink.

Functionally, the regenerative heat exchanger can be simulated by a pipe with screen mounted perpendicular to the flow at intervals along the pipe as shown in Figure 4-2-4.

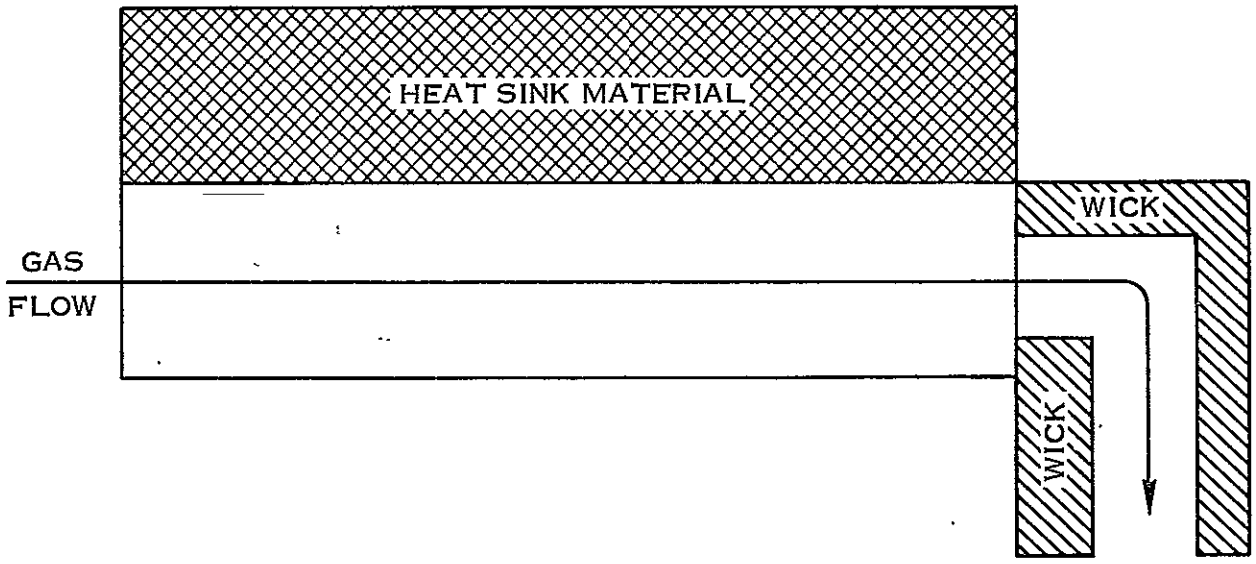


FIGURE 4-2-3 FUSIBLE HEAT SINK FUNCTIONAL SCHEMATIC

4.2 (Continued)

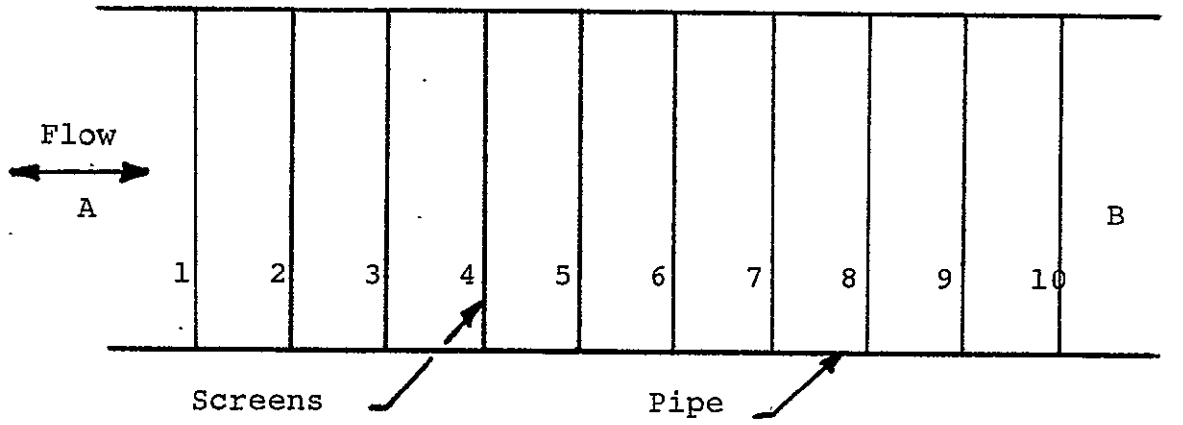


Figure 4-2-4
Regenerative Heat Exchanger

The hot gas is introduced at end A. When it passes through screen 1, it will heat up the screen with a resultant decrease in gas temperature. As the gas passes through each successive screen, additional heat is removed by heating of the screens until a significantly cooler gas exits at end B. When the flow is reversed, gas flowing from point B to point A will pick up heat from each screen until it exits at point A at a temperature close to that of the hot gas initially introduced at point A. Moisture that condenses while the gas passes through the heat exchanger remains in the device and is reevaporated during reverse flow of the gas.

By neglecting heat exchanger effectiveness, time constants and internal heat transfer of the screen, the device can be simply explained by assuming that the change in internal energy of the screen is equal to change in energy in the gas.

$C_{Pscreen}\ P_{screen}\ V_{screen}\ \text{Delta}\ T_{screen} = \dot{M}_{gas}\ C_{Pgas}\ \text{Delta}\ T_{gas}\ \Theta$

Where $C_{Pscreen}$ is the specific heat of the screen.

P_{screen} is the density of the screen.

V_{screen} is the volume of the screen.

Delta T_{screen} is the initial screen temperature - the final screen temperature.

4.2 (Continued)

$\dot{M}$ is the mass flow of the gas.

CP_{gas} is the specific heat of the gas.

Delta T_{gas} is the initial gas temperature - the final gas temperature.

Θ is the time the gas is flowing through the screen (one way).

In selecting the regenerative heat exchanger packing material, several factors were of prime importance. These were bed volume and response time. The sphere is the densest packing material as summarized in Table 4-2-3. Thus, for the mass of packing material required, the sphere is the optimum shape.

Shape	% Free Volume	Source
Rings	67	Chemical Engineers Handbook
Saddles	65	Chemical Engineers Handbook
Screens	59	Calculated
Balls	36	Calculated

Table 4-2-3
Packing Material Volume

Based on the Fourier number which is a dimensionless measure of response time, the sphere has the lowest thermal response time of various shapes. Referring to page 48 of "Temperature Response Charts", Schneider, P. J., John Wiley & Sons, Inc., if it assumed that all shapes are made of the same material (thus having the same diffusivity (α = KP/Cp)) and are of the same thickness (δ), the time (Θ) for the center temperature to respond is least for the sphere.

These two thermal control devices were integrated with the baseline system resulting in the definition of three candidate POS configurations.

Figure 4-2-5 shows POS concept number 1 which utilizes a fusible heat sink to remove latent and sensible heat from the gas stream and contains a wick separator to contain the moisture which condenses in the fusible sink. The thermal sink has an overall conductance that varies with time so the temperature and dew point of the gas leaving the sink various between 30°C (86°F) at the

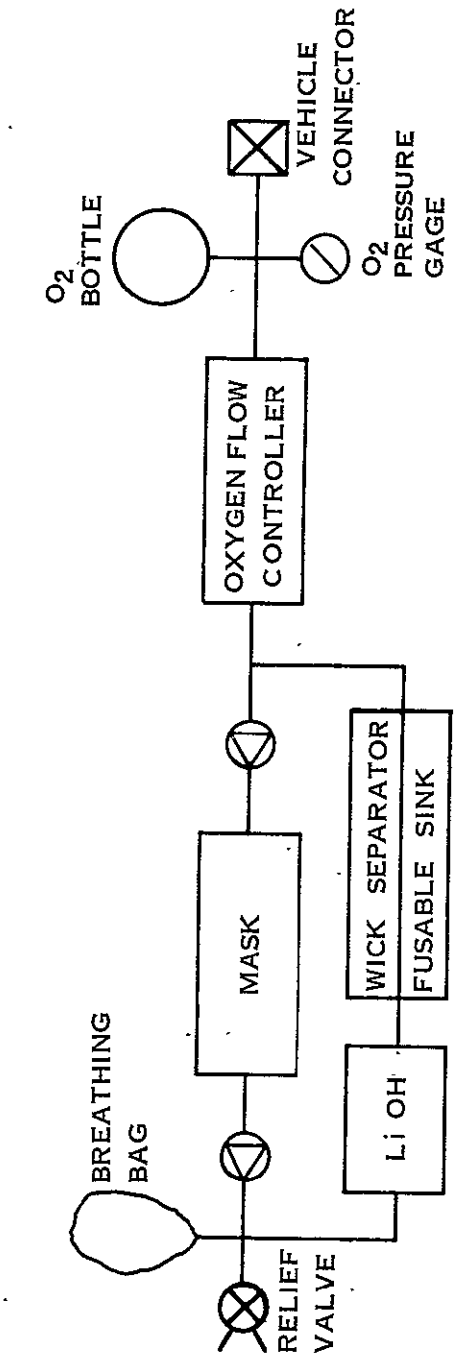


FIGURE 4-2-5 POS CONCEPT NO. 1

4.2 (Continued)

at the beginning of the mission and 37.8°C (100°F) at the end of the mission. When the outlet gas from the sink mixes with the makeup oxygen flow, the resultant mask inlet temperature ranges from 29.4°C (85°F) to 36.7°C (98°F).

Figure 4-2-6 shows the second concept considered. It utilizes both a regenerative heat exchanger and a fusible sink. The regenerative heat exchanger is used to remove most of the sensible heat added by the chemical reaction of the CO_2 with the LiOH. The fusible sink then removes the remaining sensible heat load as well as the latent load generated by the LiOH/CO_2 reaction. This system contains a bypass around the fusible sink which allows a small amount of warm, moist gas from the regenerative Hx to mix with the outlet of the fusible sink and the O_2 makeup flow. This bypass is sized so that the maximum mask inlet temperature is 43.3°C (110°F) and maximum mask inlet dewpoint is 37.8°C (100°F). The use of the regenerative heat exchanger and the bypass minimizes the size of the fusible sink required.

Figure 4-2-7 is a schematic of the third POS canidate. In use, the hot, moist gas which exits from the LiOH cartridge passes through the regenerative heat exchanger transferring heat to the bed and condensing moisture within the regenerative heat exchanger. As the exhaled gas passes from the mask through the regenerative heat exchanger, the heat stored in the bed is transferred to the gas and the moisture in the heat exchanger evaporates. The regenerative heat exchanger is sized such that its mask side outlet gas when mixed with the makeup oxygen has a temperature less than 43.3°C (110°F) and dewpoint less than 37.8°C (100°F).

The trade-off consisted of evaluation and selection on the basis of weight, volume, and relative cost. The weight and volume for each configuration were established using various O_2 makeup flow rates. These are shown in Figures 4-2-8 and 4-2-9 respectively. As shown by the Figures, the system utilizing only the regenerative heat exchanger is the least weight and least volume system.

In assessing the relative cost of each concept only the identifiable differences were considered. The cost factor was comprised of the fabrication cost assuming the manufacture of 50 units and the launch weight penalty assuming eight POS's per flight using the penalty factor of $4,545/Kg ($10,000/lb).

Figure 4-2-10 shows the relative cost of each of the three concepts. The system utilizing the regenerative heat exchanger has the lowest cost of the three approaches.

The system containing the regenerative heat exchanger for thermal control was found to be the least weight, least volume, and least costly of the concepts considered and was thus the selected concept. Figure 4-2-11 is a schematic of the selected concept.

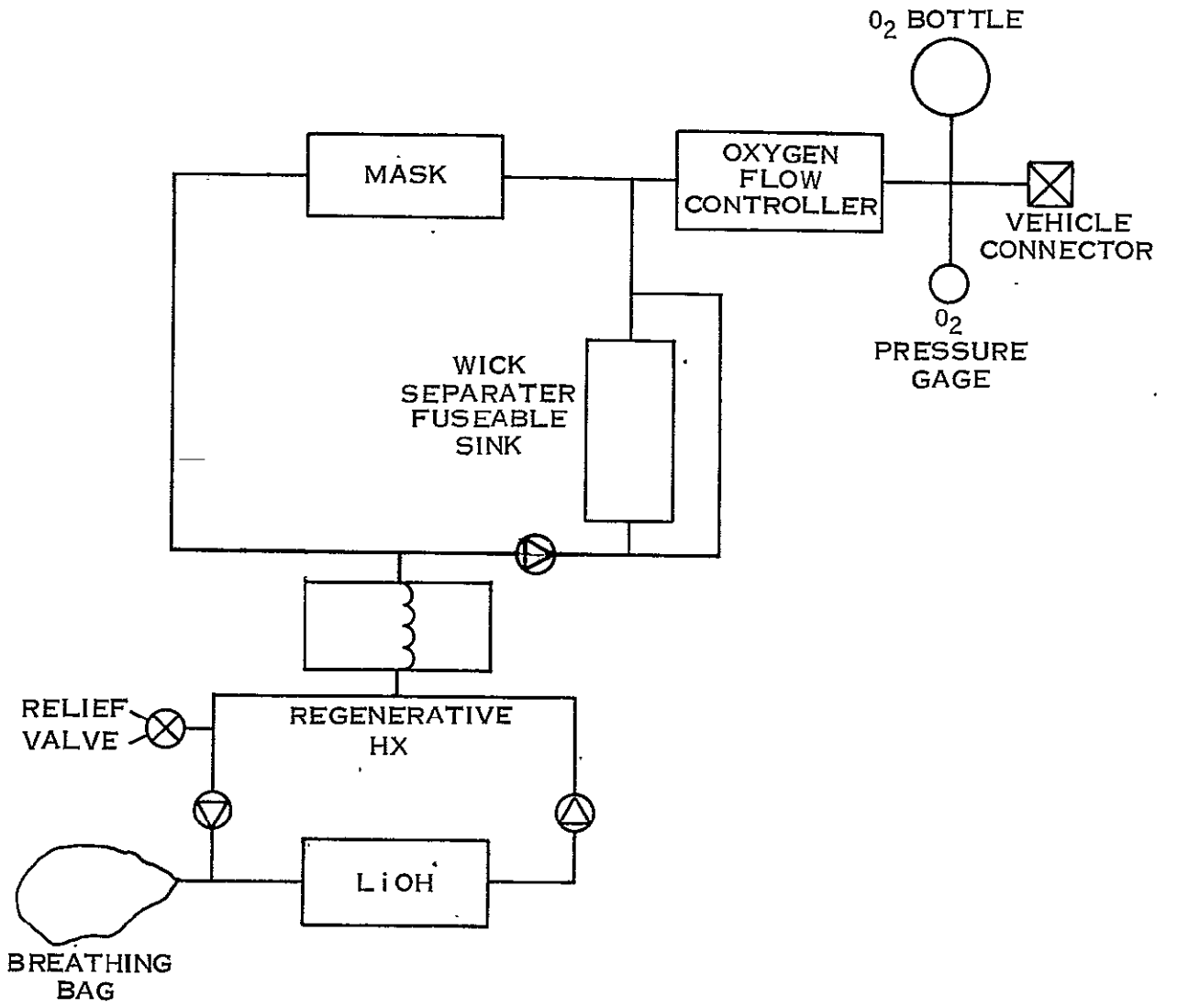


FIGURE 4-2-6 POS CONCEPT NO. 2

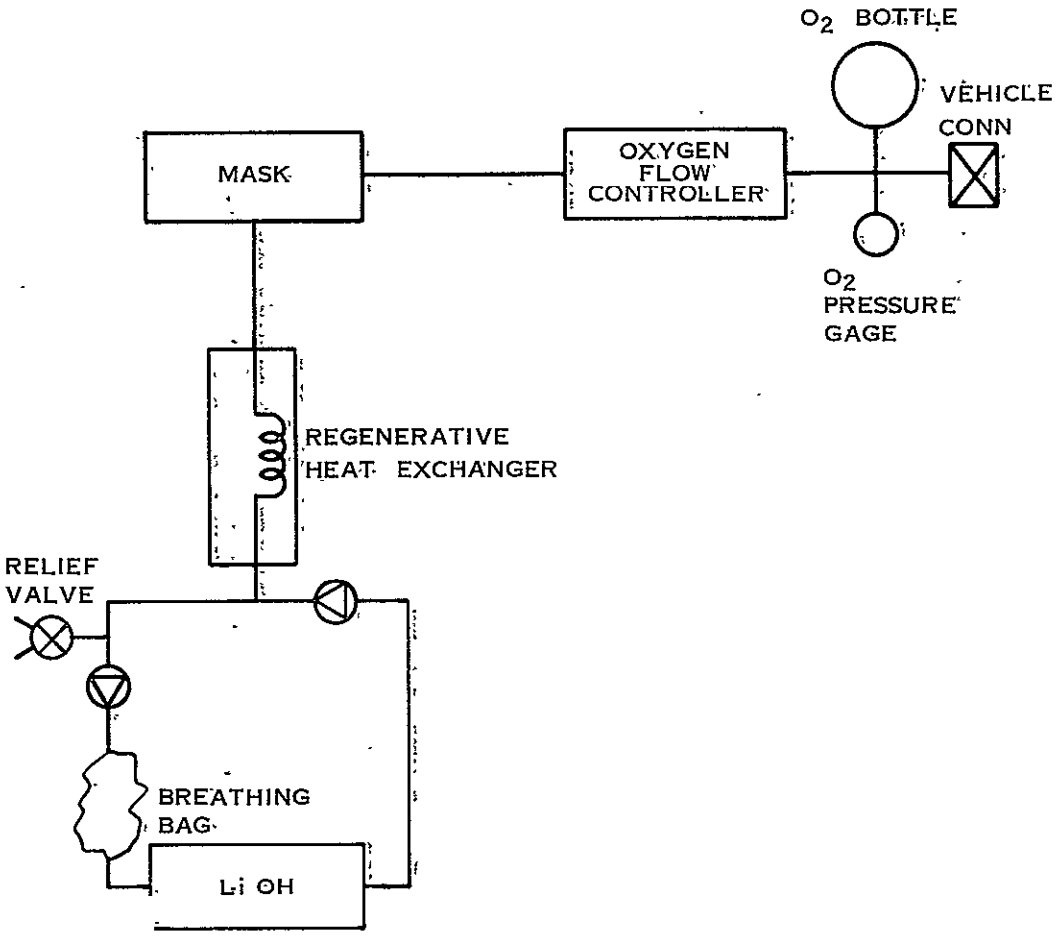


FIGURE 4-2-7 POS CONCEPT NO. 3

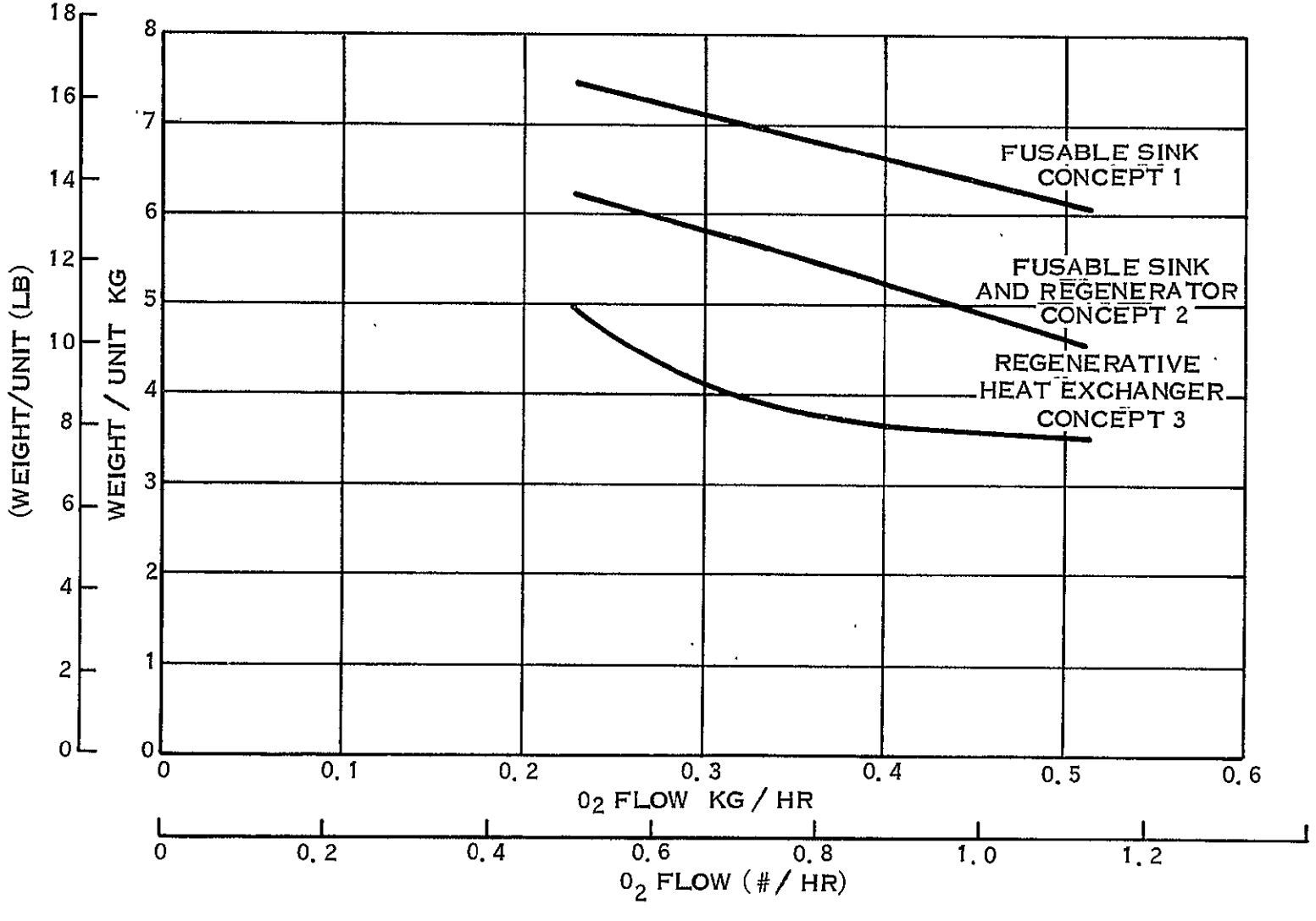


FIGURE 4-2-8 POS UNIT WEIGHT

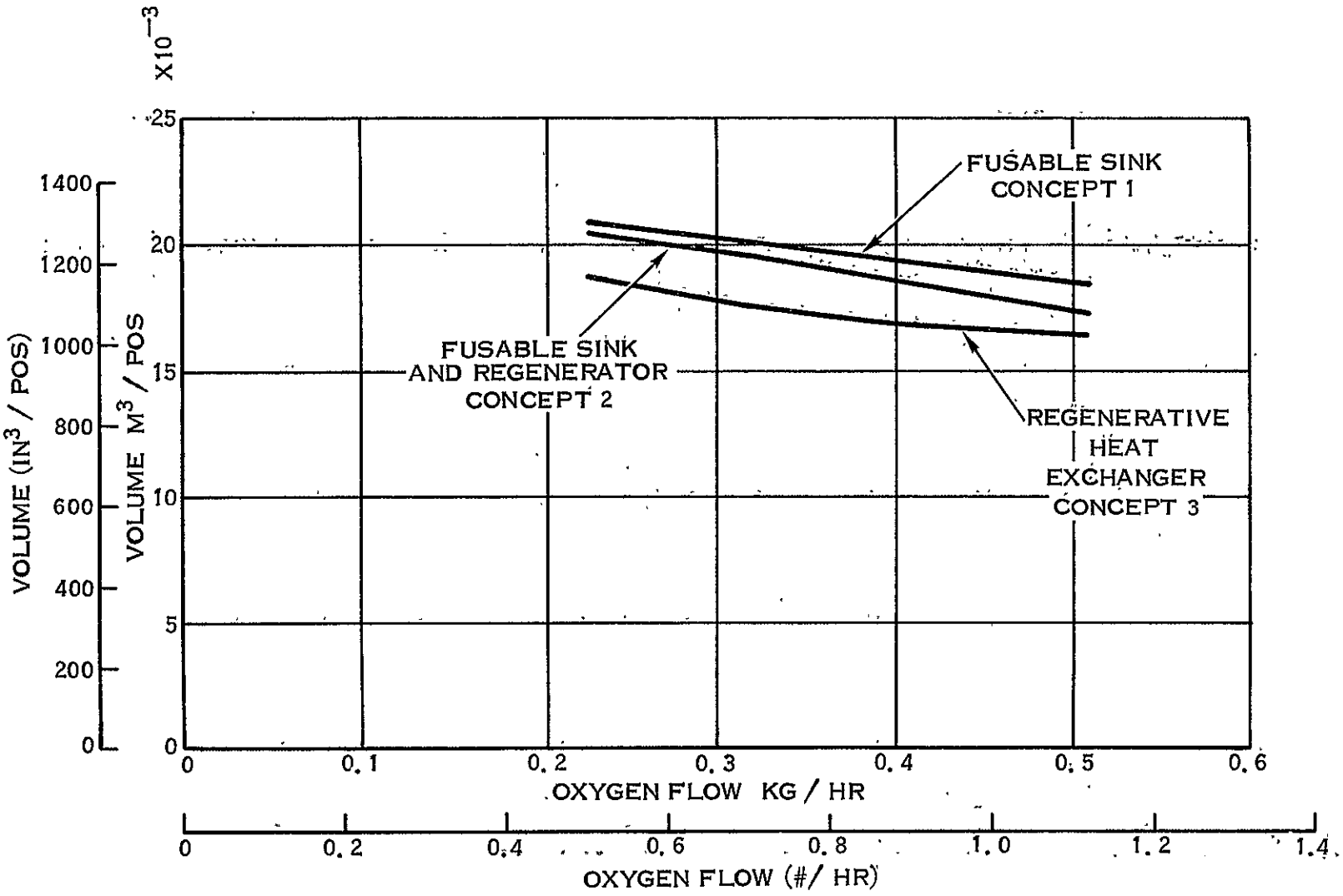


FIGURE 4-2-9 POS UNIT VOLUME

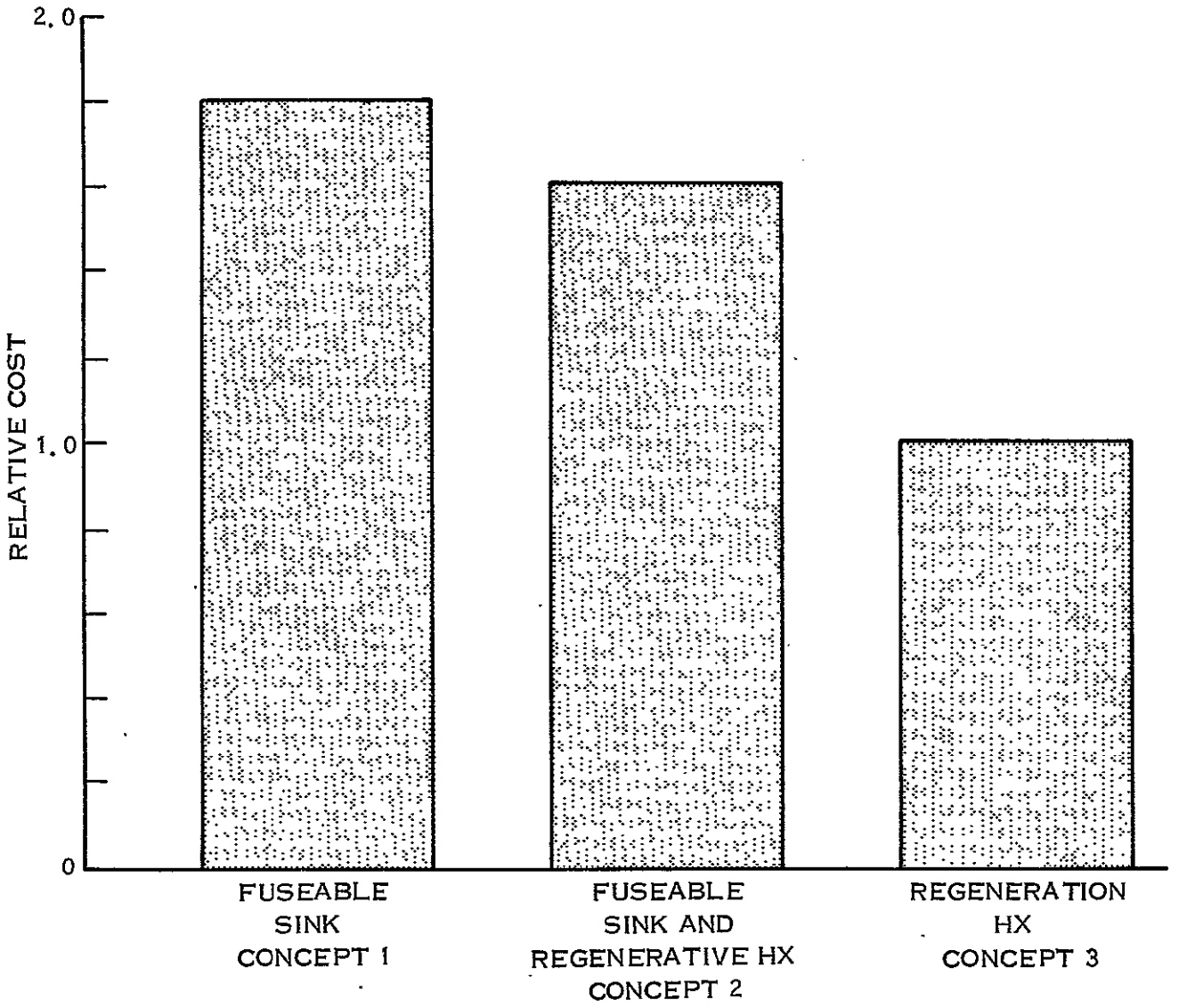


FIGURE 4-2-10 POS RELATIVE COST

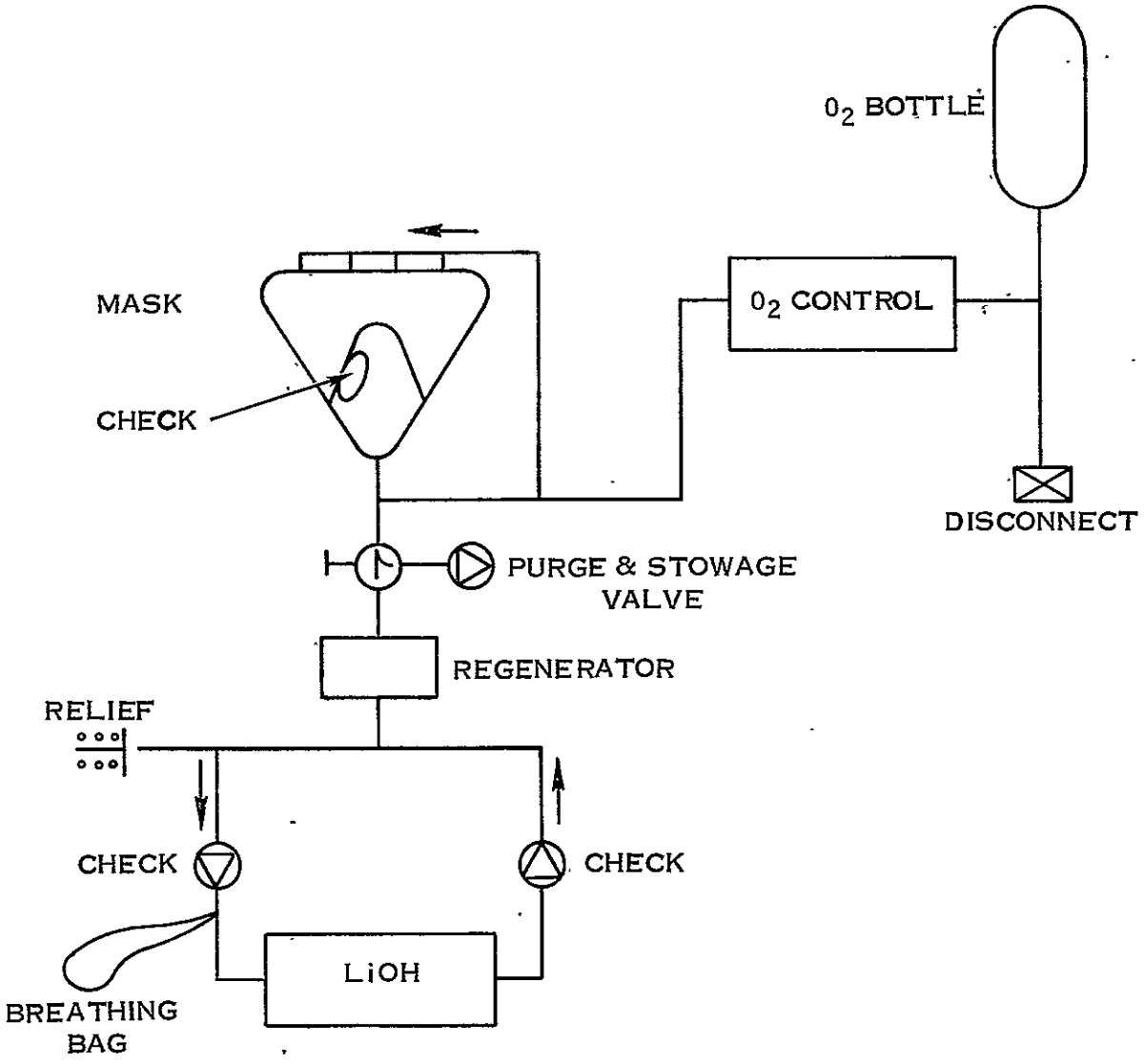


FIGURE 4-2-11 SELECTED POS CONCEPT

4.2 (Continued)

The feasibility of the selected concept had been previously demonstrated by Hamilton Standard testing of a breadboard portable breathing system which utilized a regenerative heat exchanger for thermal control. The breadboard unit and test setup are shown in Figure 4-2-12. This testing verified the predicted performance characteristics of the regenerative heat exchanger and provided actual LiOH performance data at the elevated temperatures inherent with the system approach. The data from this testing provided the basis for final sizing of the prototype POS.

4.3 Concept Optimization

Prior to initiation of the system design, the selected concept was optimized on the basis of weight, volume, cost, operability, and safety.

This effort included the generation of a computer analytical model for optimizing the regenerator bed, the LiOH cartridge, and the O_2 quantity; a component by component review aimed at minimizing cost and volume; and the generation of a detail Failure Modes and Effects Analysis (FMEA) to determine the adequacy of the system. The computer program is discussed in Appendix A.

The analytical effort resulted in the final sizing of the major system components, the regenerative heat exchanger, the LiOH cartridge, the oxygen quantity, and radiative cooling area.

As a result of the component review, the bottle operating pressure and the O_2 flow controller were changed. In the trade-off study, it was assumed that the bottle operating pressure would be 6,205 KPa (900 psig) so that the unit could be recharged from the vehicle O_2 supply. During this review, it was established that bottle recharge would only be required during the emergency IV mode. Since the independent IV activity is limited to 10 minutes, it was concluded that the bottle could be sized on the basis of providing 10 minutes of operation when charged to 6,205 KPa (900 psi) instead of 60 minutes of operation after charging to 6,205 KPa (900 psi). The normal charge pressure was increased to 24,129 KPa (3,500 psi) so the bottle would contain sufficient oxygen to provide 60 minutes of operation. This resulted in a bottle volume savings of 1.75×10^{-3} m^3 (107 in^3).

The oxygen flow controller utilized during the trade-off study was a two stage device and is shown in Figure 4-3-1. The first stage pressure reducer contained a set point selector and shutoff feature while the second stage was a demand regulator capable of providing various flows depending upon demand. This was a complex and costly device which required the use of a precice exhalation relief valve setting to assure proper operation. It also

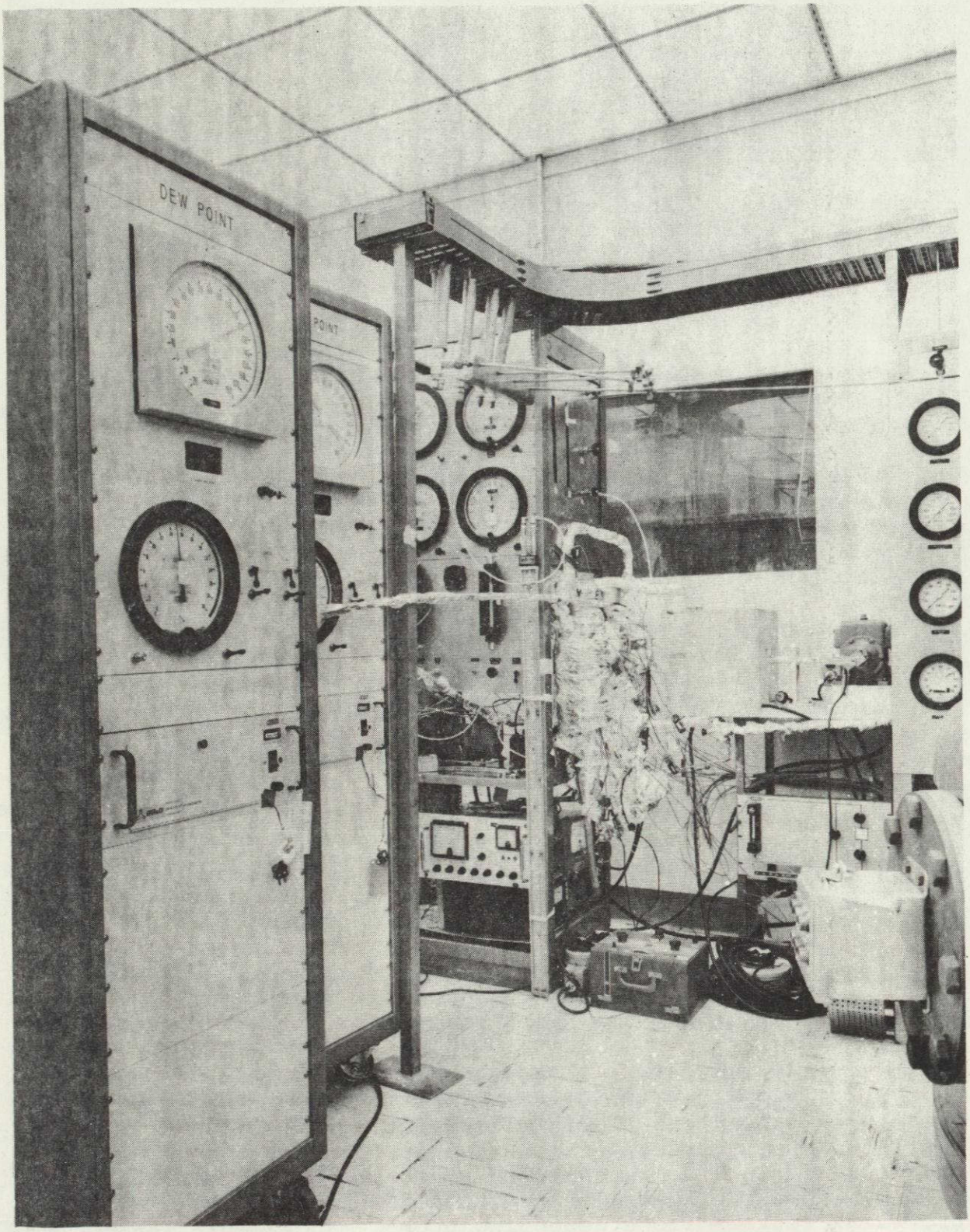


FIGURE 4-2-12 BREADBOARD TEST SET-UP

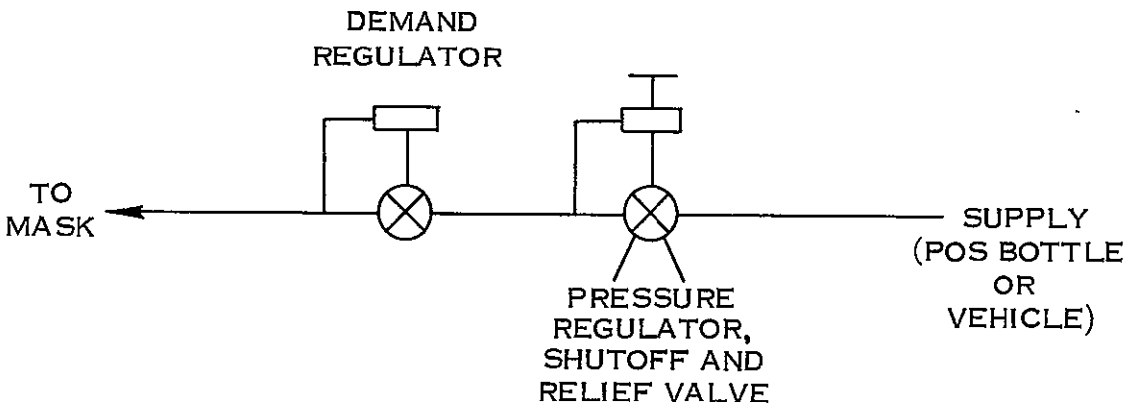


FIGURE 4-3-1 O_2 FLOW CONTROLLER INITIAL CONCEPT

4.3 (Continued)

required a manual change in pressure setting for use in the rescue enclosure. The advantage of this system was that it shut off O_2 makeup flow during exhalation, thus minimizing the quantity of oxygen required.

As a result of the optimization effort, a significant less expensive and less complex O_2 flow controller was evolved. This concept, shown in Figure 4-3-2, contains a separate shutoff valve, a simple pressure reducer, a simple demand regulator, a flow limiting orifice and small breathing bag which stores the makeup oxygen during exhalation. This approach retained the key desirable feature of the initial concept, and since the need to manually change regulator settings was eliminated, it improved the operability. This change reduced the cost of the prototype oxygen flow controller to one half its original cost and would reduce the cost of flight hardware to one sixth that estimated for the initial approach.

The detail Failure Modes and Effects Analysis (FMEA) and Critical Item List (CIL) are included in Appendix B. This analysis identified the need to be able to check the operation of the system prior to an/or during use. A system operation and check out procedure was generated to assure that all critical functions could be checked during start up of the system. The procedure, included in Appendix C, identified the need for an interstage pressure gage to verify proper function of the pressure reducer to assure that the system would meet its independent operations requirements.

The various system changes identified during the optimization effort were combined, and the new system schematic, shown in Figure 4-3-3, was generated. The oxygen bottle (1) is sized to contain 0.196 Kg (.432 lb) of oxygen at 24,129 KPa (3,500 psi), and if only changed to 6,205 KPa (900 psi), it will provide the 0.045 Kg (0.1 lb) of gas required for ten minutes of independent IV operation. The pressure gage (2) continuously monitors the bottle pressure making the system status easy to verify. The shutoff valve (3) is located between the POS bottle and the vehicle O_2 supply connection because the bottle is normally charged to a higher pressure than the vehicle O_2 supply, and for the system to retain its one hour independent operation capability, this higher pressure must be retained even while the system is operating with the vehicle O_2 supply. The check valve (4) in the fill line prevents the sudden loss of stored gas should the POS shutoff valve be open when the system is connected to the vehicle supply. This disconnect (5) provides a means of connecting a vehicle O_2 supply umbilical. The high pressure regulator (6) reduces the varying

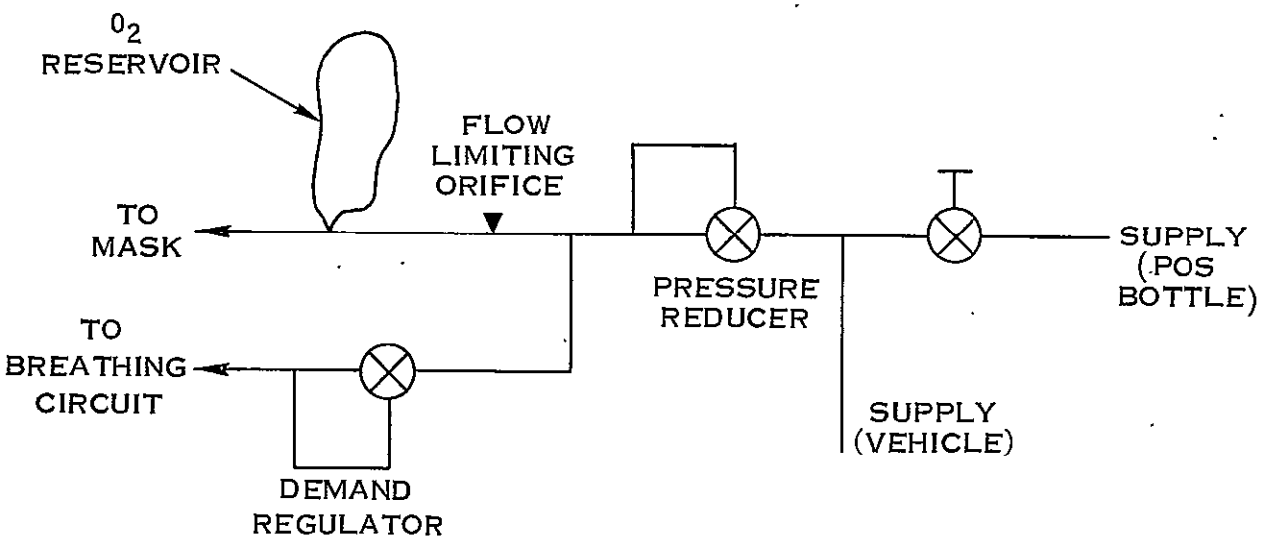


FIGURE 4-3-2 O_2 FLOW CONTROLLER FINAL CONCEPT

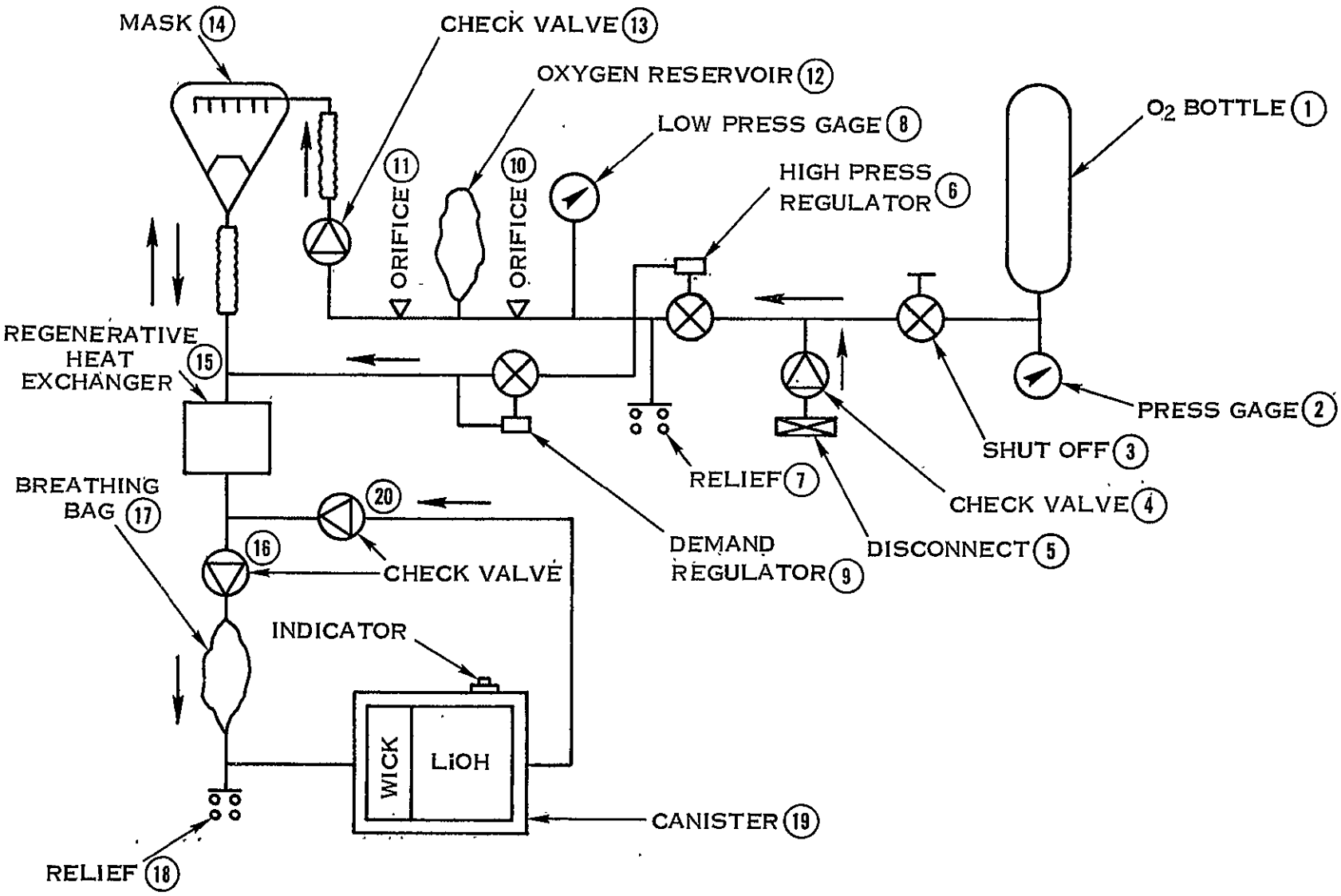


FIGURE 4-3-3 POS FINAL CONFIGURATION

4.3 (Continued)

supply pressure to an essentially constant level for controlling the flow through the orifice. The relief valve (7) prevents overpressurization of the system in the event the high pressure regulator fails open. The low pressure gage (8) provides a status check on the performance of the high pressure regulator. The demand regulator (9) provides additional makeup oxygen in the unlikely event the crewman totally collapses the breathing bag. The first orifice (10) limits the oxygen flow to the system to 0.227 Kg/hr (0.5 lb/hr) while at an ambient of 101 KPa (14.7 psia) and 0.196 Kg/hr (0.42 lb/hr) while at an ambient of 34.5 KPa (5 psia) due to a change in the absolute outlet pressure of the high pressure regulator. The second orifice (11) is used to match the flow from the oxygen reservoir with the flow from the breathing bag. The oxygen reservoir (12) is a small breathing bag used to contain the makeup oxygen flow which occurs during the exhalation phase of the breathing cycle. The check valve (13) prevents exhaled gas from reaching the O_2 reservoir. The total makeup oxygen is introduced at the top of the mask and the dry gas flowing across the visor prevents fogging or condensation in the visor area. The mask (14) is a full face mask which provides protection for the eyes as well as the oral nasal area. The regenerative heat exchanger (15) maintains the mask inlet temperature and dew point at approximately the same levels as exhaled by the crewman, thus preventing exposure to the high gas temperature and dew point which results from the $LiOH/CO_2$ reaction. The check valve (16) upstream of the breathing bag prevents rebreathing of unrevitalized gas while the breathing bag (17) stores most of the exhaled gas for revitalization and reuse on the next inhalation. The relief valve (18) dumps the excess makeup flow and thus purges the system of nitrogen, some water vapor and some of the exhaled CO_2. The LiOH canister/cartridge (19) revitalizes the recirculating gas by removing the CO_2. It contains a wick to retain any moisture which may condense upstream of the cartridge. The canister is sealed at both ends prior to use and is pressurized slightly above ambient. The pressure indicator on the canister provides a visual means of verifying that the LiOH has been protected from exposure to a degrading environment during storage. The check valve (20) at the outlet of the cartridge prevents back flow to the cartridge and thus minimizes the amount of gas which is not revitalized by exposure to the LiOH.

4.4 POS Design Review

The design of the system was initiated by defining the detail requirements for each component and determining those items for which available commercial and/or aerospace items could be utilized and those which required detail design effort.

4.4 (Continued)

Table 4-4-1 lists the POS components and manufacturers. The design review in this report is limited to those items designed by Hamilton Standard since design information for the purchased components is either proprietary or available from the manufacturer's catalogs.

4.4.1 Flow Compensating Orifice

The flow compensating orifice is an adjustable device used to match the flow from the O_2 reservoir and the breathing bag. The orifice is adjusted after the entire unit is assembled and does not require subsequent adjustment. The device, as shown in Figure 4-4-1, consists of a housing and a threaded poppet and is part of a subassembly which contains the low pressure O_2 supply check valve.

4.4.2 Mask Assembly

The mask used for the POS is a Scott Aviation P/N 27234 mask with deflector which has been modified as shown in Figure 4-4-2. The large opening in the visor is sealed with a plate containing two through tubes. The larger diameter tube is connected by hose to the recirculating portion of the system, while the small diameter tube is connected by hose to the oxygen supply portion of the system. The deflector retains the moist recirculating gas in the oral/nasal area minimizing fogging due to a moist gas contact with the visor. The dry makup oxygen is directed by a tube to the top of the visor. The gas enters the facial area through holes in the tube which are oriented such that the incoming gas sweeps across the visor removing any trace of fogging which may exist.

4.4.3 Regenerative Heat Exchanger

The regenerative heat exchanger assembly (Figure 4-4-3) consists of a lower housing assembly, the body and bed and an upper cover. The lower housing assembly contains the inhalation and exhalation check valves and an actuation lever for the cartridge canister assembly. The body which contains the packed bed is made of teflon to minimize axial heat transfer. The bed consists of small diameter aluminum shot retained at both ends by an aluminum screen. The upper cover contains the duct which connects to the large diameter hose from the mask.

4.4.4 Canister/Cartridge Assembly

The canister/cartridge assembly, Figure 4-4-4, consists of an outer shell with a pressure indicator, a LiOH cartridge, a cover/wick assembly, and an inlet and an outlet poppet.

TABLE 4-4-1
POS COMPONENTS LIST

Name	Manufacturer	Manufacturer's Part Number
O_2 Bottle	Hoke	4HSM95
Bottle Pressure Gage	Kratos	G-6327-4000
Interstage Pressure Gage	Kratos	G-6418-100
O_2 Shutoff Valve	Carleton Controls	1970 090-M2-0014
Pressure Reducer	Carleton Controls	2192-003-3
Demand Regulator	Carleton Controls	1601002-11
Exhalation Relief Valve	Carleton Controls	1800001-1
High Pressure Check Valve	Circle Seal	C220A-1Q
High Pressure Relief Valve	Circle Seal	D524A-6D-75
Breathing Bag	Ohio Medical	211-2808-800
O_2 Reservoir	Ohio Medical	307-5041-800
O_2 Check Valve	Ohio Medical	211-1450-300
Inhalation and Exhalation Check Valve	Sierra Eng.	Ring 798-05 Flapper 798-06
Fill Fitting (GFE)	Snap Tite	4599-220
Flow Limiting Orifice	Lee	JeTA 1872460
Flow Compensating Orifice	Hamilton Standard	SVSK 90391-101 SVSK 90391-105
Mask Assembly	Hamilton Standard	SVSK 90486
Regenerative Hx	Hamilton Standard	SVSK 90395
Canister Cartridge Assembly	Hamilton Standard	SVSK 90387

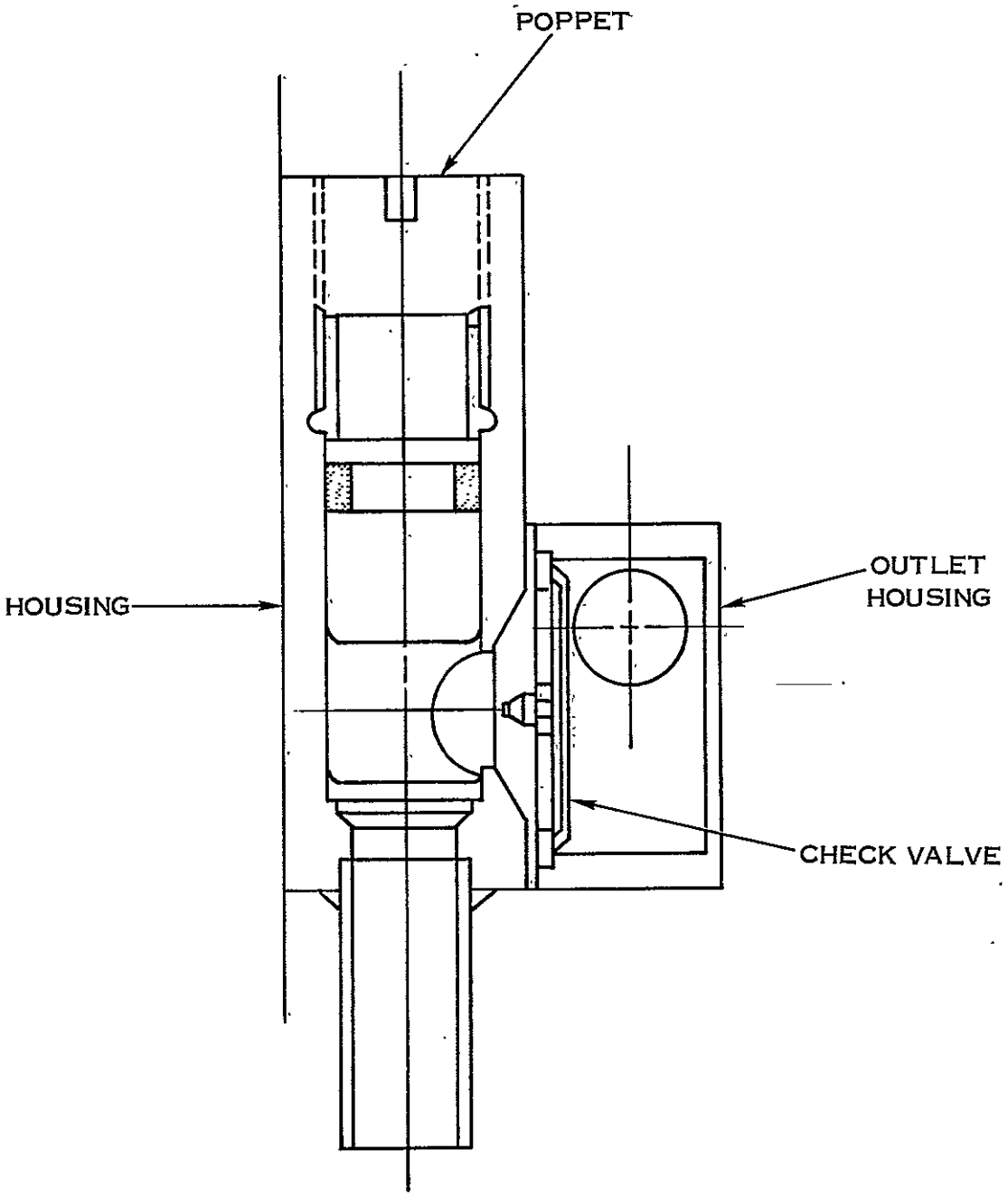


FIGURE 4-4-1 ADJUSTABLE ORIFICE ASSEMBLY

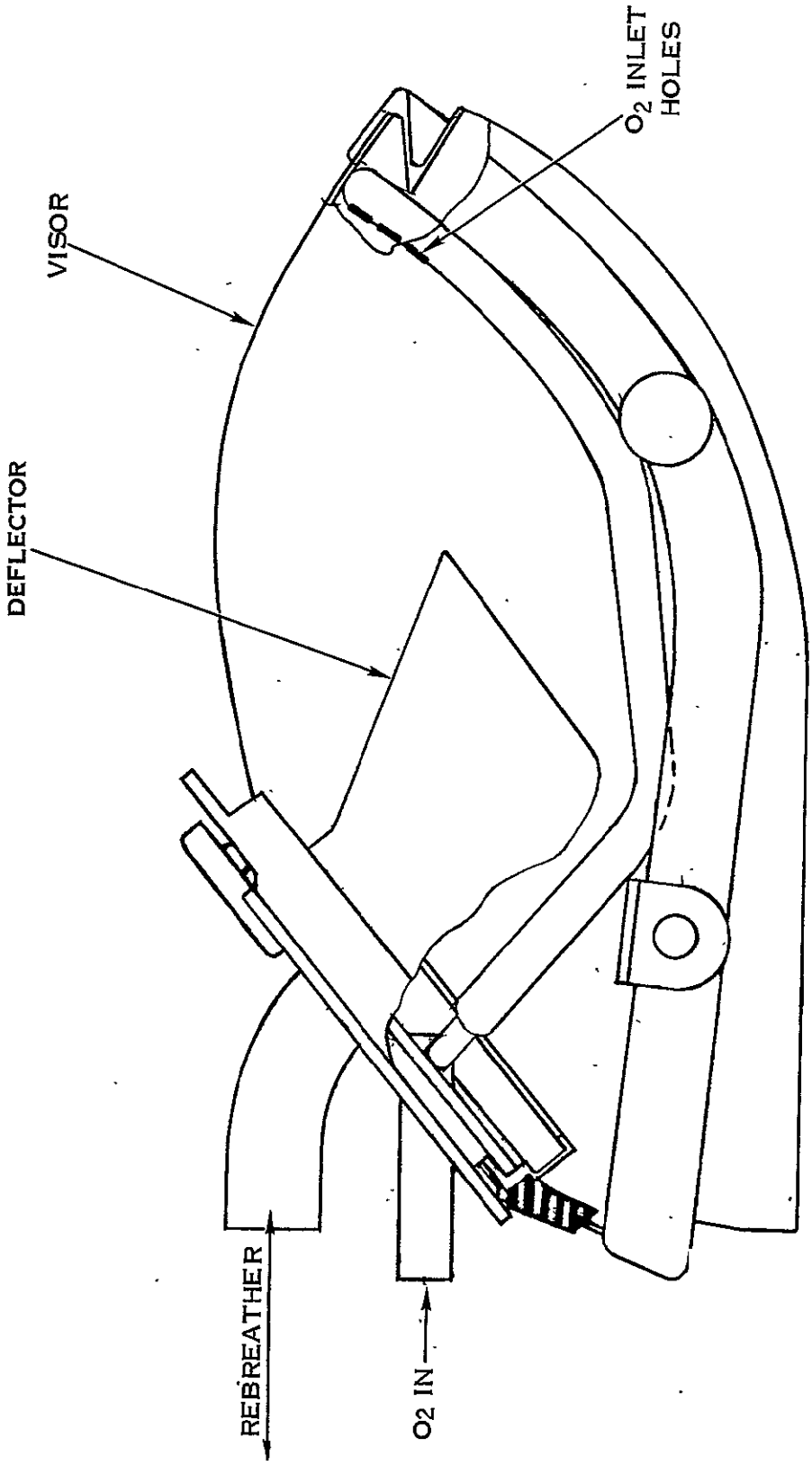


FIGURE 4-4-2 MASK ASSEMBLY

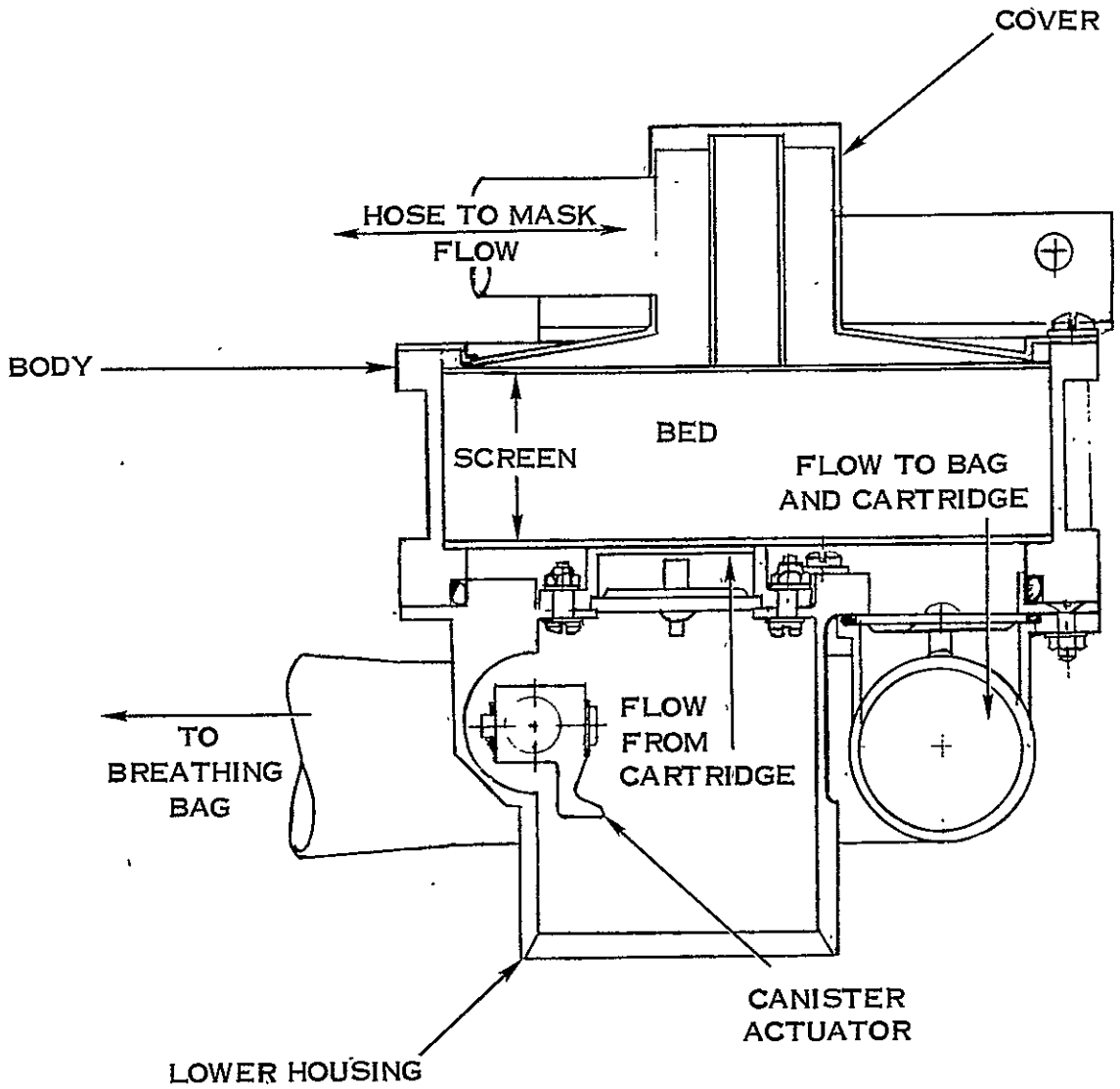


FIGURE 4-4-3 REGENERATIVE HEAT EXCHANGER

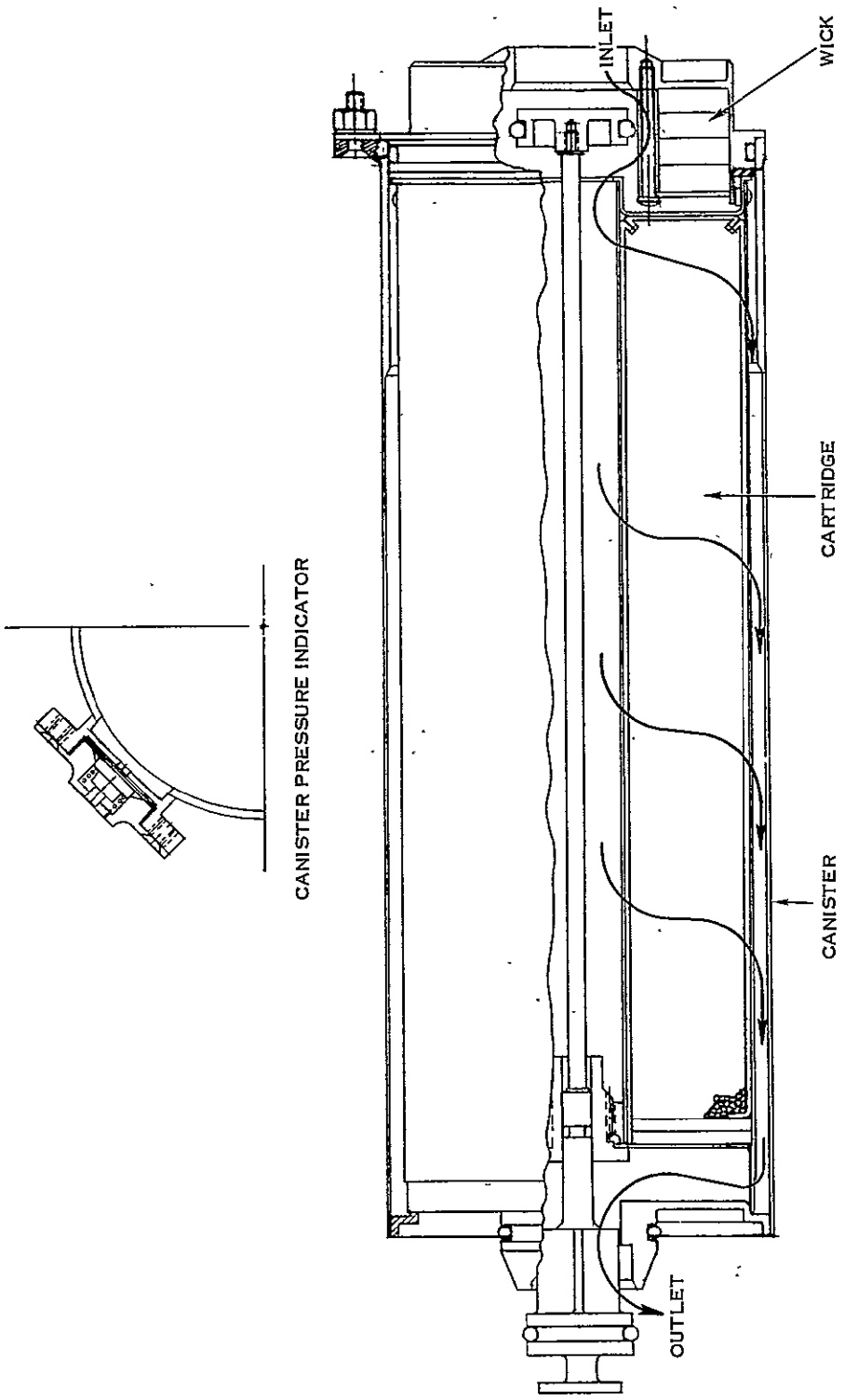


FIGURE 4-4-4 CARTRIDGE/CANISTER ASSEMBLY

4.4.4 (Continued)

The outer shell of the canister is constructed of aluminum coated with black anodize to maximize radiative cooling. The pressure indicator which consists of a cover, spring, poppet, and rubber disc is located on the side of the canister. When the pressure inside the canister exceeds 3.4 KPa (0.5 psi), the side of the indicator pin is visible. When the cartridge is installed in the canister, the assembly is charged to 13.8 KPa (2 psi) with oxygen. The indicator pin provides a visual means of verifying that the pressure in the canister is in excess of 3.4 KPa (0.5 psi) and thus assuring that the LiOH has not been exposed to degrading environments such as water vapor or CO_2.

The LiOH cartridge consists of an aluminum shell with the inner and outer cylinders made of perforated stock, a filter bag assembly made of teflon and nomex nylon felt and a 0.5 Kg (1.1 lb) charge of MIL-L-20213 LiOH. Gas flow enters at the inside tube, flows radially through the LiOH, and exits through the filter and outer tube.

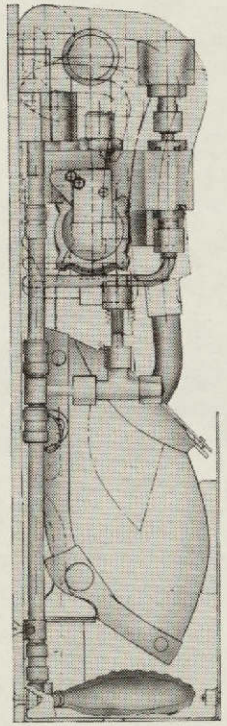
The bottom cover of the canister contains a dacron wick which traps any water which may condense and be carried to the canister/cartridge assembly. The inlet and outlet poppet seal the canister and retain the pressure during storage. These poppets are connected by a rod and are opened when engaged with the activation lever located in the regenerative heat exchanger.

4.4.5 Packaging

The basic structure for the POS is a mounting panel assembly made of sheet fiberglass and aluminum angles.

Figure 4-4-5 shows the mounting panel and shows where the various subassemblies are mounted. The controls and pressure gages are located on the top of the unit, while the canister pressure indicator is visible from the side of the POS.

As shown in Figure 4-4-6, all components are protected by an aluminum cover which contains a large door to permit easy access to the stowed mask. The basic cover is blue anodized, and the perforated plate in the canister area is painted black to maximize radiative cooling of the cover. The interior of the cover in the area of the canister is coated with gold to minimize the amount of heat absorbed by the cover. The assembly is provided with adjustable harnesses. The upper harness passes behind the crewman's neck while the lower harness passes around the crewman's waist to secure the system in front of the crewman.



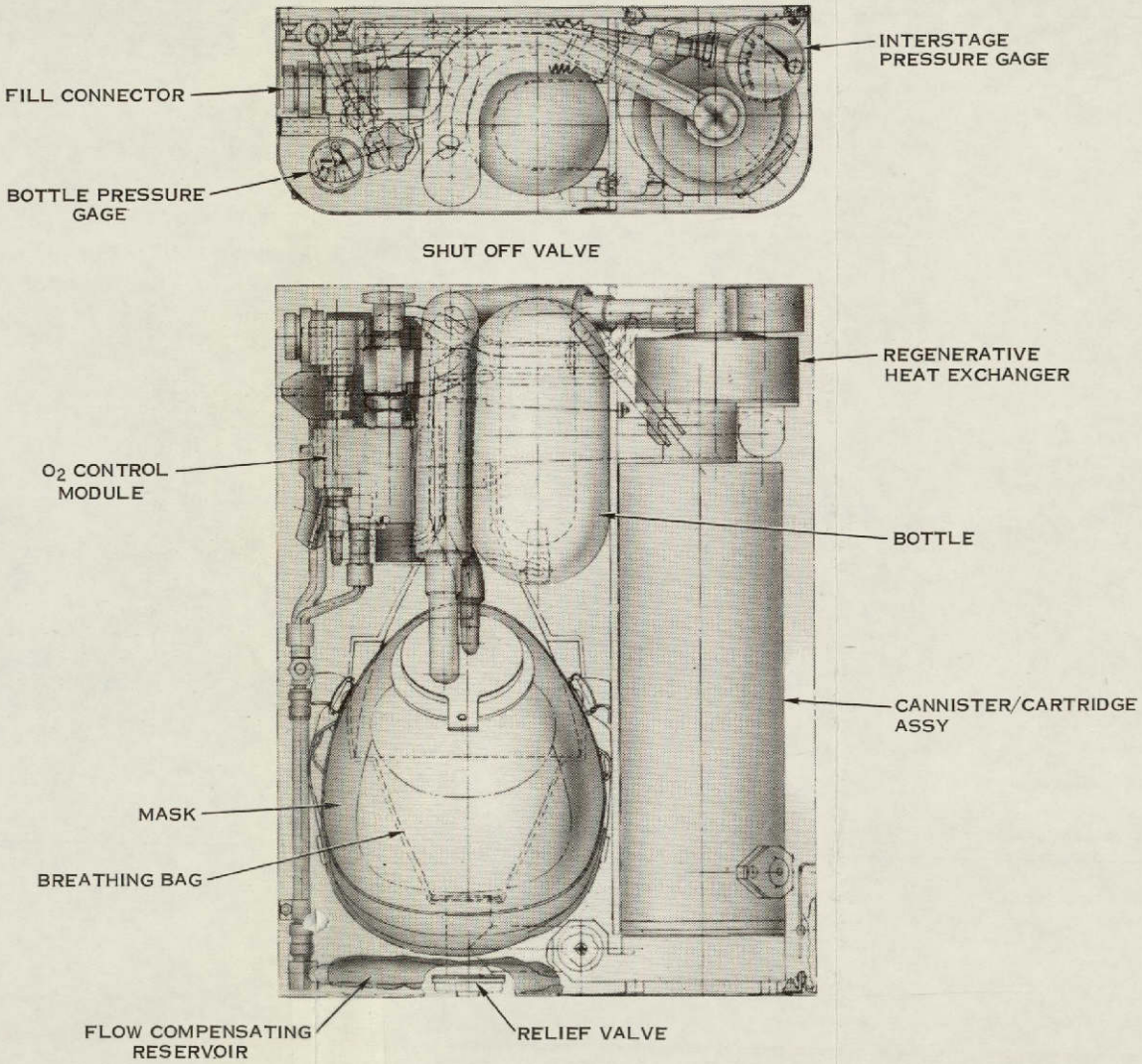


FIGURE 4-4-5 PORTABLE OXYGEN SUBSYSTEM (POS)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

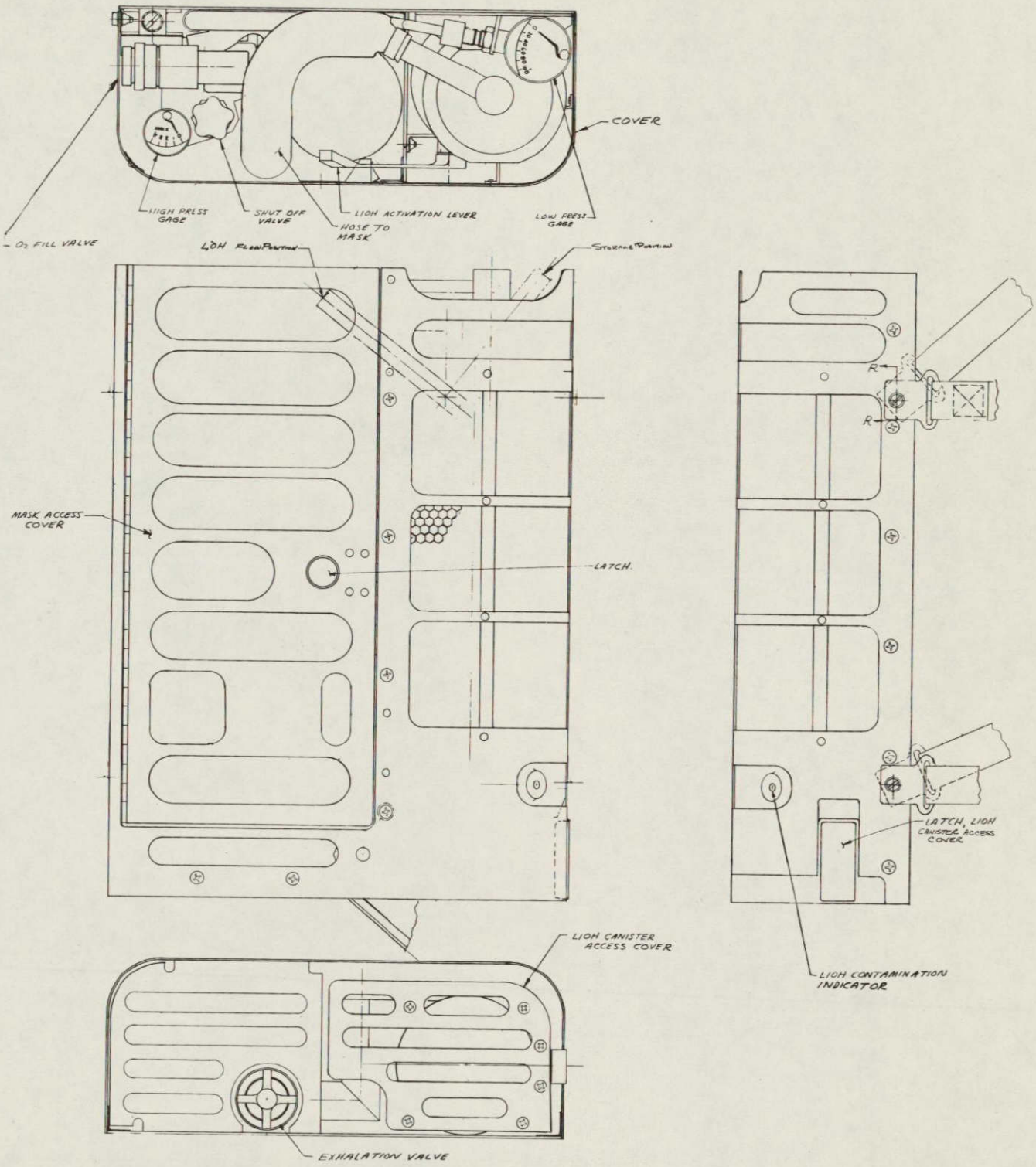


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FIGURE 4-4-6 POS COVER ON

4.4.5 (Continued)

The packaging effort also included the identification of limited life items and preparation of a Limited Life List. The list, SVHS 7016, is included in Appendix D.

4.5 Fabrication and Acceptance Test

The various purchased and in-house designed components and packaging hardware were assembled in accordance with drawing SVSK 90390. All operations were completed in work stations compatible with the cleanliness requirements of the system in accordance with step by step assembly procedures with inspection verification as required. During the assembly of the unit, some minor reworking was required to eliminate interferences and to improve the operation of the hardware. All drawings were updated to reflect the final hardware configuration.

The completed unit, less cover and pressure gages, is shown in Figure 4-5-1, while the unit with the cover installed is shown in Figure 4-5-2. The pressure gages were not included in the initial assembly as they were long lead items and were not available by the time the remainder of the unit was assembled. It was mutually agreed that the unmanned and manned testing could be completed without the gages provided the gages were installed prior to shipment. The completed assembly was subjected to the acceptance test procedures defined by PDA 7015 to demonstrate compliance with the Acceptance Test Plan Specification SVHS 7015, both of which are included in Appendix E. The detail test results are included in the acceptance data package shipped with the hardware.

The initial acceptance testing consisted of the following tests:

- Supply Circuit Proof Pressure
- Breathing Circuit Proof Pressure
- Pressure Reducer Performance
- Orifice Performance
- Demand Regulator Performance
- High Pressure Check Valve Performance
- Exhalation Relief Valve Performance
- Exhalation/Inhalation Resistance
- Exhalation/Inhalation Check Valve Performance
- High Pressure Supply External Leakage
- Breathing Circuit External Leakage
- Cartridge/Canister Performance

Subsequent to receipt and installation of the pressure gages, the unit was subjected to the supply circuit proof pressure, gage performance, and the high pressure supply external leakage tests.

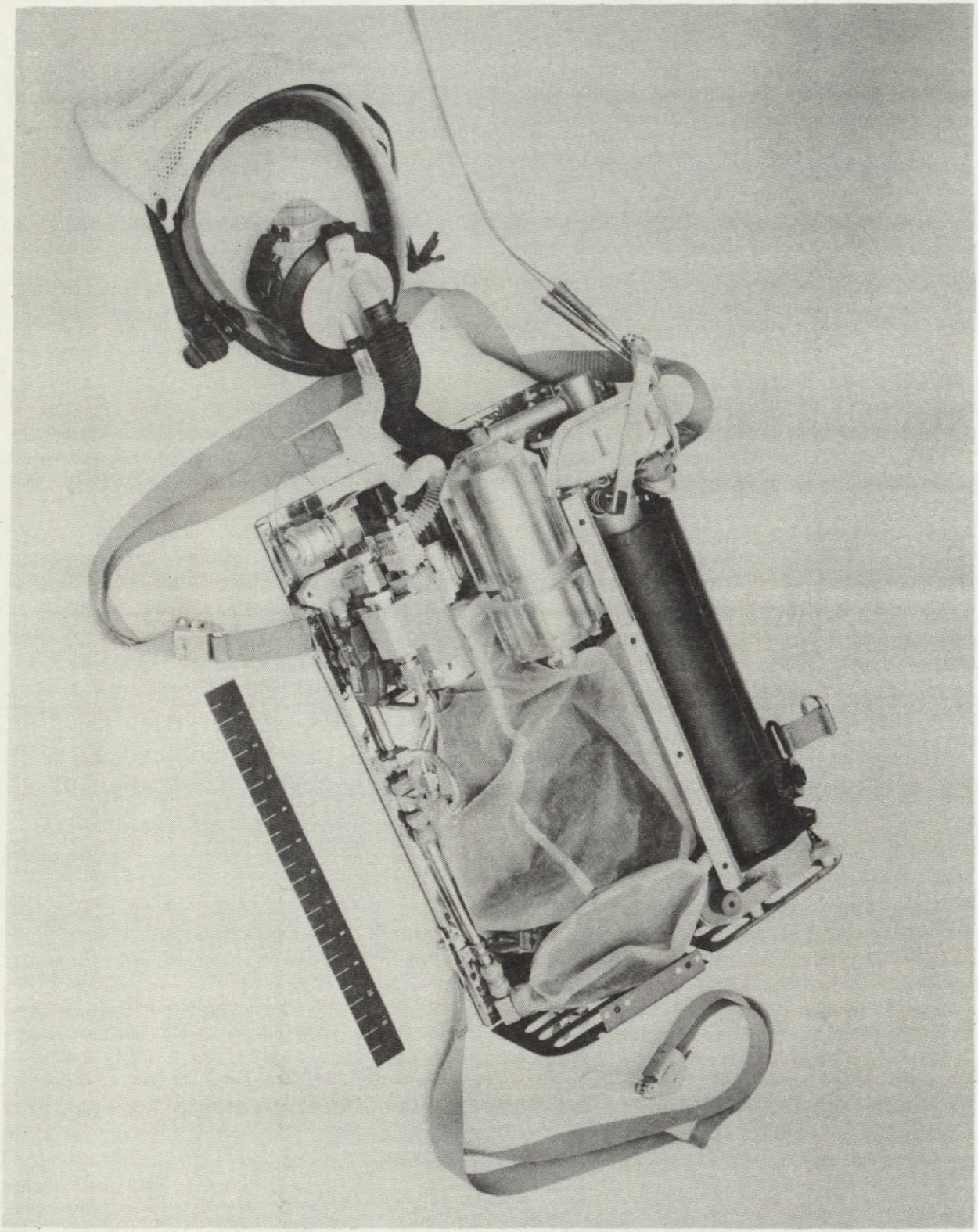


FIGURE 4-5-1 POS COVER OFF

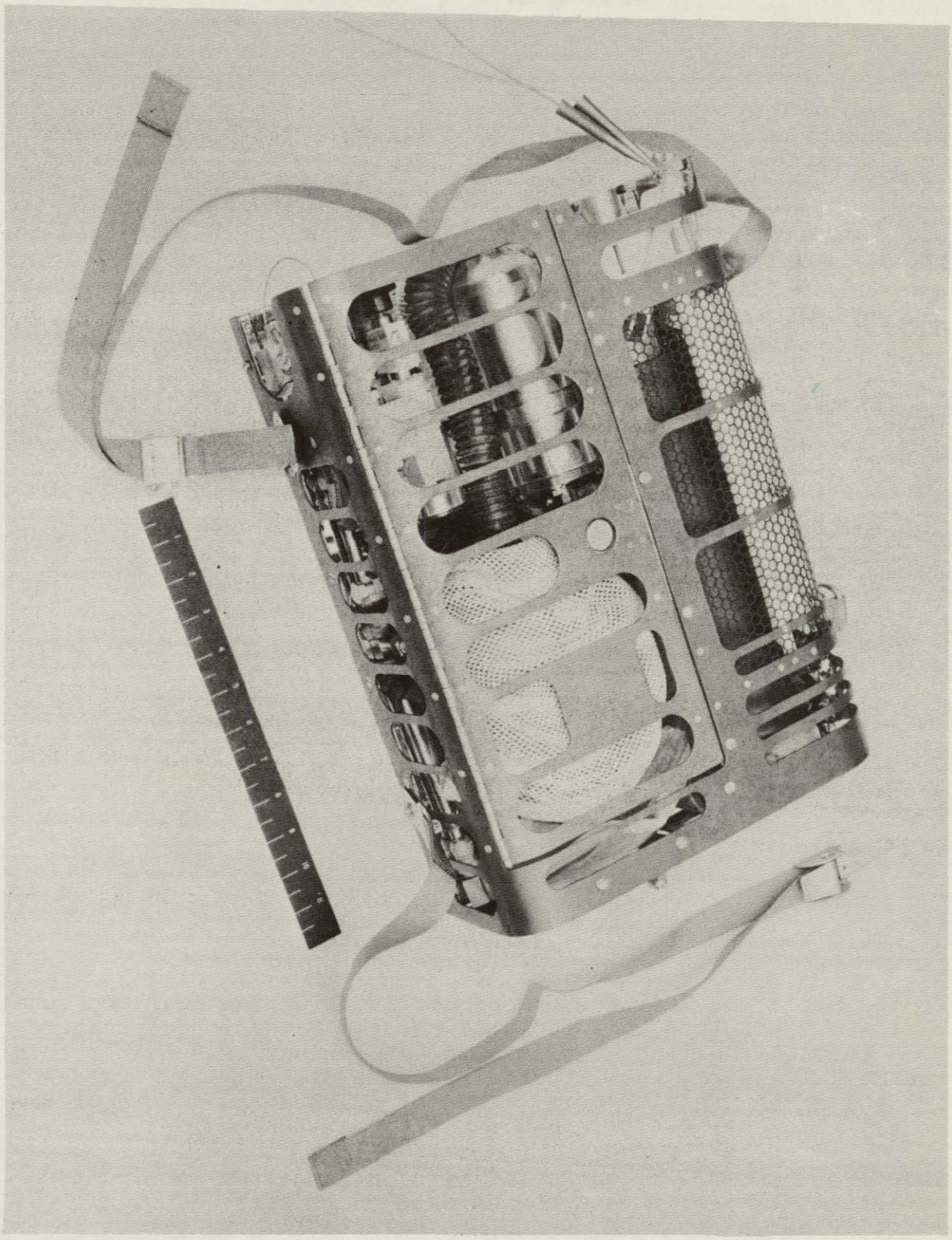


FIGURE 4-5-2 POS WITH MASK STOWED

4.5 (Continued)

During the breathing circuit proof pressure tests, some leaks were detected in various weld joints. These leaks were eliminated by coating the welds with epoxy (EA934).

The demand regulator required a deeper vacuum than specified to provide the required flow as shown in Figure 4-5-3.

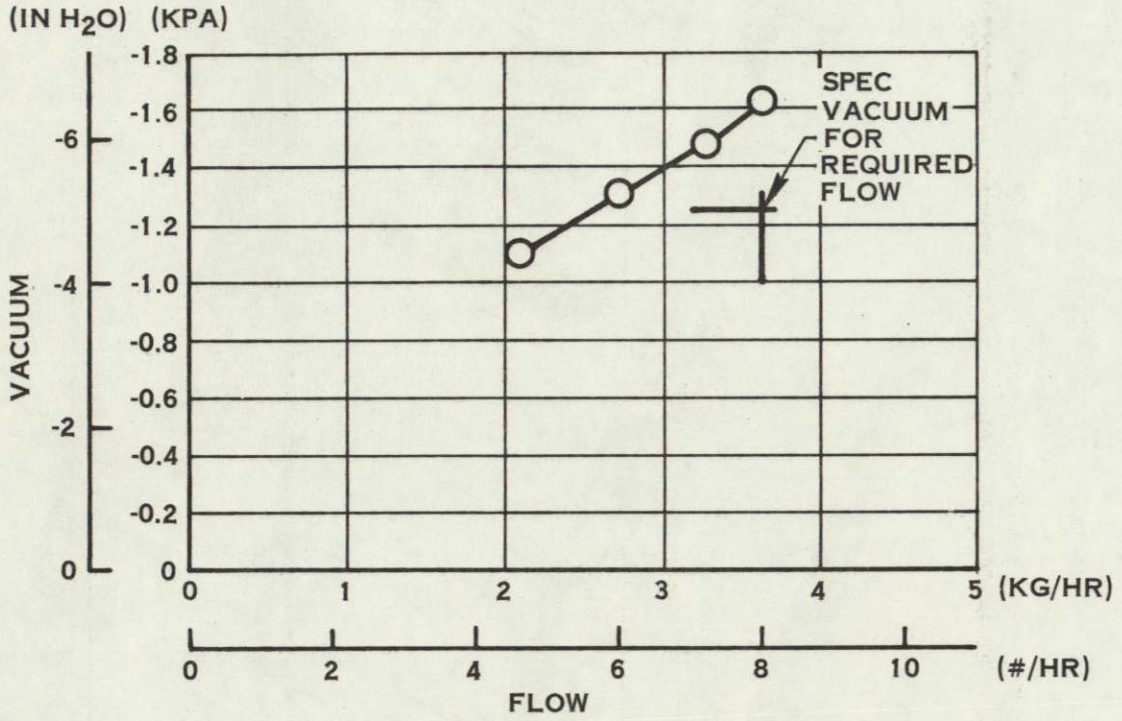


Figure 4-5-3
Demand Regulator Performance

In the prototype POS, the demand regulator outlet port and sensing port are manifolded to a common line. As a result of pressure drop through the line, the sensing port pressure is higher than the mask pressure, thus to obtain a pressure of -1.12 KPa (-4.5 in H_2O) at the sensing port, the mask pressure must be approximately -1.62 KPa (-6.5 in H_2O).

This problem could be corrected by separating the sensing and outlet lines to eliminate the effects of pressure drop. It was mutually agreed that no change was required in the prototype unit since the demand function could be demonstrated.

4.5 (Continued)

The check valve located between the LiOH cartridge and the regenerative heat exchanger was found to be leaking at a rate of 461 cc/min versus a requirement of 25 cc/min. Examination of the valve upon removal from the system revealed that the rubber flapper was distorted which prevented it from sealing. This distortion resulted from the flapper being packaged in an evacuated plastic bag when shipped from the manufacturer. The manufacturer was notified and will revise packaging procedures to preclude recurrence of this problem. The distortion of the flapper was eliminated by thermal soaking of the valve for two hours at a temperature of 177°C (350°F). The valve was reinstalled in the system, and the leakage test was completed with the leakage being only 11 cc/min.

In the high pressure leakage test, the check valve in the supply line leaked at a rate of 2.5 scc/min versus a limit of 2 scc/hr, and various fittings in the high pressure system were found to be leaking. It was agreed that the performance of the check valve was acceptable and that the requirement was too stringent. After retorquing of the leaking fittings, all high pressure leaks were eliminated except for two "MS" type flareless fittings located upstream of the shutoff valve. These fittings were replaced when the gages were installed and were found to be leak tight during subsequent testing.

4.6 Unmanned and Manned Performance Testing

Upon completion of acceptance testing (less pressure gages), the unit was subjected to the unmanned tests defined by Test Procedure POS-P-1 and to the manned tests defined by Test Procedure POS P-2. These test procedures are included in Appendix F.

4.6.1 Unmmaned Test

The unmanned performance tests consisted of one run which simulated IV operation, and one run which simulated rescue operation. The test setup utilized is shown in Figure 4-6-1. The instrumentation includes dew pointers, CO_2, O_2, and N_2 gas analyzers, a temperature recorder, pressure gages, and water manometers set up in accordance with Test Procedure POS-P-1. The POS mask was mounted on a styrofoam wig "head" which was in turn connected to the breathing machine shown in Figure 4-6-2. The breathing machine consists of a bellows, a small plenum, and a variable speed motor. The linkage connecting the motor to the bellows is adjustable so the stroke can be varied. During the test, the speed and stroke were adjusted in accordance with the test procedure to simulate the various work rates. Metabolic CO_2 was added to the

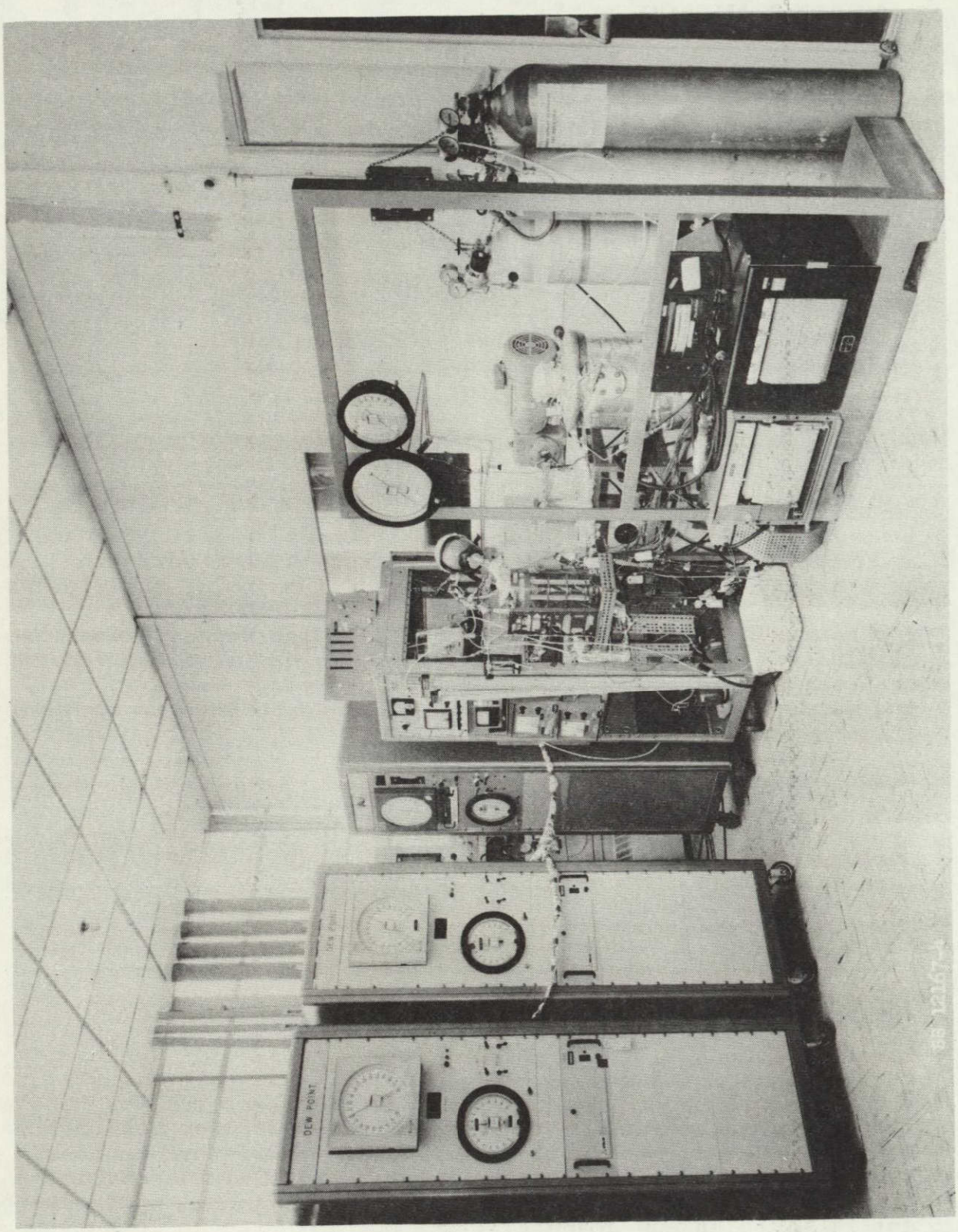


FIGURE 4-6-1 POS AND UNMANNED TEST SET-UP

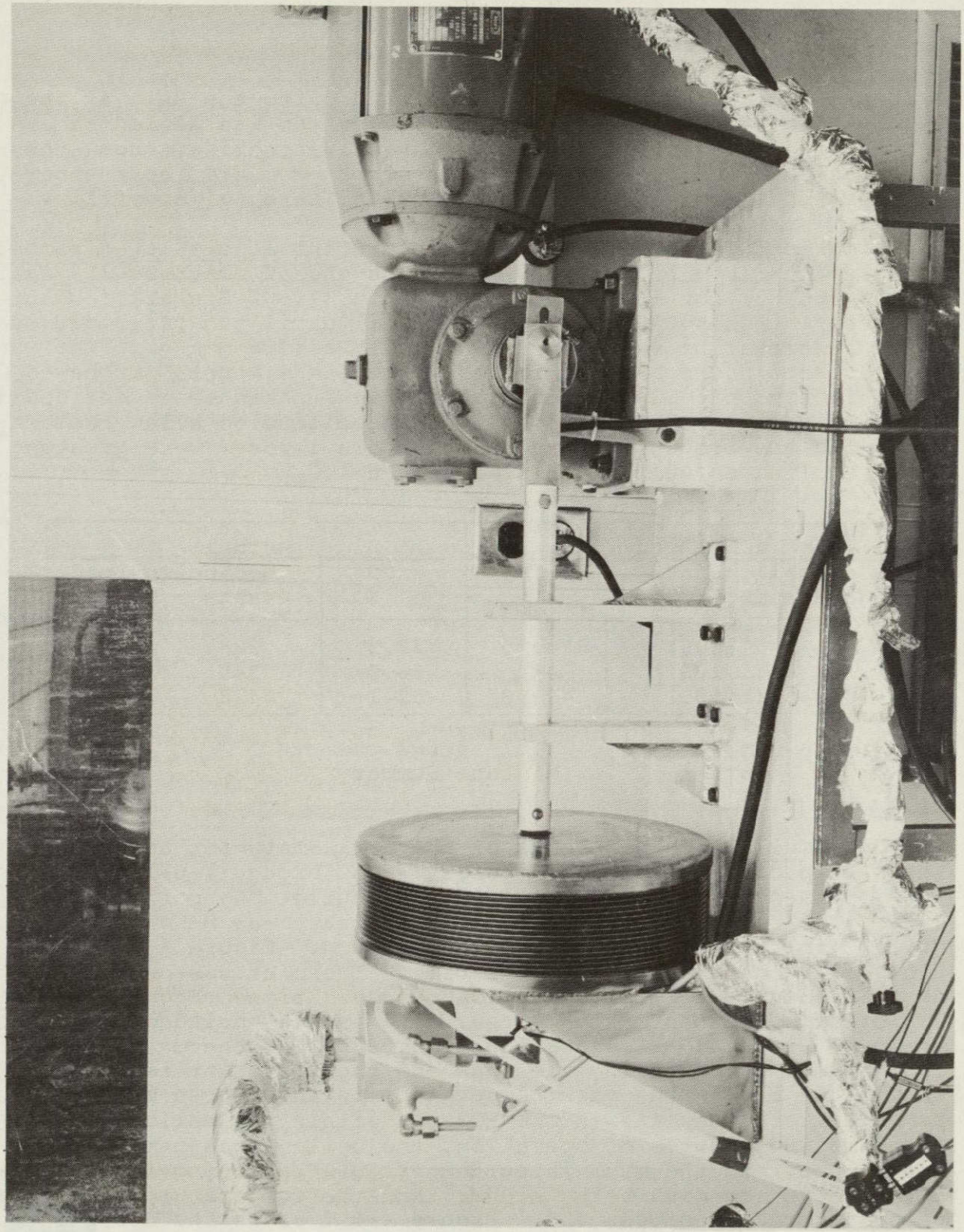


FIGURE 4-6-2 BREATHING MACHINE

4.6.1 (Continued)

system by supplying a mixture of CO_2 and O_2 to the unit at the O_2 supply line. The canister area of the system was sealed in a wrap of clear plastic to prevent convective cooling, thus, the temperatures recorded during this test program are representative of those that would be experienced during zero 'g' operations.

The simulated IV test consisted of operating at simulated rates of 235 watts (800 Btu/hr) for two hours and 42 minutes, 323 watts (1,100 Btu/hr) for 15 minutes, 440 watts (1,500 Btu/hr) for three minutes, and then 235 watts (800 Btu/hr) until the cartridge outlet CO_2 partial pressure exceeded 1.01 KPa (7.6 mm Hg). The run lasted three hours and 30 minutes. The gas mixtures purchased for this test had CO_2 concentations greater than those defined in the test procedure and were delivered too late to allow replacement with the proper mixture so the loads imposed were greater than required as summaried in Table 4-6-1.

Desired			Actual	
Metabolic Load Watts	(Btu/Hr)	% CO_2	% CO_2	Metabolic Load Watts (Btu/Hr)
235	(800)	24.35	27.5	265 (903)
323	(1,100)	34	36.5	345 (1,177)
440	(1,500)	47.93	52.1	478 (1,630)

Table 4-6-1
Gas Mixture Summary

The unit met all requirements of the Work Statement as shown in the data plots included in Figures 4-6-3 through 4-6-11. Figure 4-6-3 is a plot of cartridge inlet and outlet CO_2 partial pressure. The cartridge outlet partial pressure was below the required limits for the required three hours. Figure 4-6-4 is a plot of N_2 concentration versus time. The plot has been corrected to account for instrumentation response time. Figure 4-6-5 is a plot of O_2 concentration versus time and is included for information. Figure 4-6-6 shows the temperature of the O_2 and breathing circuit gas entering the mask and the resultant temperature within the mask. The mask temperature is influenced by both the temperature of the gas in the POS and within the bellows. During the first 80 minutes of operation, the bellows gas temperature was higher than the mask inlet temperature resulting in the temperature in the mask being higher than the temperature of the gas being returned from the POS. Figure 4-6-7 shows the dew point of

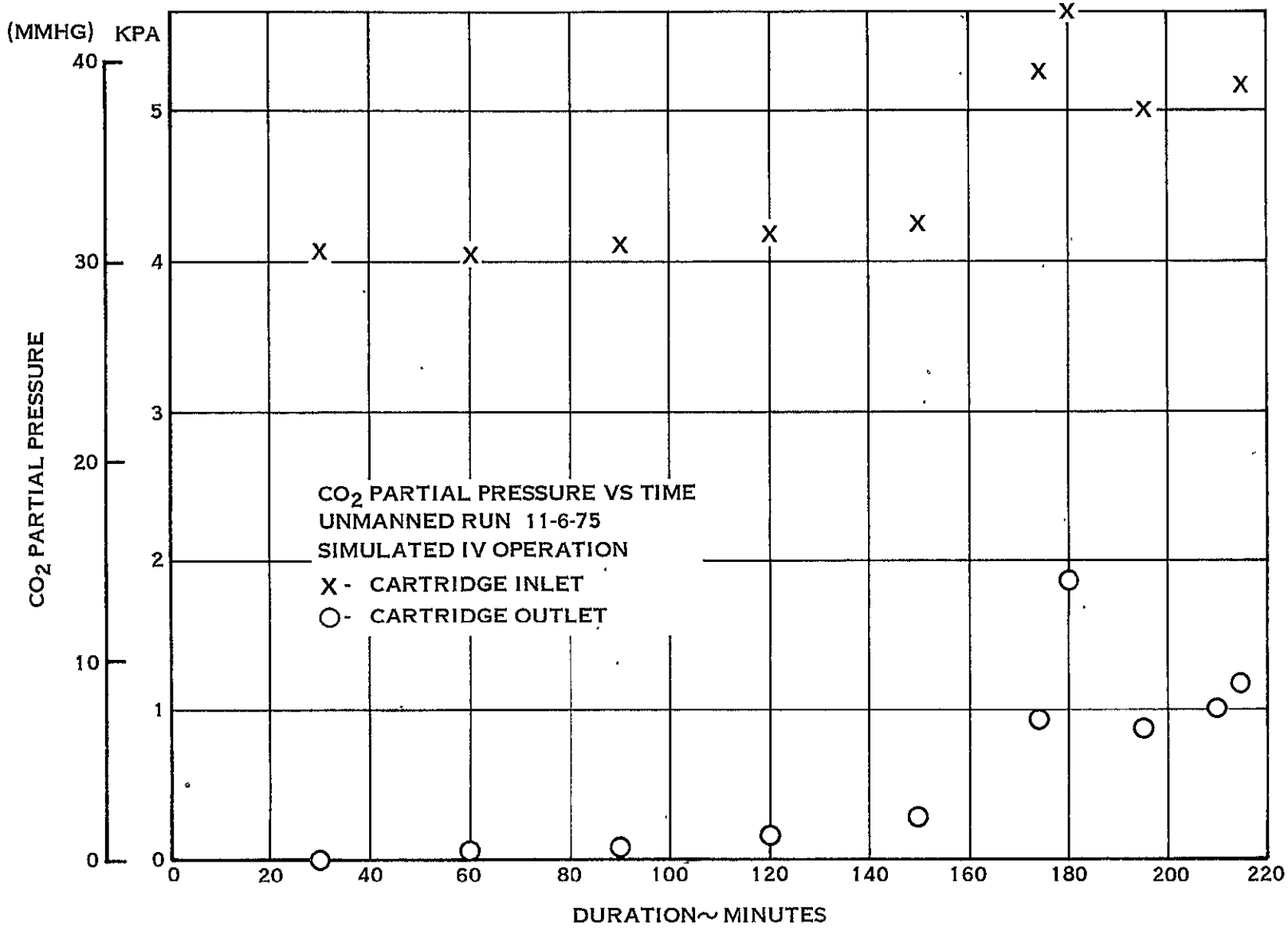


FIGURE 4-6-3 CARTRIDGE INLET AND OUTLET CO_2 PARTIAL PRESSURE

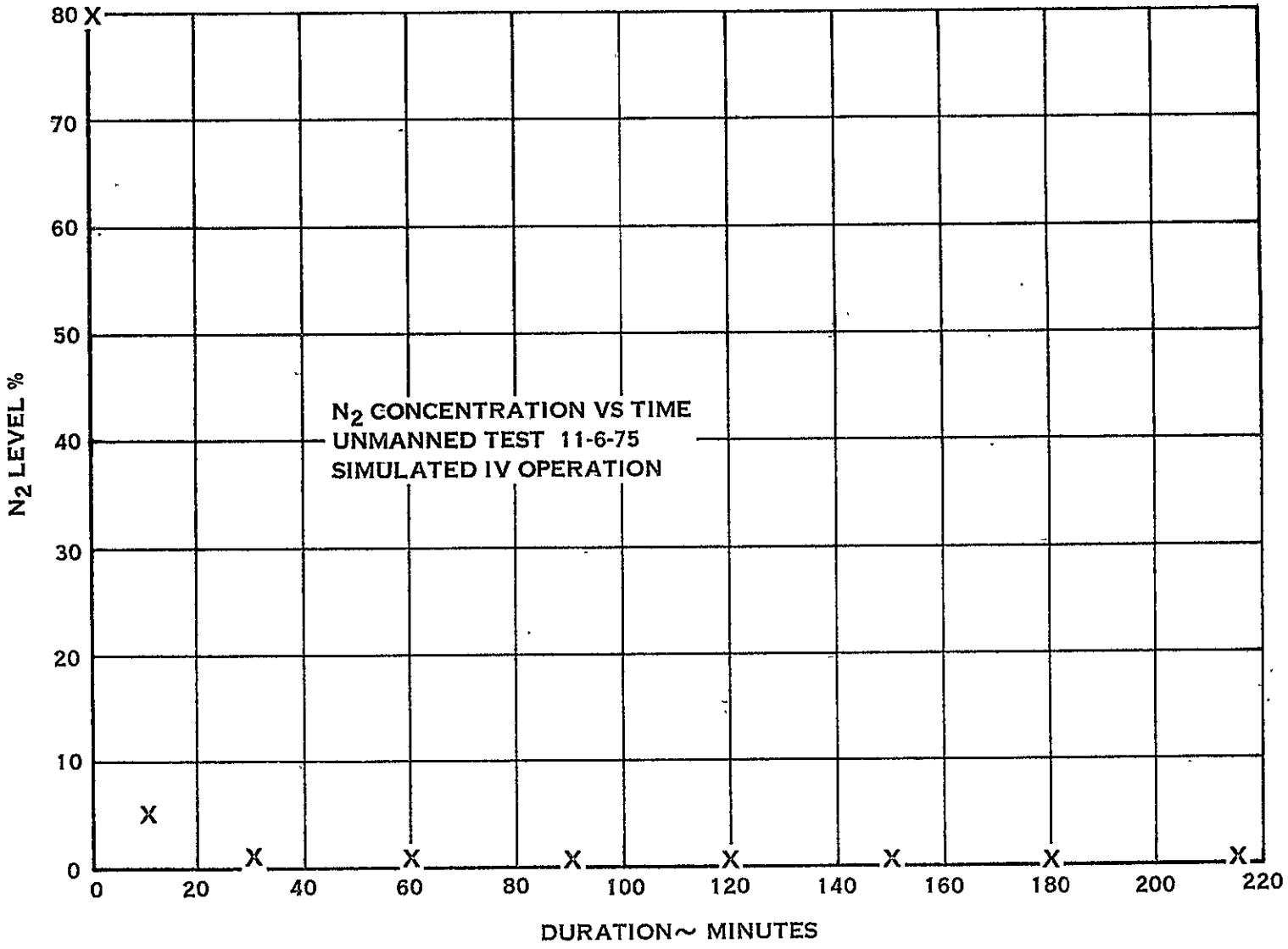


FIGURE 4-6-4 N_2 CONCENTRATION VS TIME

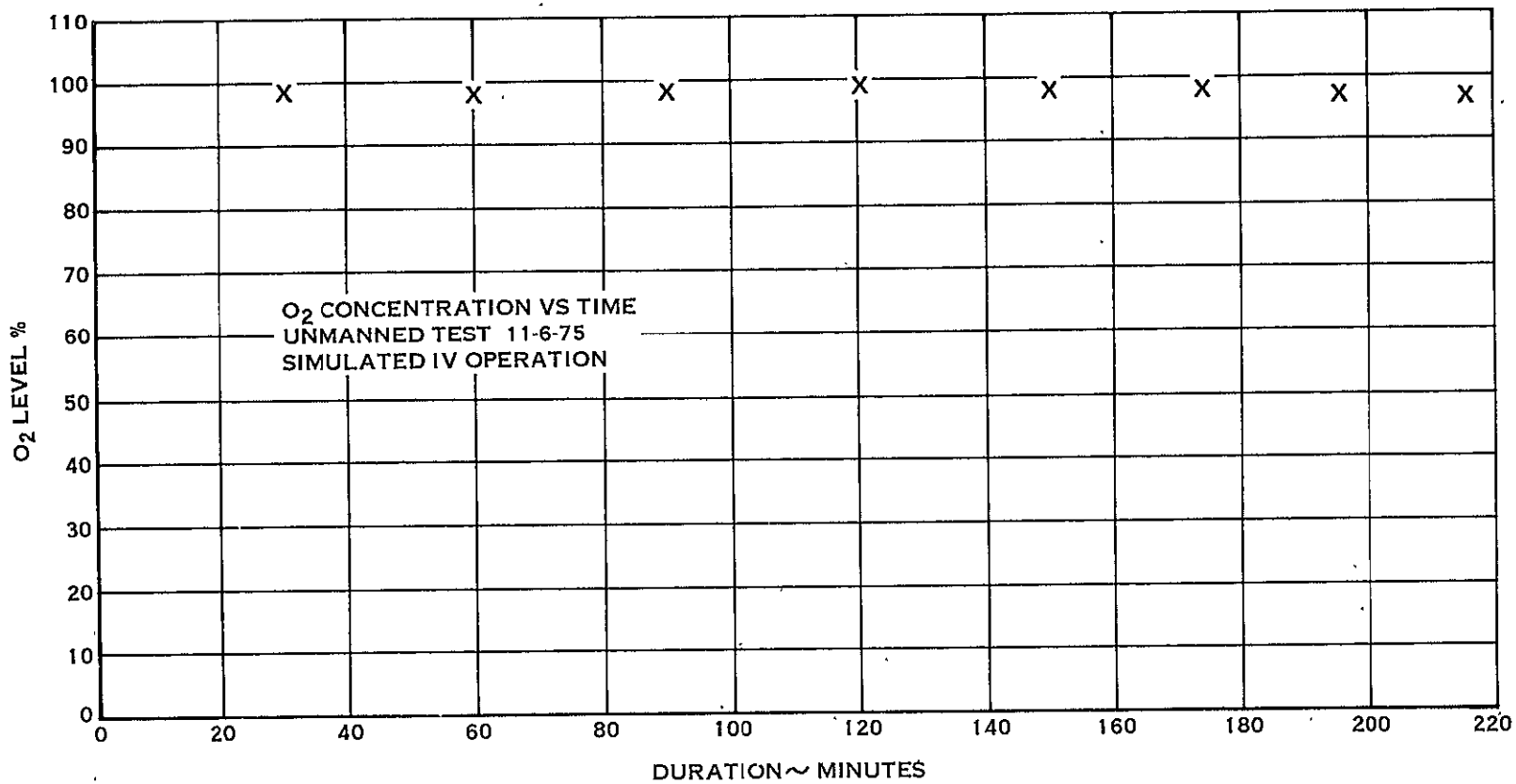


FIGURE 4-6-5 O_2 CONCENTRATION VS TIME

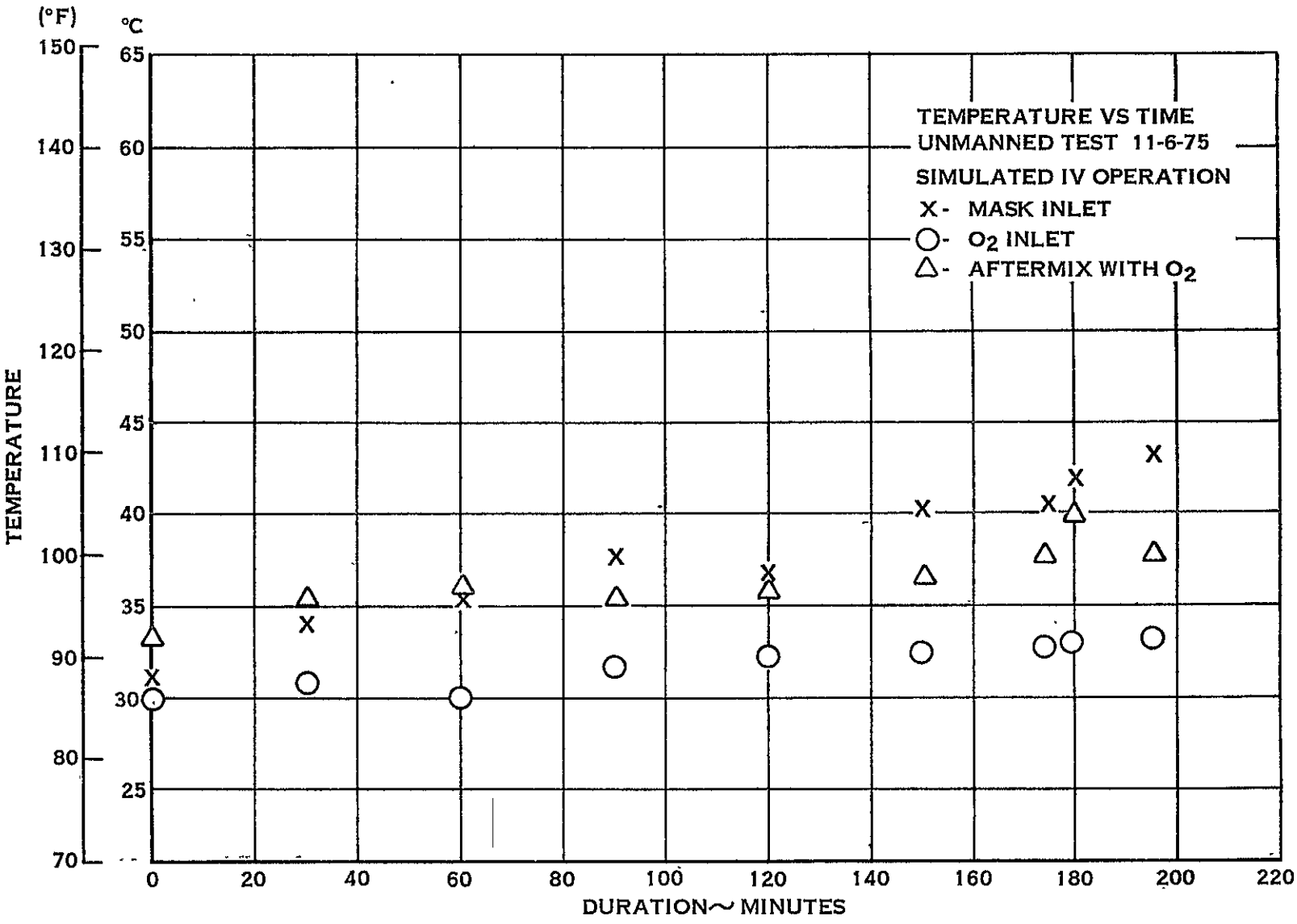


FIGURE 4-6-6 TEMPERATURE VS TIME UNMANNED TEST

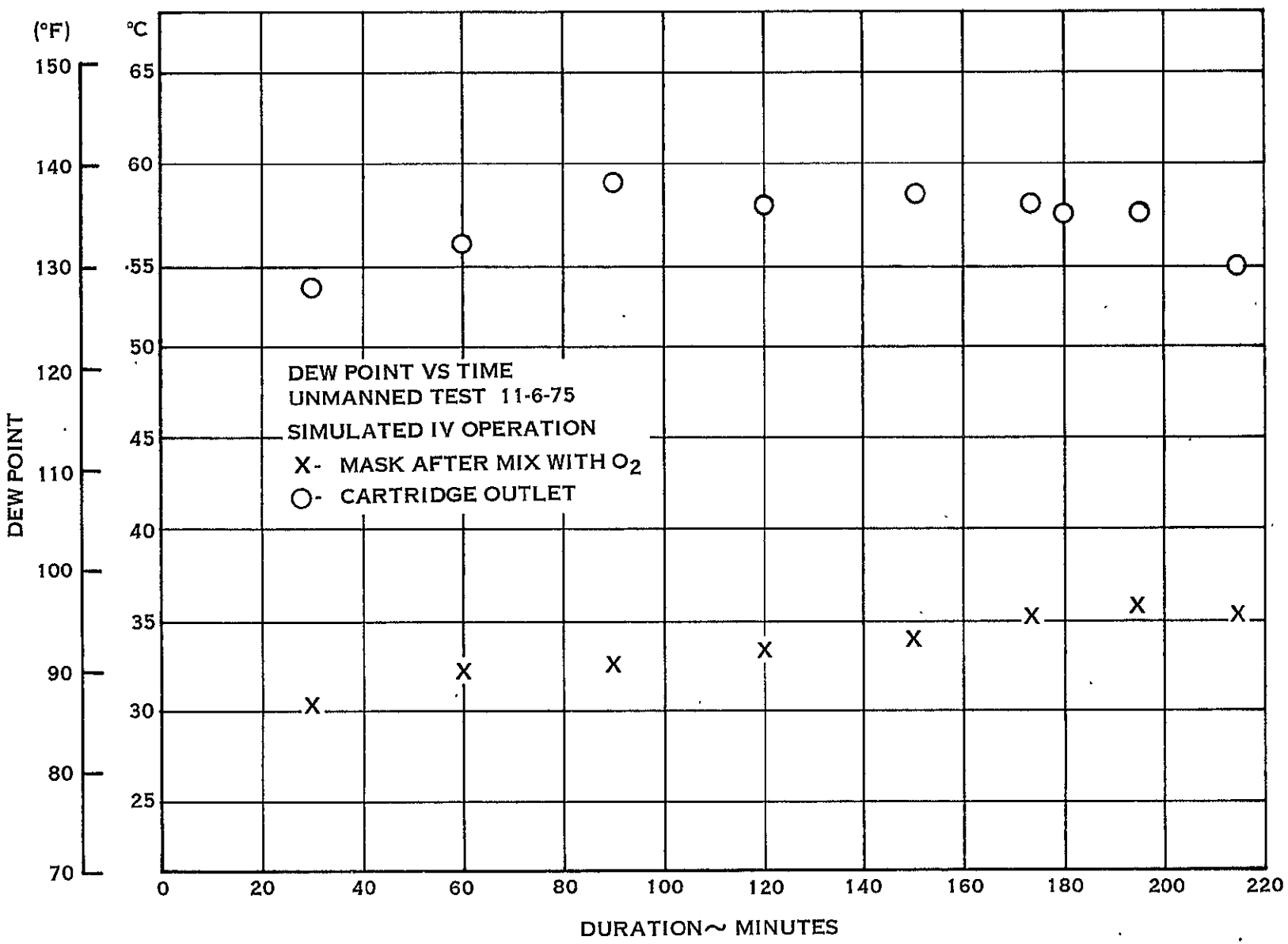


FIGURE 4-6-7 DEW POINT VS TIME

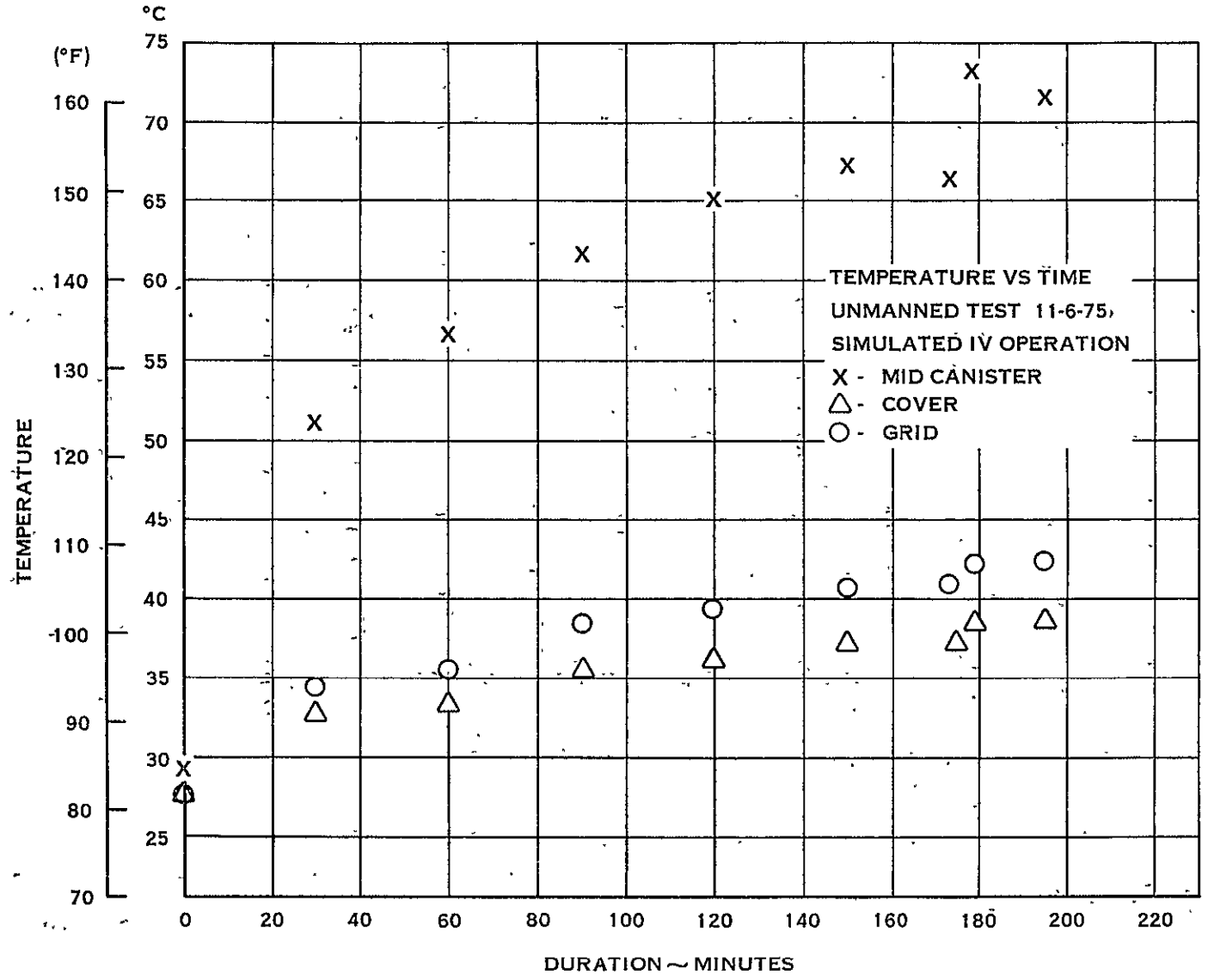


FIGURE 4-6-8 TEMPERATURE VS TIME

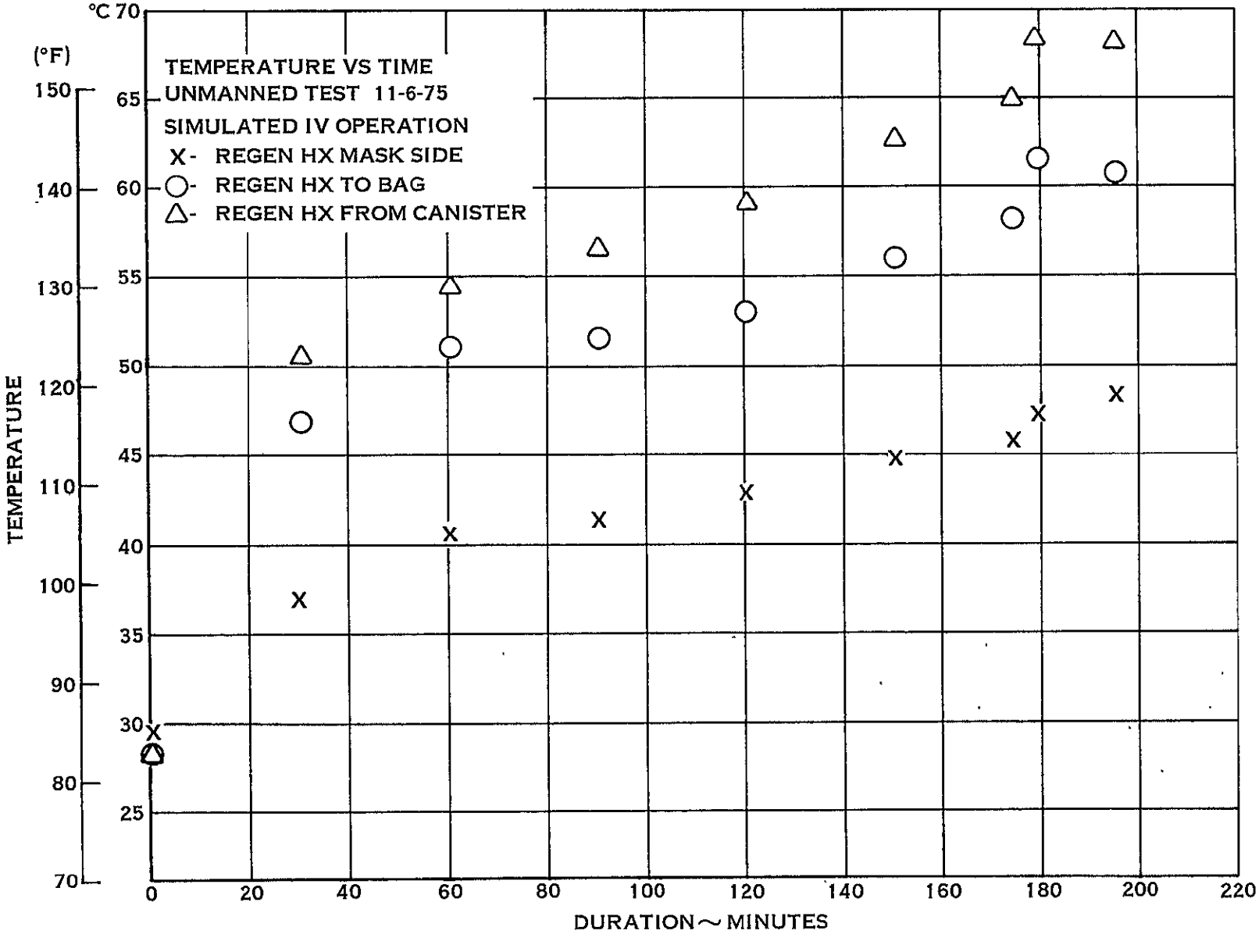


FIGURE 4-6-9 TEMPERATURE AT VARIOUS LOCATIONS

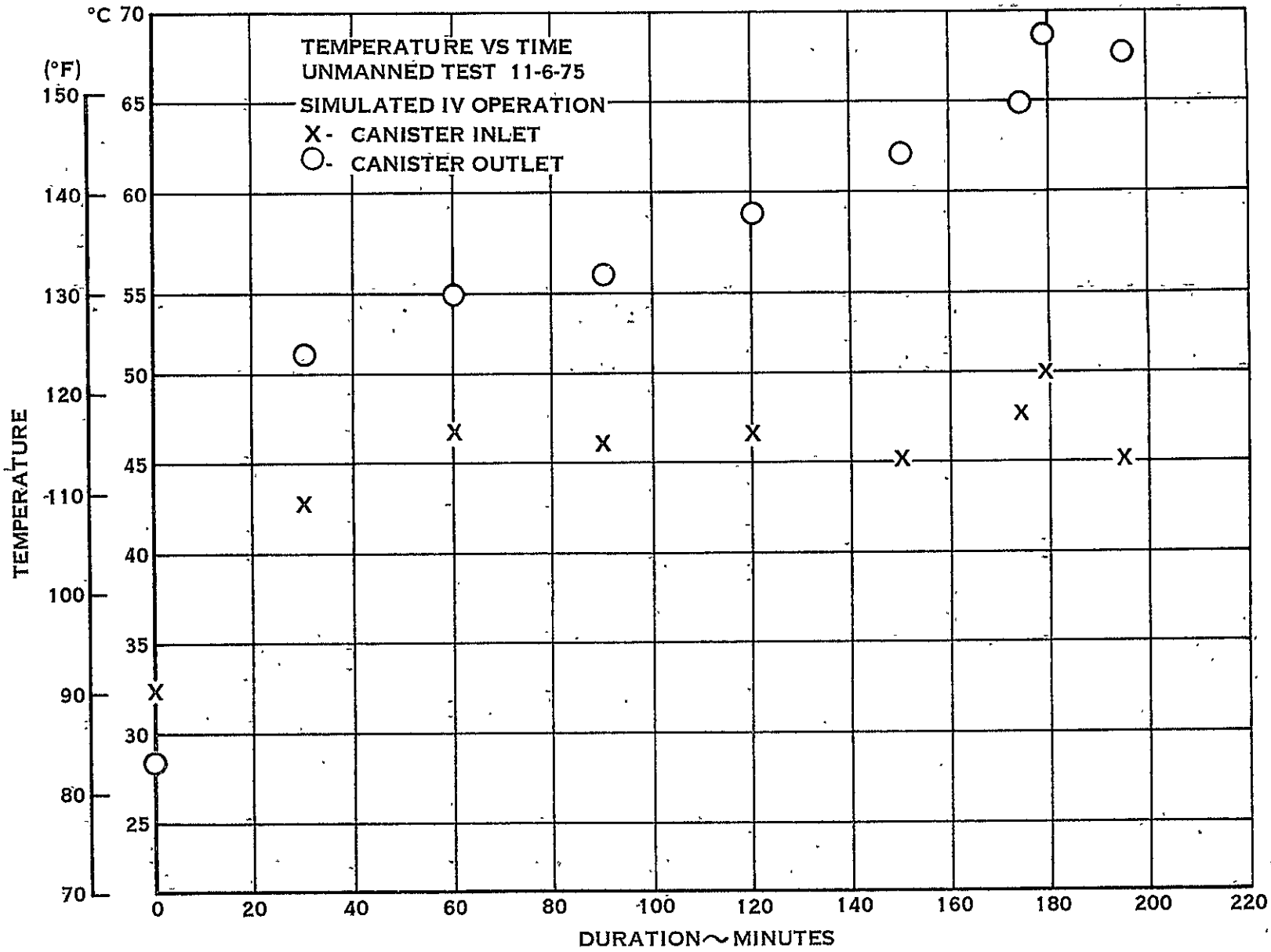


FIGURE 4-6-10 TEMPERATURE AT VARIOUS LOCATIONS

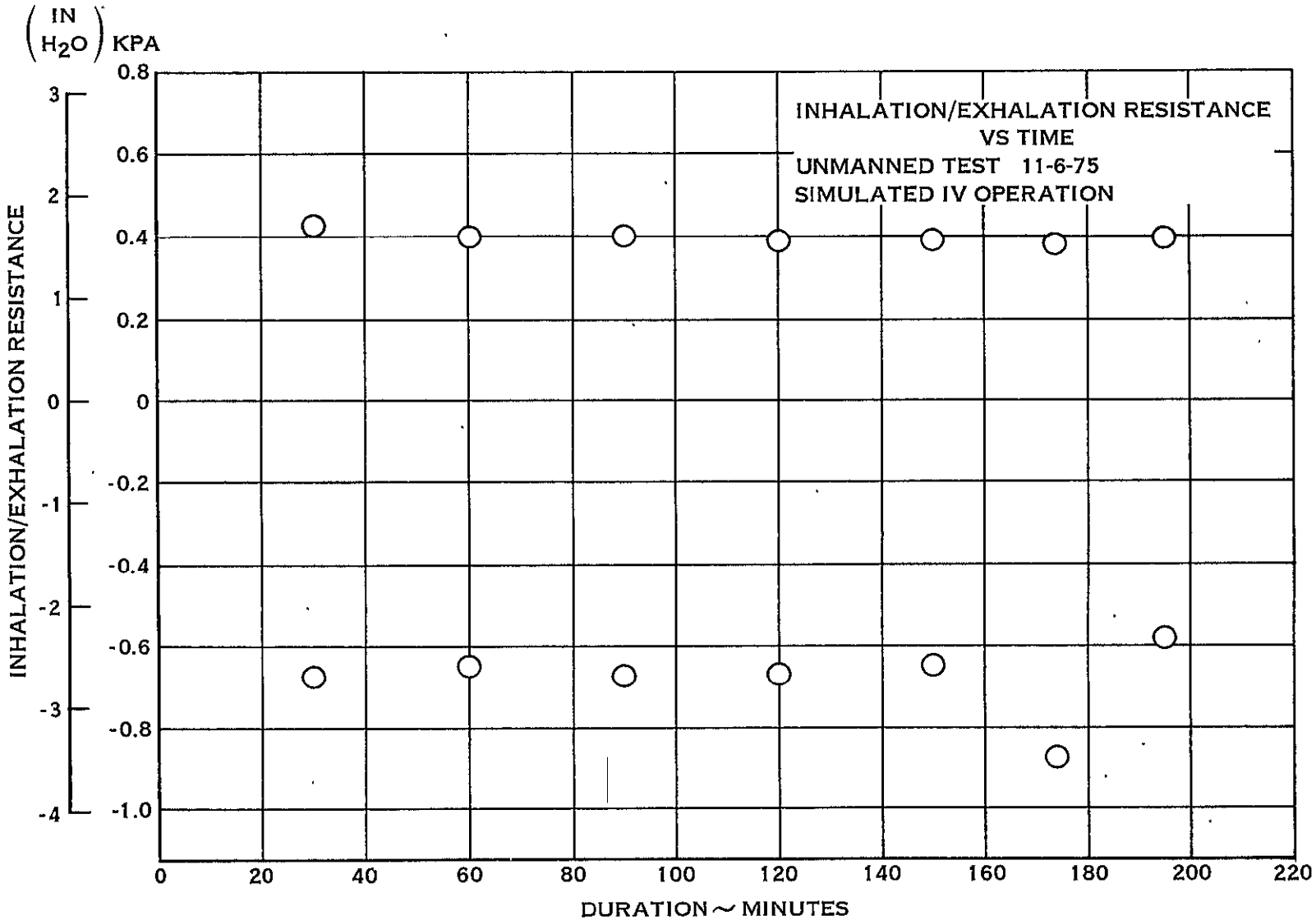


FIGURE 4-6-11 INHALATION/EXHALATION RESISTANCE VS TIME

4.6.1 (Continued)

the gas leaving the cartridge and within the mask. The dew point within the mask is a resultant of the dew point in the bellows which was maintained at approximately 37.8°C (100°F), the dew point of the gas returning from the POS and the dew point of the makeup gas.

Figure 4-6-8 is a plot of the canister which is radiating heat from the unit and of the cover and grid which can be touched by the crewman. As shown in the Figure, the touch temperatures were well below the 45°C (113°F) allowable. Figures 4-6-9 and 4-6-10 provide temperature data at various locations within the system. There are no required limits for these data points. Figure 4-6-11 is a summary of the inhalation and exhalation resistance taken within the mask. During this test, two gas samples were obtained for verification that the unit was safe for manned use. The first sample was taken at 160 minutes of operation, and the second was taken at 175 minutes of operation. The samples were analyzed and were found to be free of harmful concentrations of toxic materials.

The simulated rescue mission consisted of a two hour denitrogenization at a work rate of 176 watts (600 Btu/hr) followed by a one hour simulation of operation in the rescue enclosure at a work rate of 235 watts (800 Btu/hr). During the one hour simulated rescue, the flow was reduced to simulate the LiOH cooling that would occur during zero 'g' operation in the rescue enclosure so the temperatures obtained are equivalent to those that would be experienced in an actual zero 'g' rescue operation.

As in the previous test, the CO_2 concentrations were slightly higher than required as summarized in Table 4-6-2.

Desired			Actual	
Metabolic Load Watts	(Btu/Hr)	% CO_2	% CO_2	Metabolic Load Watts (Btu/Hr)
176	(600)	18	19.7	192 (656)
235	(800)	28.72	31.9	260 (886)

Table 4-6-2

At these slightly higher metabolic loads, the unit lasted well in excess (33%) of the three hours minimum duration. The data from the test is presented in Figures 4-6-12 through 4-6-20. The test

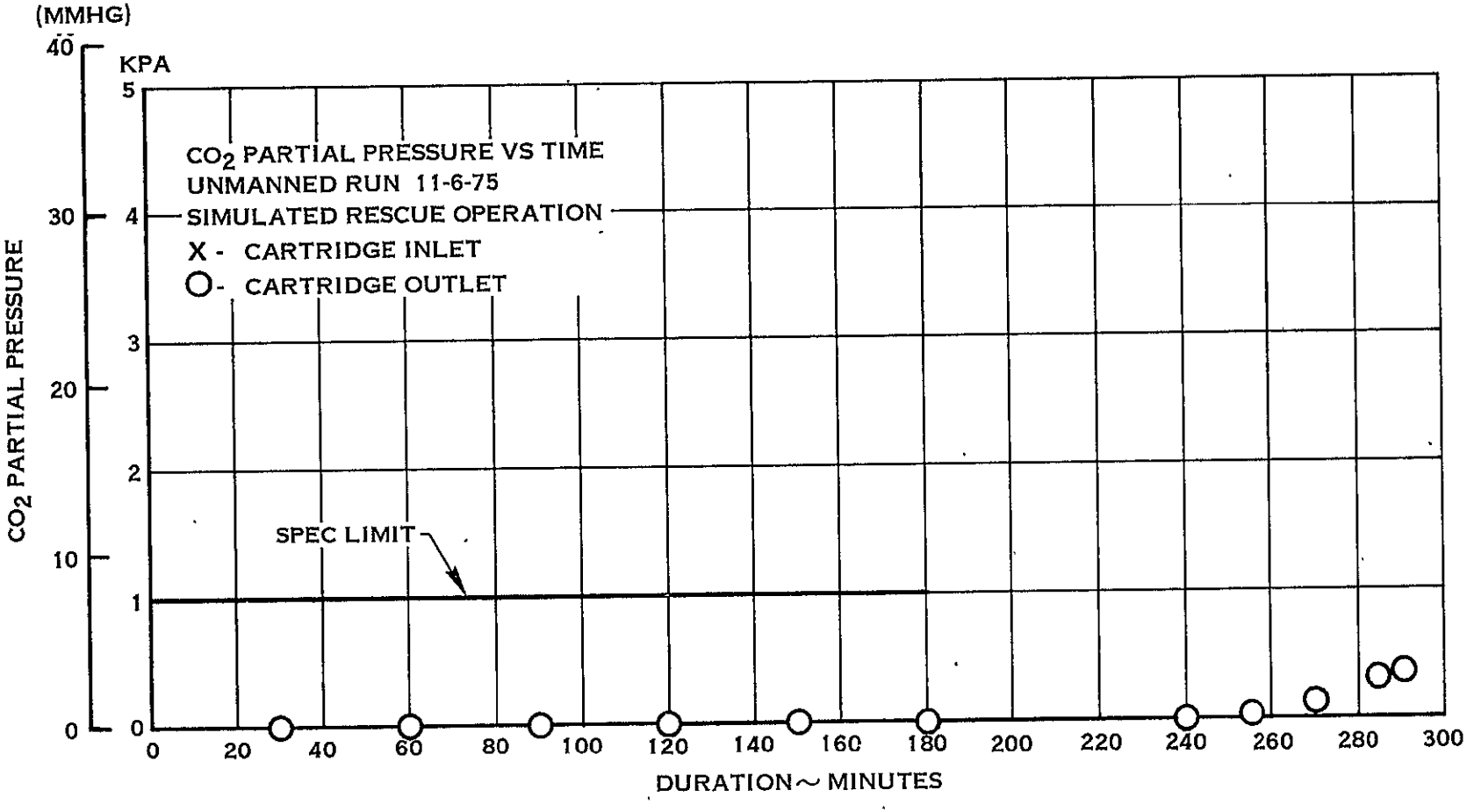


FIGURE 4-6-12 CO_2 PARTIAL PRESSURE VS TIME

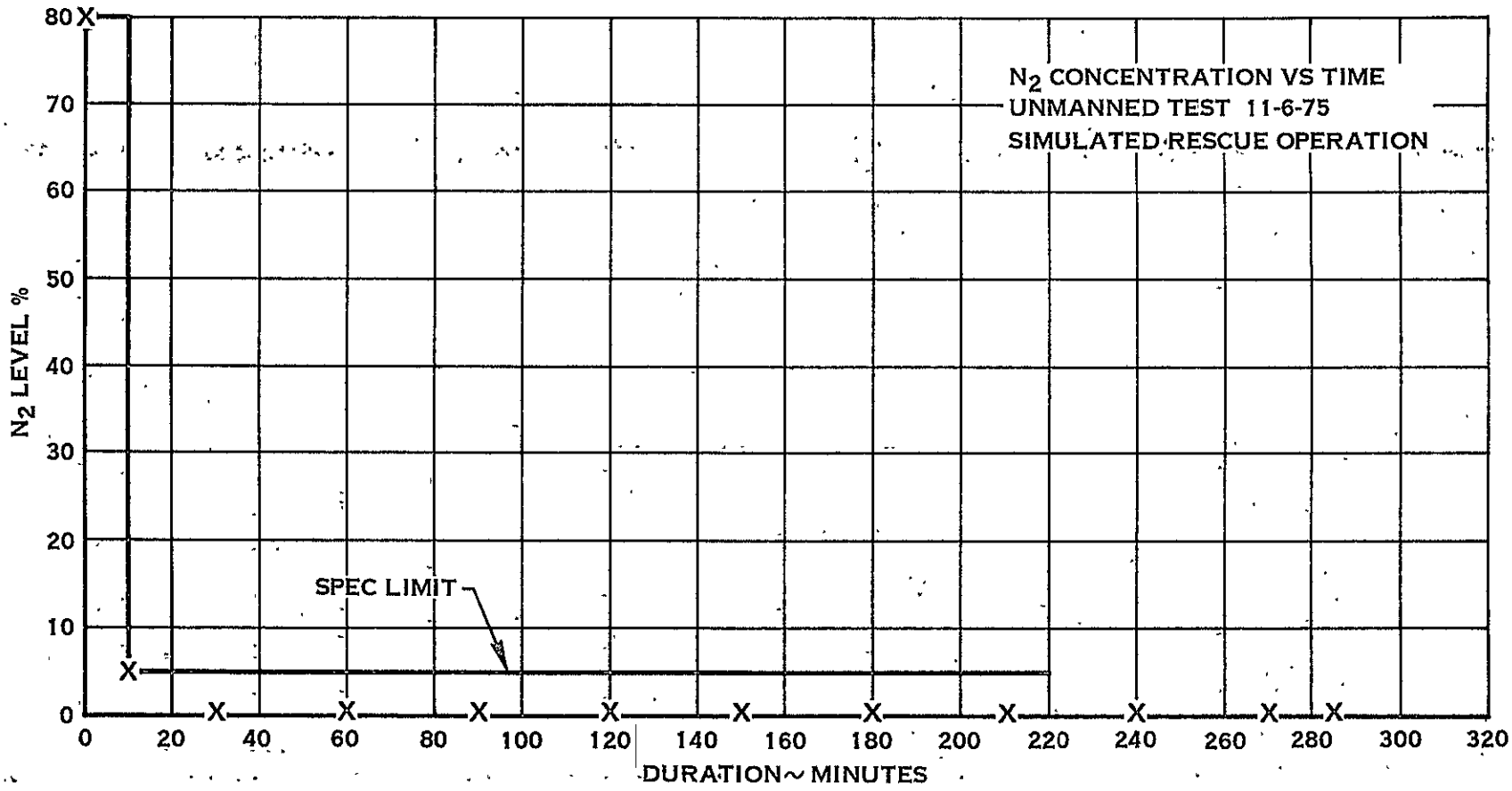


FIGURE 4-6-13 N_2 CONCENTRATION VS TIME

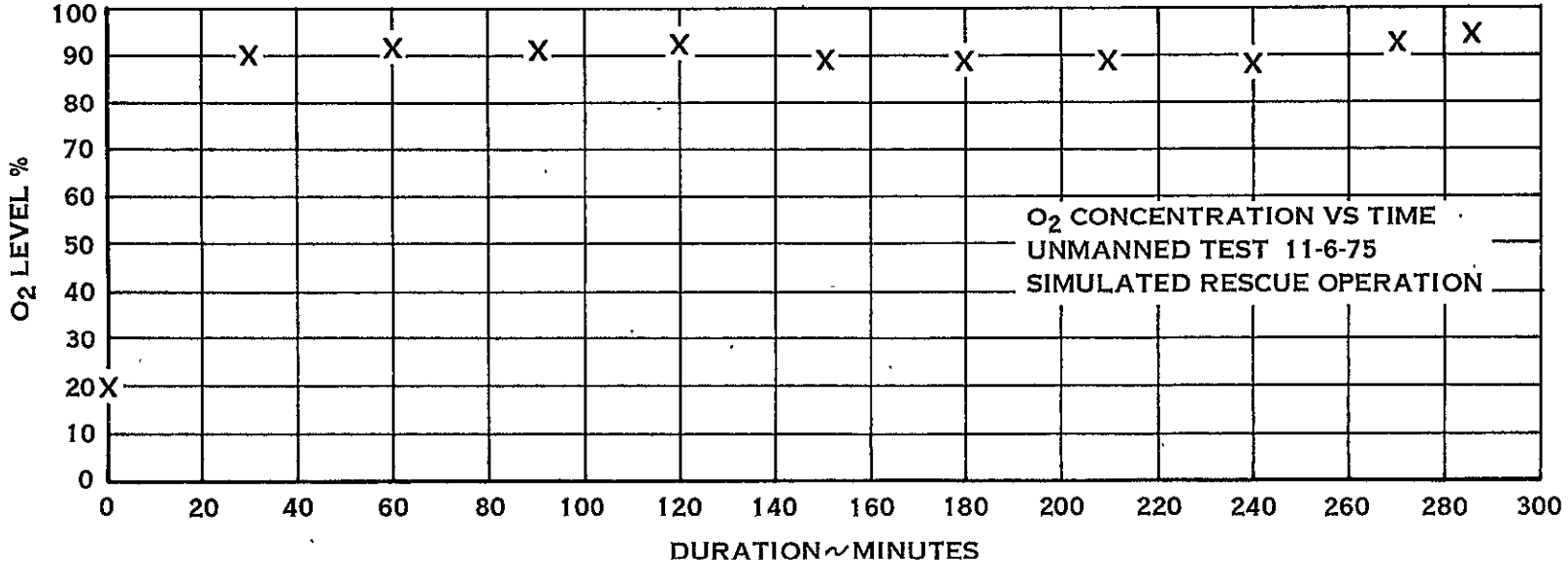


FIGURE 4-6-14 O_2 CONCENTRATION VS TIME

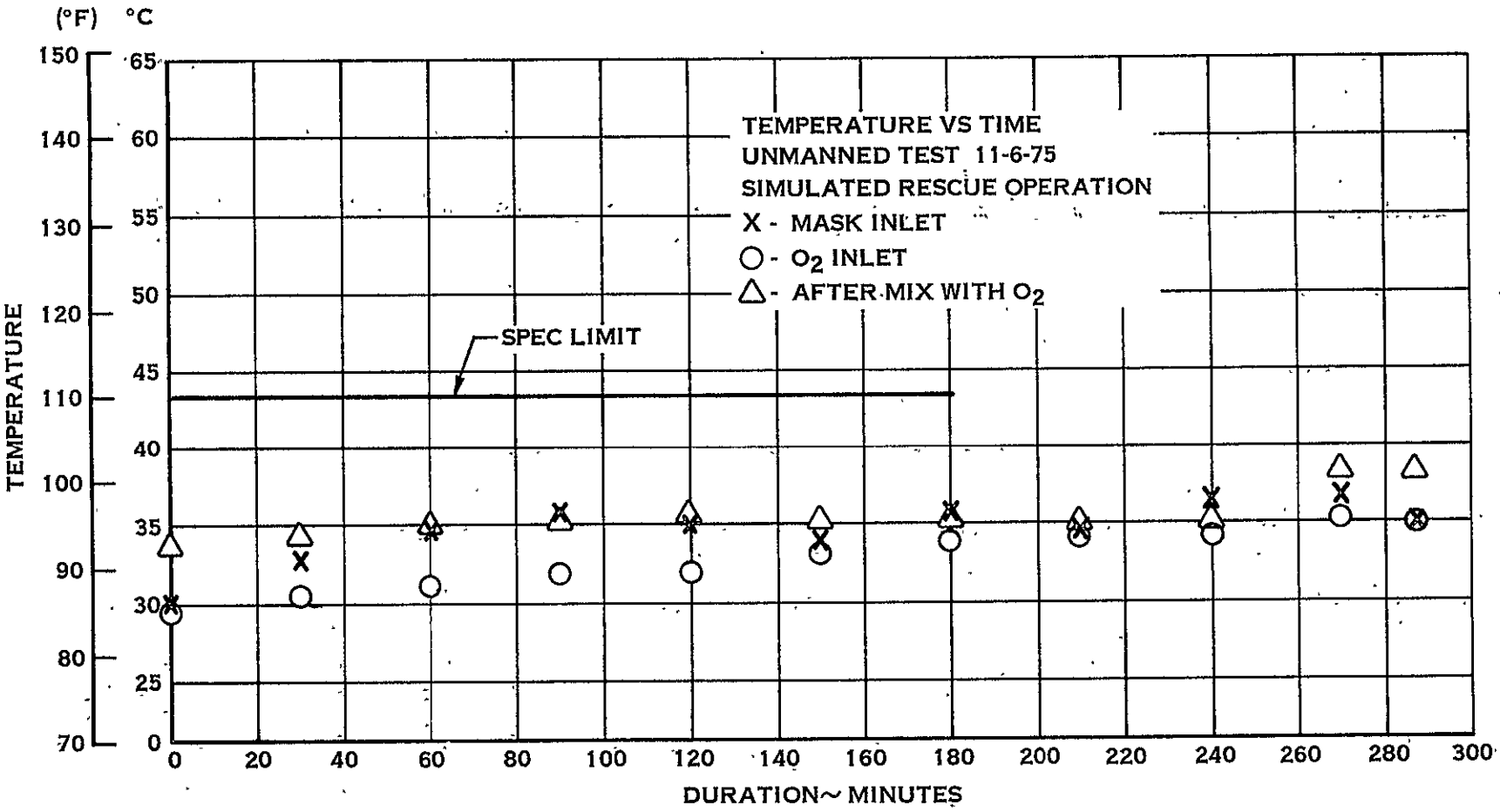


FIGURE 4-6-15 TEMPERATURE VS TIME

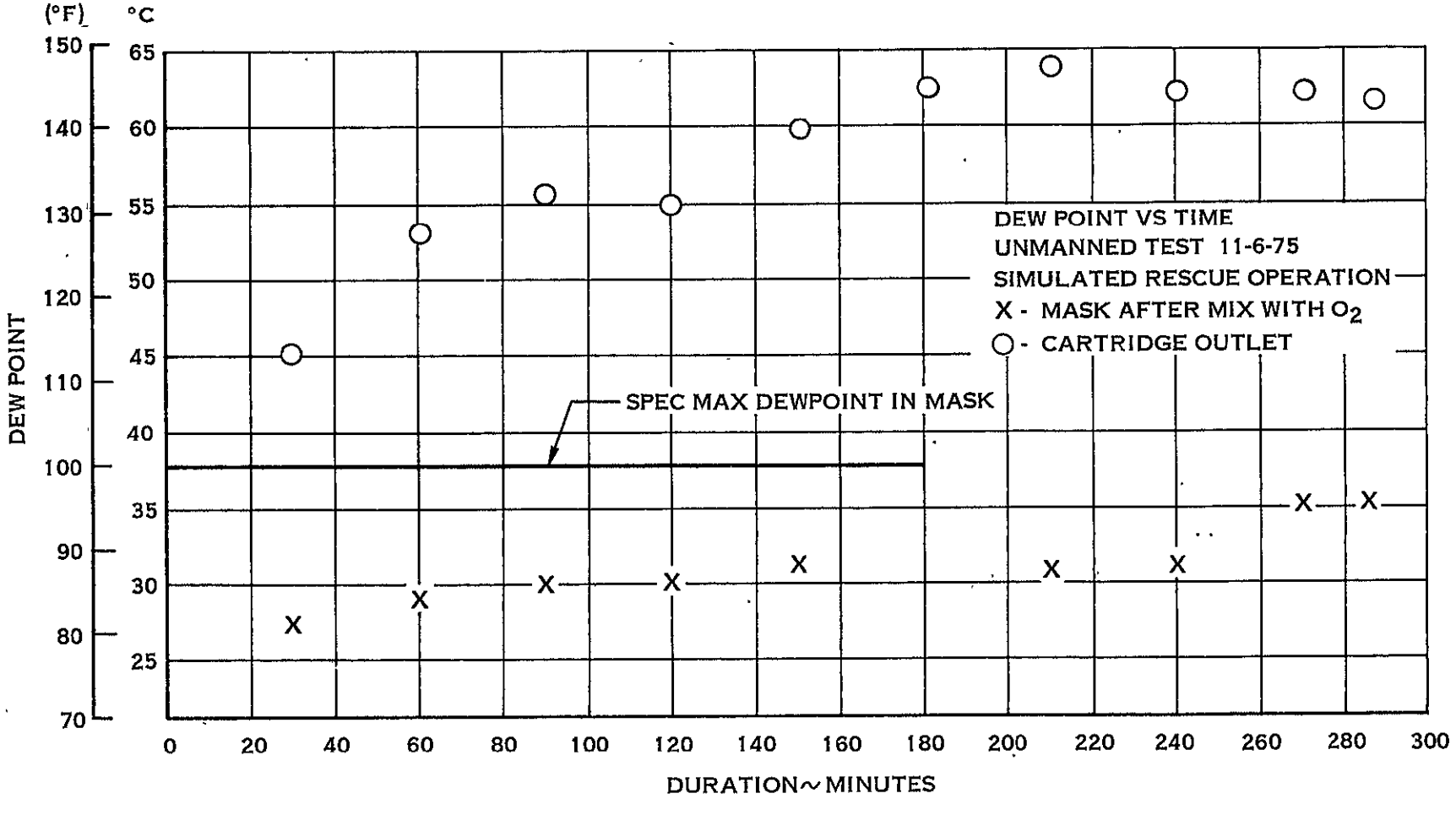


FIGURE 4-6-16 DEW POINT VS TIME

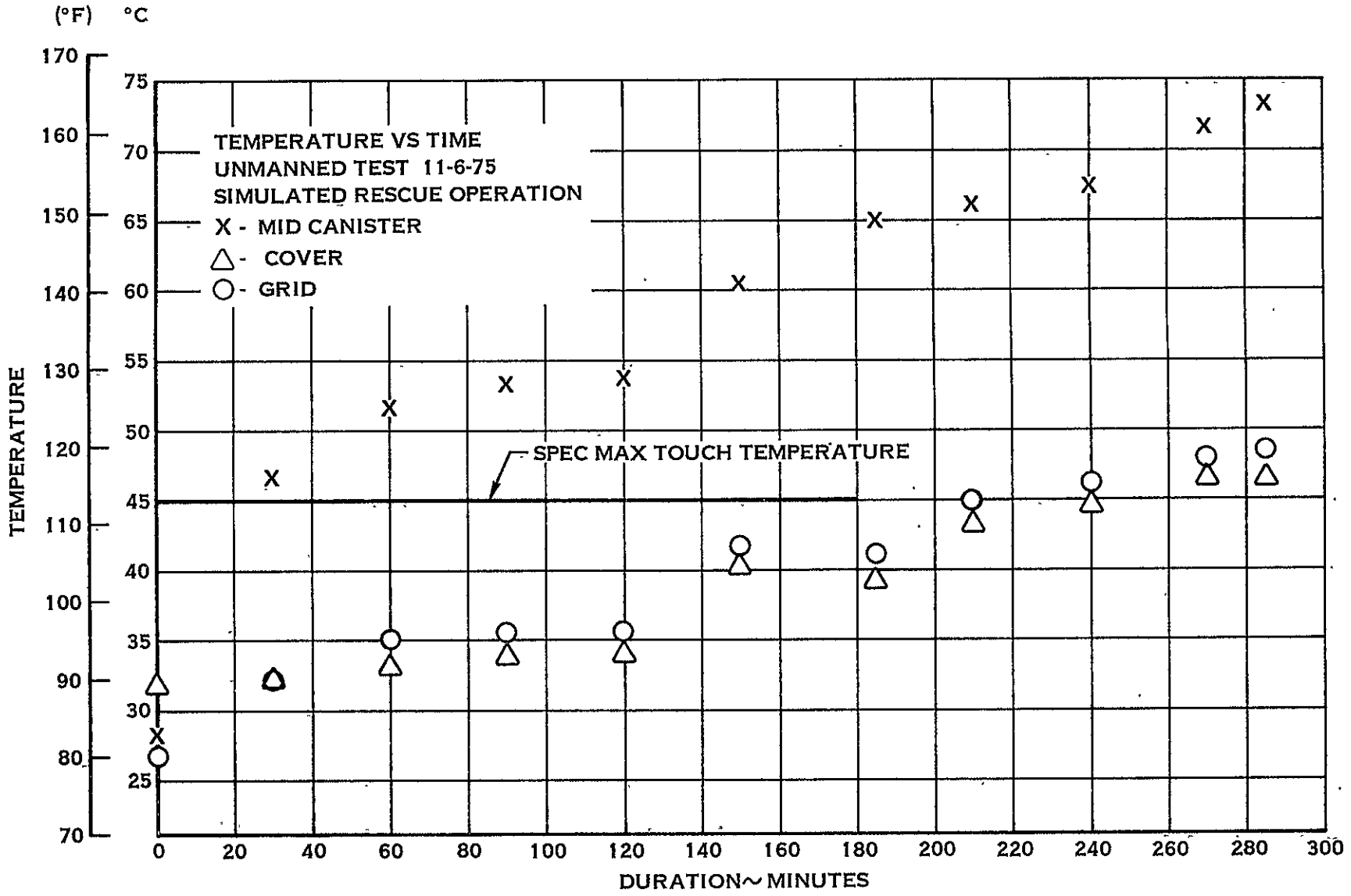


FIGURE 4-6-17 TEMPERATURE VS TIME

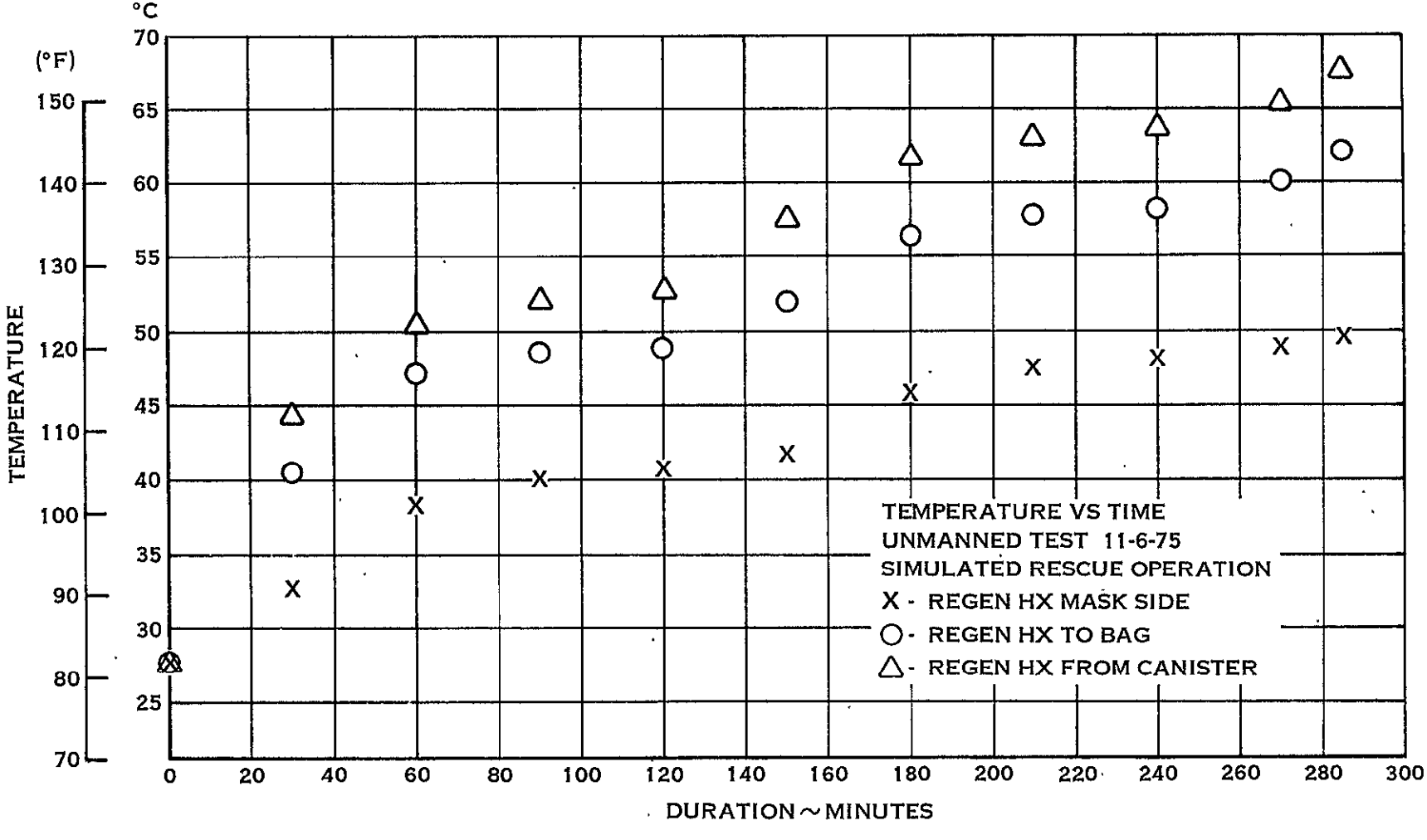


FIGURE 4-6-18 TEMPERATURE VS TIME

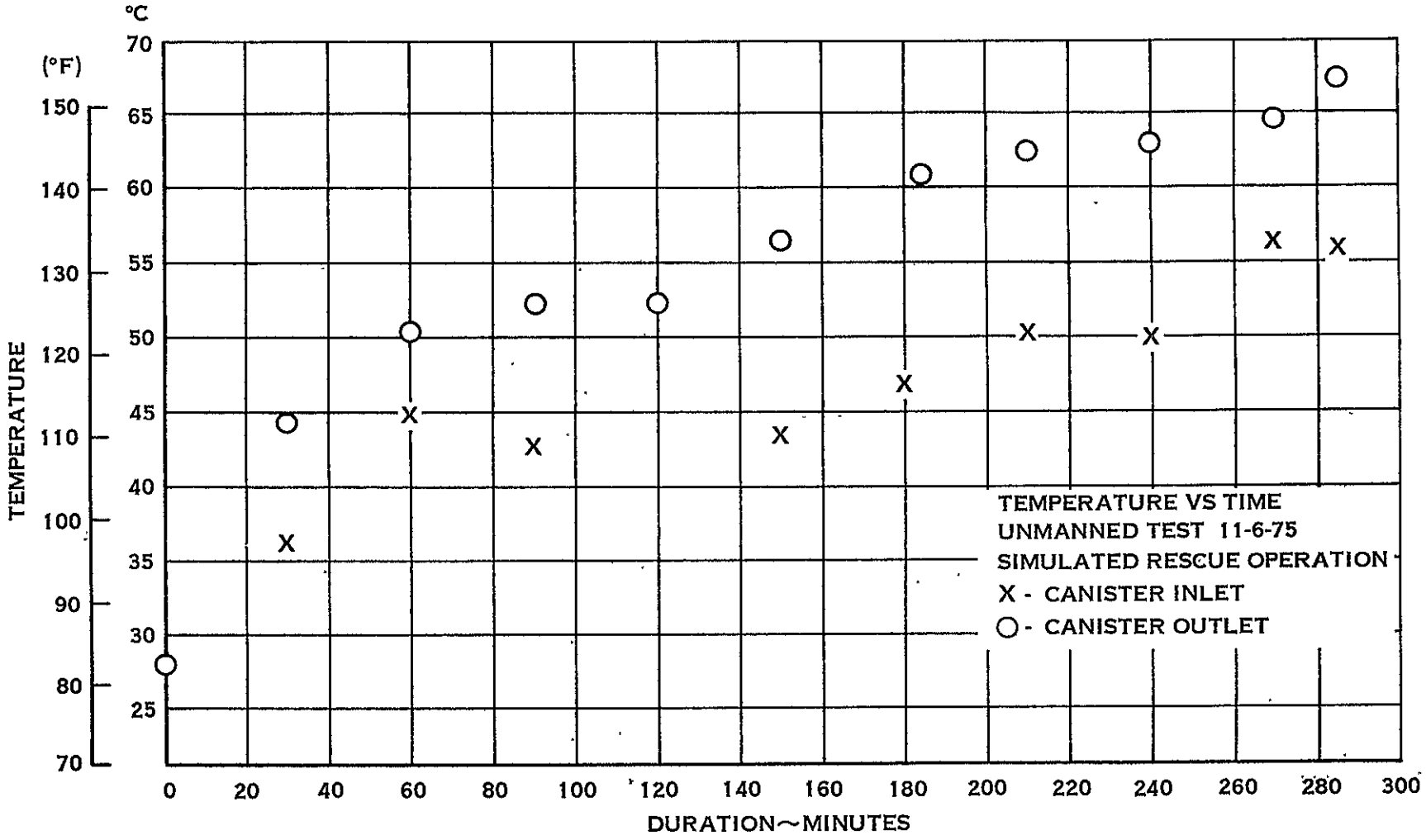


FIGURE 4-6-19 TEMPERATURE VS TIME

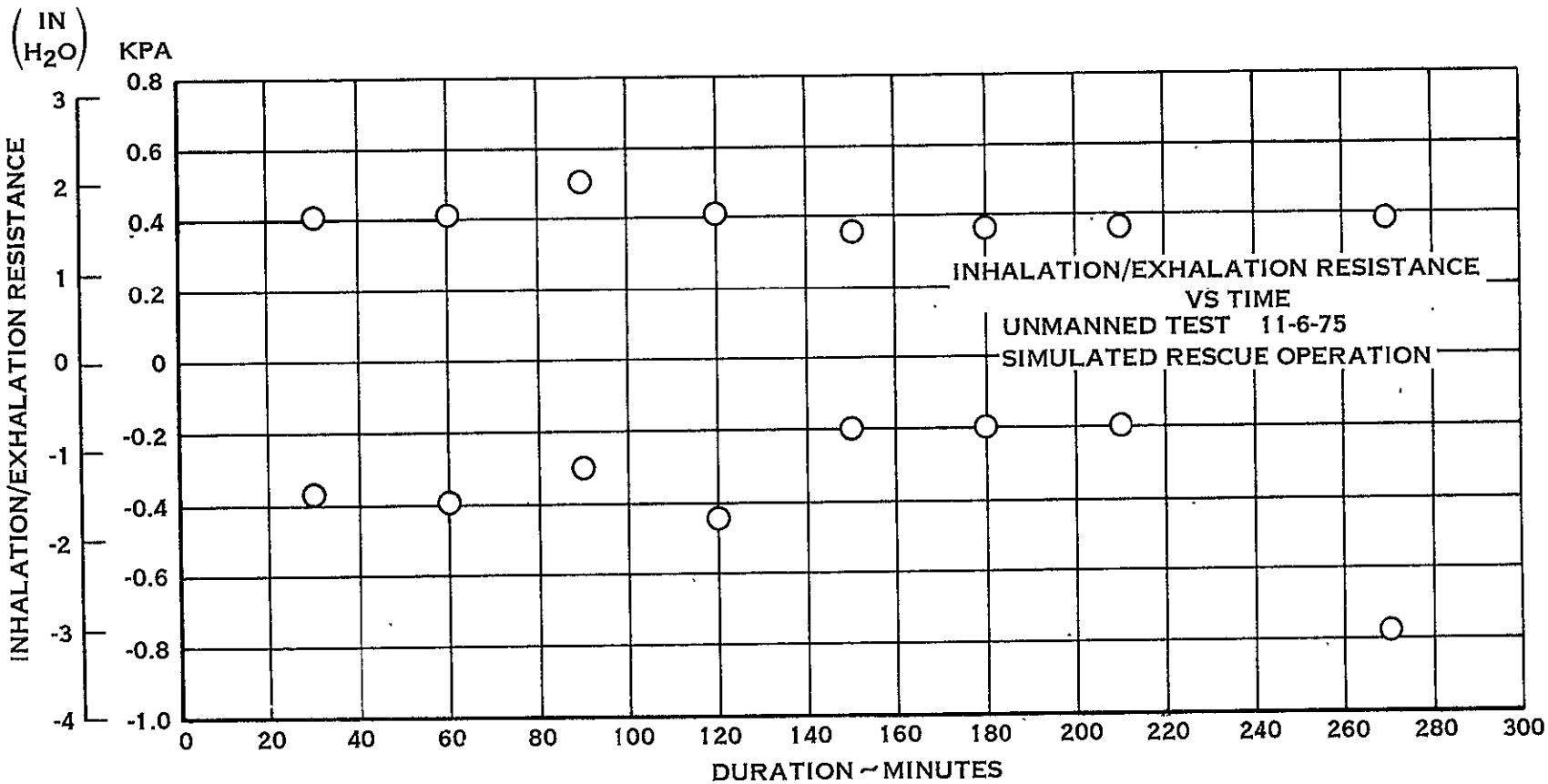


FIGURE 4-6-20 INHALATION/EXHALATION RESISTANCE VS TIME

4.6.1 (Continued)

was terminated after four hours and forty-five minutes of operation. The data collected was clearly sufficient to demonstrate the acceptability of the unit for this mode of operation. Gas samples were collected at 160 and 190 minutes of operation, and their analysis showed no harmful concentrations of toxic materials.

The two unmanned test runs confirmed that the unit was safe for manned test use and demonstrated that the unit complied with Work Statement requirements.

4.6.2 Manned Test

The manned test utilized much of the test setup used for the unmanned test, except that the breathing machine and O_2/CO_2 mixtures were replaced by a test subject who walked on a tread mill to obtain the desired work rate. The subject and test setup are shown in Figure 4-6-21. The test setup used is shown in Test Procedure POS-P-2, except that there was no instrumentation located in the mask. This change was made to eliminate a possible leak path in the mask seal. The N_2 and O_2 analyzers were connected in series with the cartridge inlet CO_2 analyzer, and the mask dew pointer and pressure gage were connected to the hose between the POS and the mask. In addition, the manometer was replaced by a pressure transducer in order to obtain a pressure reading free from the dynamic effects of constantly changing pressure.

A total of four manned tests were conducted. The first two were of short duration due to the subject working at work rates in excess of the specified levels. Only the final two tests which were conducted in accordance with the test procedure will be discussed in this report.

The first manned test conducted per the test procedure was similar to the initial unmanned test, while the second test was a steady state test conducted to supplement the data obtained during the first test. The day before the first run, the metabolic calibration of the subject was performed providing metabolic rate versus heart rate and tread mill rate.

Prior to the performance run, the subject conducted the applicable portions of the preuse check-out procedure defined in the test procedure (pressure gages were not in unit and thus could not be checked). This test verified that a crewman can check the operation of the exhalation check valve, the exhlation relief valve, and of the demand regulator. The subject was unable

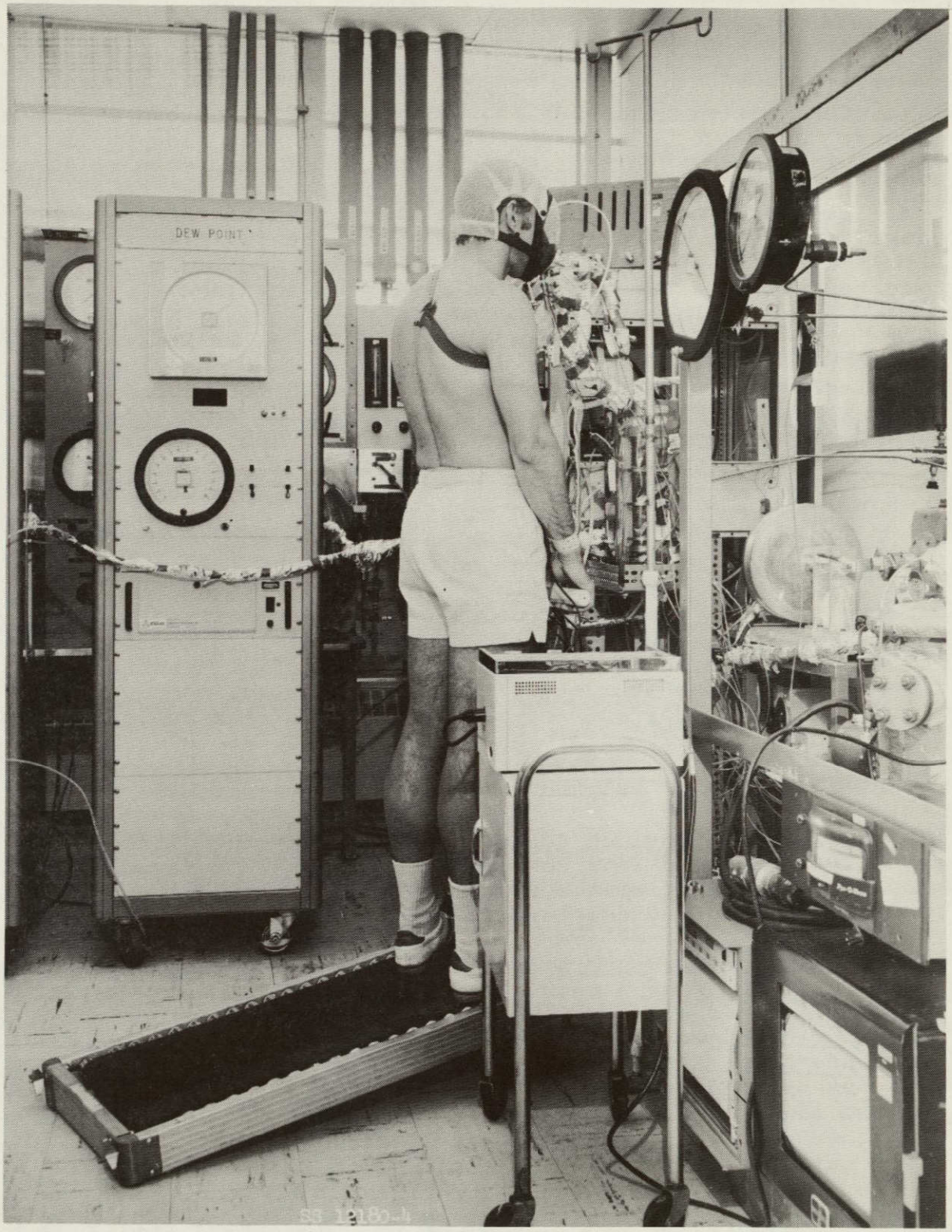


FIGURE 4-6-21 POS MANNED TEST SET-UP

4.6.2 (Continued)

to feel the normal makeup flow so this approach cannot be utilized for verifying the presence of makeup flow during a flight preuse check-out. It was noted that the makeup flow can be heard so it is possible for a crewman to verify makeup flow by listening to the system once the O_2 supply is connected. As an alternate, the crewman could exhale on the center of the visor and verify the presence of makeup flow when the fog clears.

The tests were conducted in the following sequence:

a) The N_2, O_2, and CO_2 analyzers were calibrated.

b) Proper function of other instruments verified.

c) Bioinstrumentation attached to test subject and heart rate readout verified.

d) Subject mounted tread mill.

e) System gas supply charged with O_2.

f) Subject donned mask using demand regulator for inhalation.

g) When subject could feel no leaks in face seal, the cartridge was activated, the timer started, the O_2 bottle weight recorded, and the demand regulator outlet tube was clamped shut to prevent actuation during the run.

h) The subject started walking at the prescribed rate.

This procedure provided for a rapid purge of the nitrogen in the system and if used in a contaminated cabin would rapidly remove any contaminates from the system prior to opening the canister, thus preventing any deleterious effect on the LiOH.

In the simulated IV operation run, the subject inhaled seven times from the demand regulator before the cartridge was activated. After the cartridge was activated, subject commenced walking at a speed equivalent to a metabolic rate of 235 watts (800 Btu/hr). After about 15 minutes of operation, the heart rate stabilized at the level obtained during the calibration. As the run progressed, the heart rate started to climb indicating a higher work rate; thus, it was elected to slow the tread mill as required to maintain a constant heart rate. The subject worked at the 235 watt (800 Btu/hr) level for two hours and forty four minutes and then increased speed to the level equivalent to 323 watts (1,100 Btu/hr) and maintained this level for 15.5 minutes. The tread mill was then increased to represent a rate

4.6.2 (Continued)

of 440 watts (1,500 Btu/hr). This rate was maintained for three minutes after which the subject slowed to the tread mill speed equivalent to 235 watt (800 Btu/hr) rate. He continued to work at this rate until the cartridge outlet partial pressure exceeded 1.01 KPa (7.6 mm Hg). It was observed that the tread mill speed and heart rate did not correlate with the data obtained during calibration. Based on heart rate, the actual work rates were as summarized in Table 4-6-3.

Desired Work Rate	Work Rate Based on Heart Beats/Min	
323 Watts (1,100 Btu/Hr)	@ 0 - 9 Min @ 13 Min @ 15 Min	346 Watts (1,180 Btu/Hr) 366 Watts (1,250 Btu/Hr) 422 Watts (1,440 Btu/Hr)
440 Watts (1,500 Btu/Hr)		492 Watts (1,680 Btu/Hr)
235 Watts (800 Btu/Hr) (After Work Spike)	@ 2 Min @ 12 & 20 Min	323 Watts (1,100 Btu/Hr) 293 Watts (1,000 Btu/Hr)

Table 4-6-3
Actual Work Rates Versus Desired Work Rates

The actual CO_2 absorbed by the bed, based on a chemical analysis, correlated with the amount predicted based on the actual work rates observed.

Upon reaching the 1.01 KPa (7.6 mm Hg) level, the mask was removed from the subject, and the O_2 supply was shut off. Immediately after the run, a metabolic gas sample was collected and analyzed with the subject walking at a rate lower than used during the test. The analysis indicated that the subject was working at 337 watts (1,150 Btu/hr).

About 10 minutes prior to the high work rates, the subject reported that he thought the breathing bag was bottoming although the system was providing his inhalation demands. To prevent breathing difficulty during the high work rates, the clamp isolating the demand regulator was removed. At the high work rate, the demand regulator was activated six times although the subject only was aware of two activations, and based on hearing flow, there were only two periods of significant flow through the demand regulator.

4.6.2 (Continued)

When the crewman reported that he thought the breathing bag was bottoming, it was observed that the breathing bag was not fully inflating and that the exhalation pressure was significantly lower than at other times during the run. It was suspected that this shift in performance was due to water collecting on the exhalation relief valve causing its setting to change. This was supported by observing a large quantity of water expelled from the valve during the high work rates. After the water was expelled, the exhalation pressure returned to normal, and the subject did not report feeling the bag bottom during the remainder of the test.

The data collected during this run is summarized in Figures 4-6-22 through 4-6-30. The unit met all requirements of the Work Statement. It was noted that the inhalation resistance was higher than predicted and tended to climb as the run progressed. This phenomina was further evaluated during the final manned test and will be discussed in the review of that test.

Prior to initiation of the final manned test, water manometers were connected to the unit to determine the pressure drop between the breathing bag and canister outlet and between the canister outlet and the mask inlet to permit further evaluation of the higher predicted inhalation resistance observed during the first test.

The final test was initiated following the same procedure as for the previous test. The subject took slightly longer to adjust the mask and assure that he could feel no leaks, thus, the demand regulator was activated twelve times prior to opening the canister.

The subject started walking at the same rate as used at the beginning of the previous run. Unlike the previous test, the subject's heart rate did not increase, so in an attempt to make the heart rate increase, the subject's speed was increased. After thirty minutes, the subject reported that he was working harder than he did during rhe previous run. The inhalation resistance was also high, indicating a high work rate, and the LiOH cartridge outlet CO_2 partial pressure showed a slight but premature increase. The subject's walking rate was decreased below the 235 watts (800 But/hr) rate to compensate for the high work rate. The subject's heart rate finally approached the level maintained during the previous run. The subject increased speed slightly to the speed maintained through most of the other test. This speed was then maintained for the remainder of the test even though the subject's heart rate did climb slightly ($\simeq$17.6 watts (60 Btu/hr)). The cartridge outlet pressure exceeded 1.01 KPa (7.6 mm Hg) after

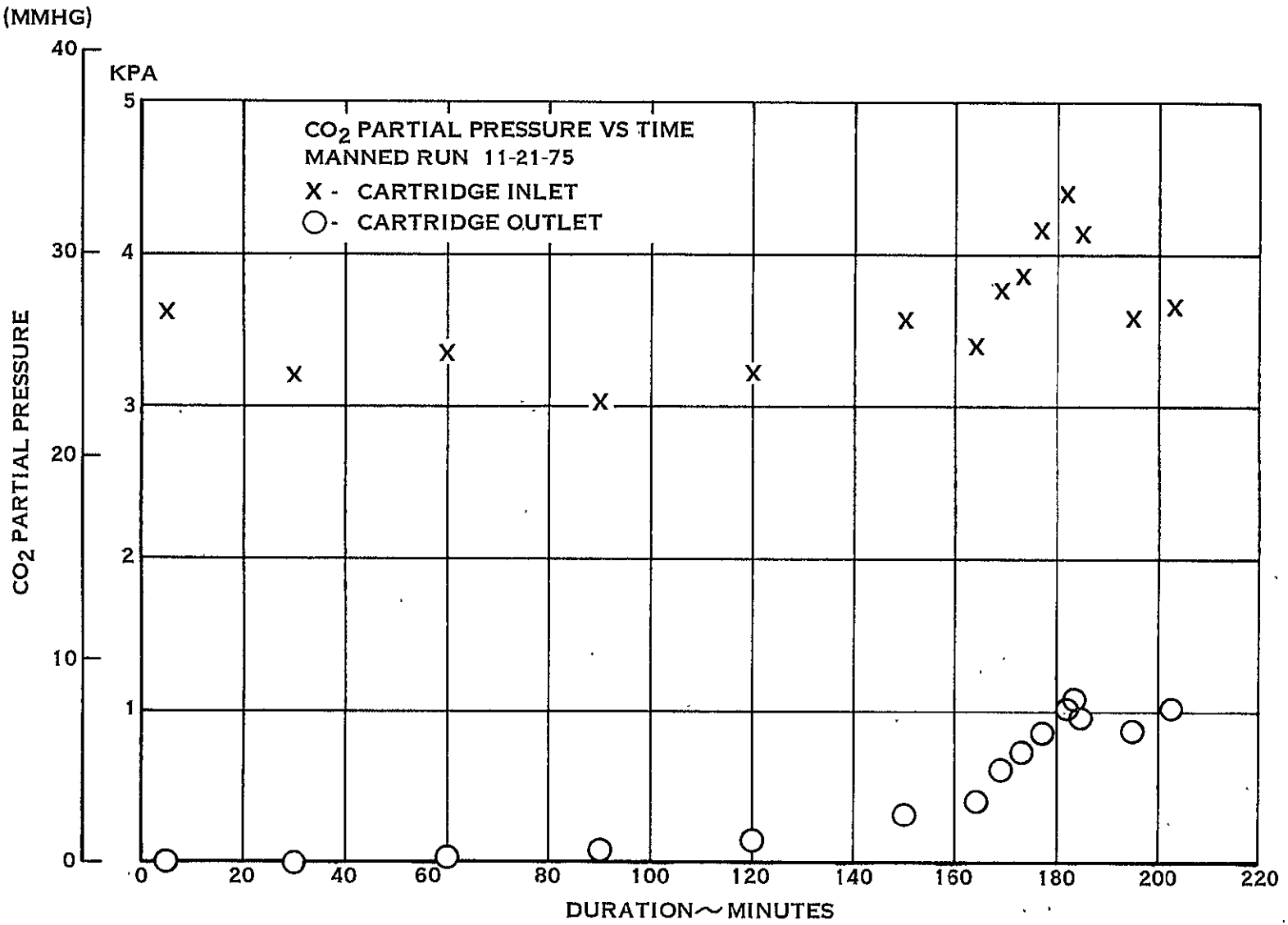


FIGURE 4-6-22 CO_2 PARTIAL PRESSURE VS TIME

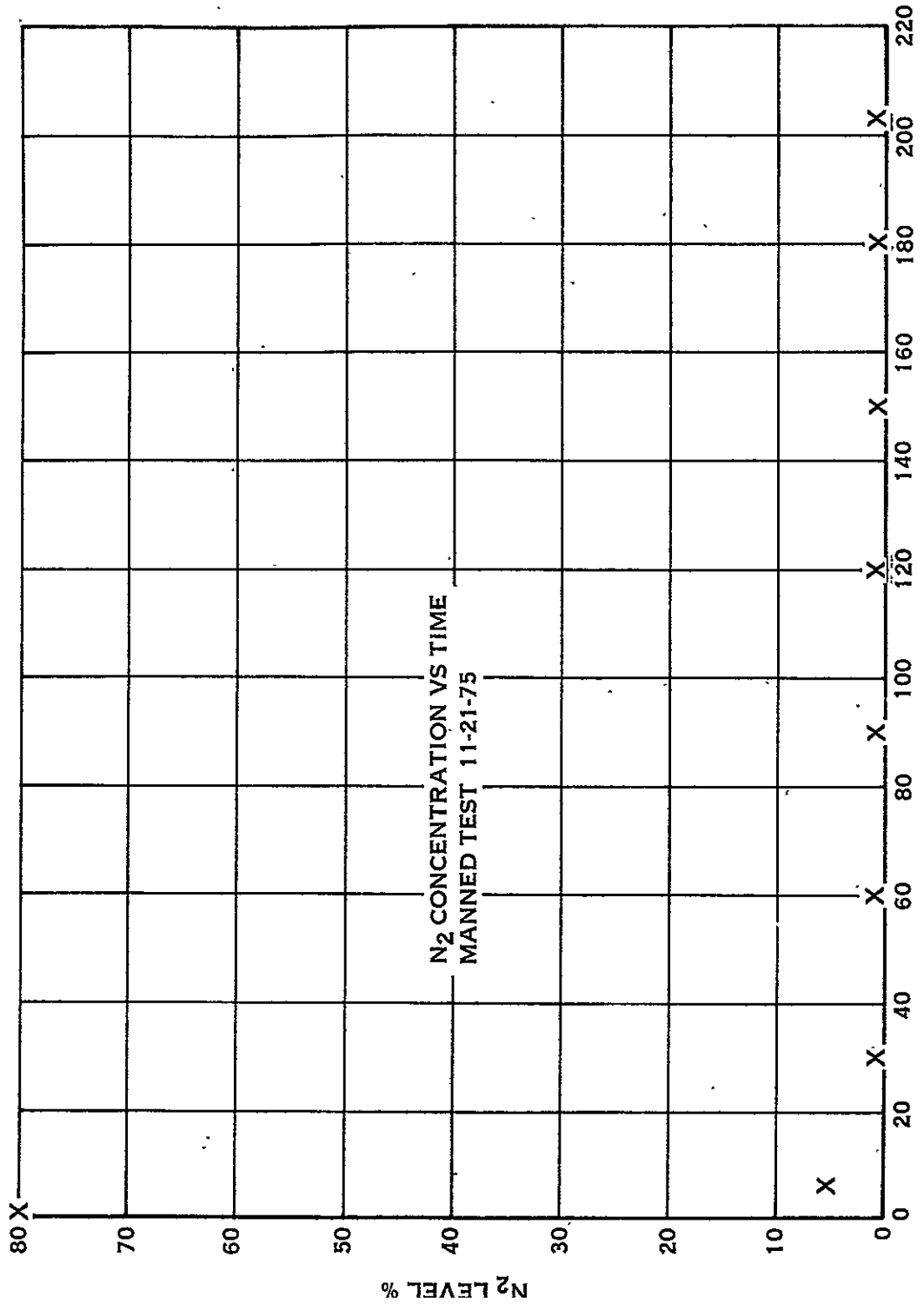


FIGURE 4-6-23 N_2 CONCENTRATION VS TIME

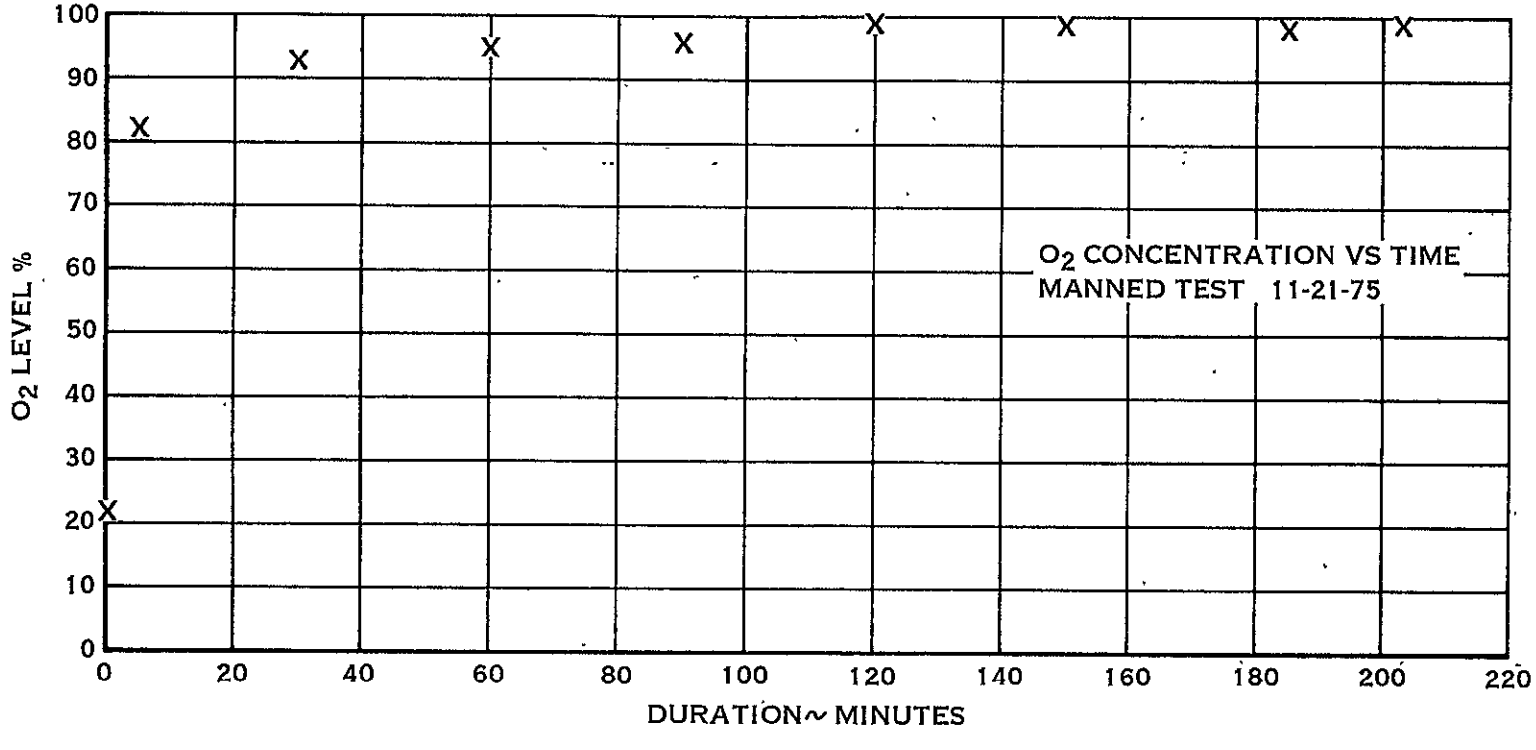


FIGURE 4-6-24 O_2 CONCENTRATION VS TIME

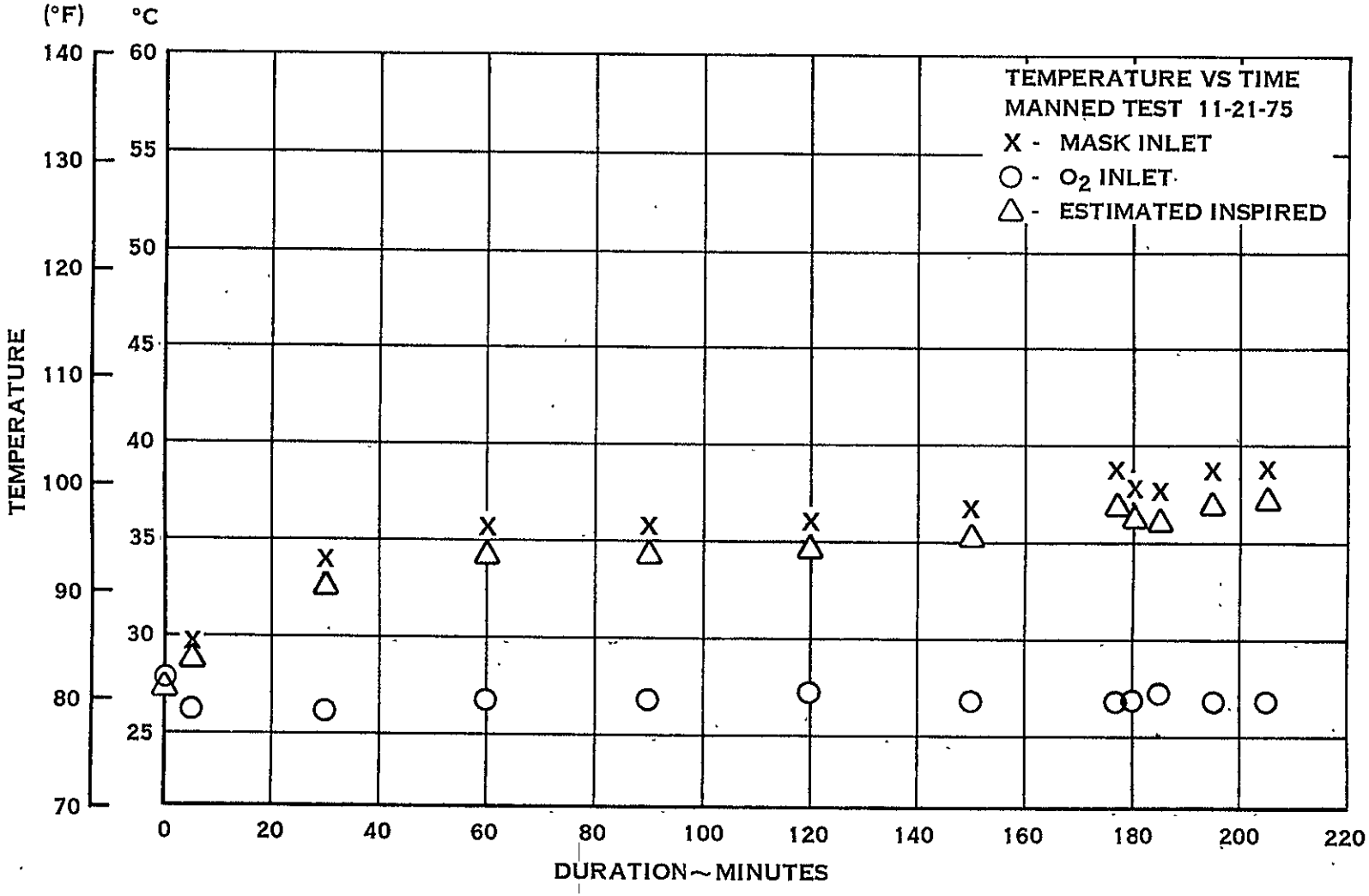


FIGURE 4-6-25 TEMPERATURE VS TIME

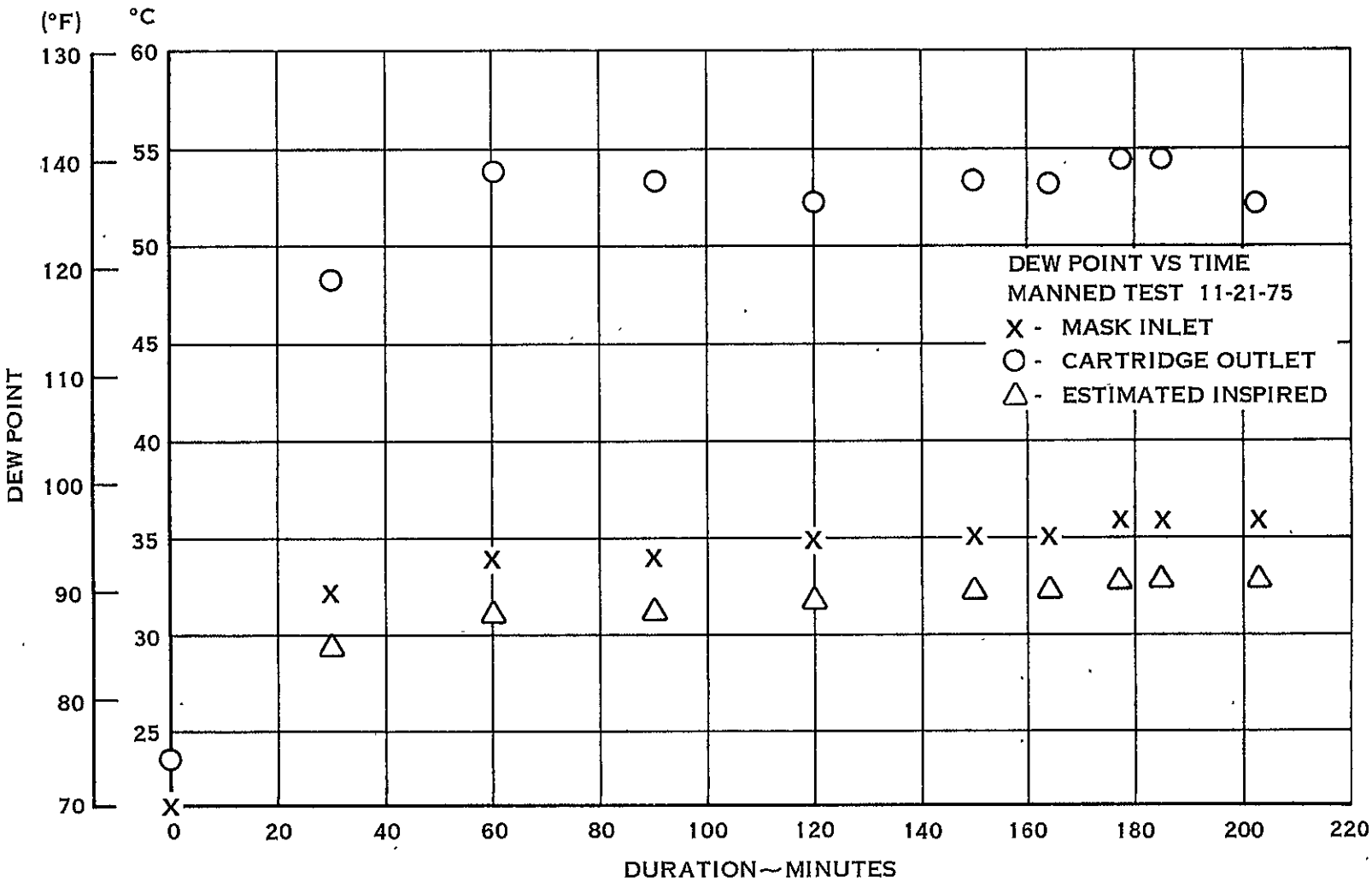


FIGURE 4-6-26 DEW POINT VS TIME

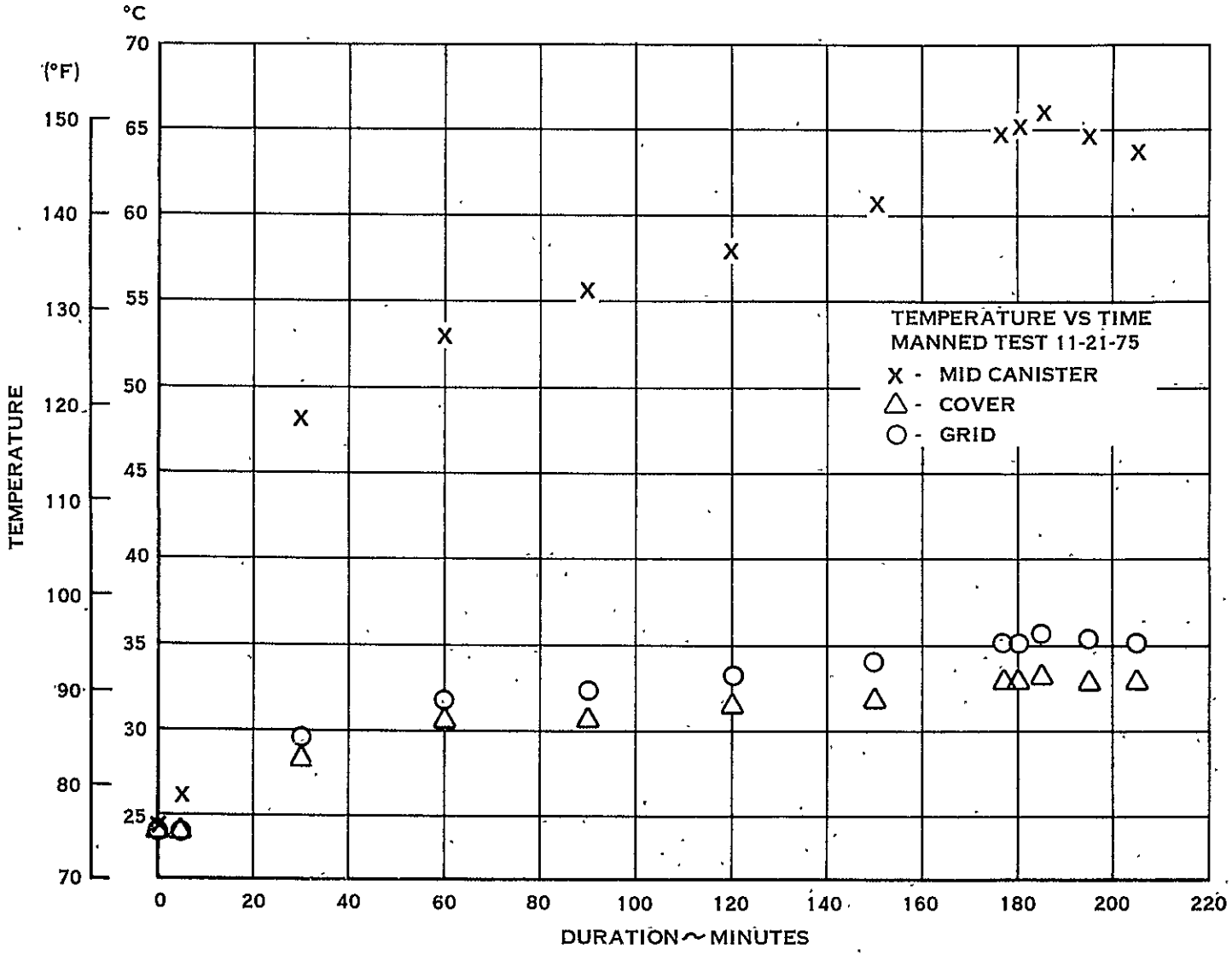


FIGURE 4-6-27 TEMPERATURE VS TIME

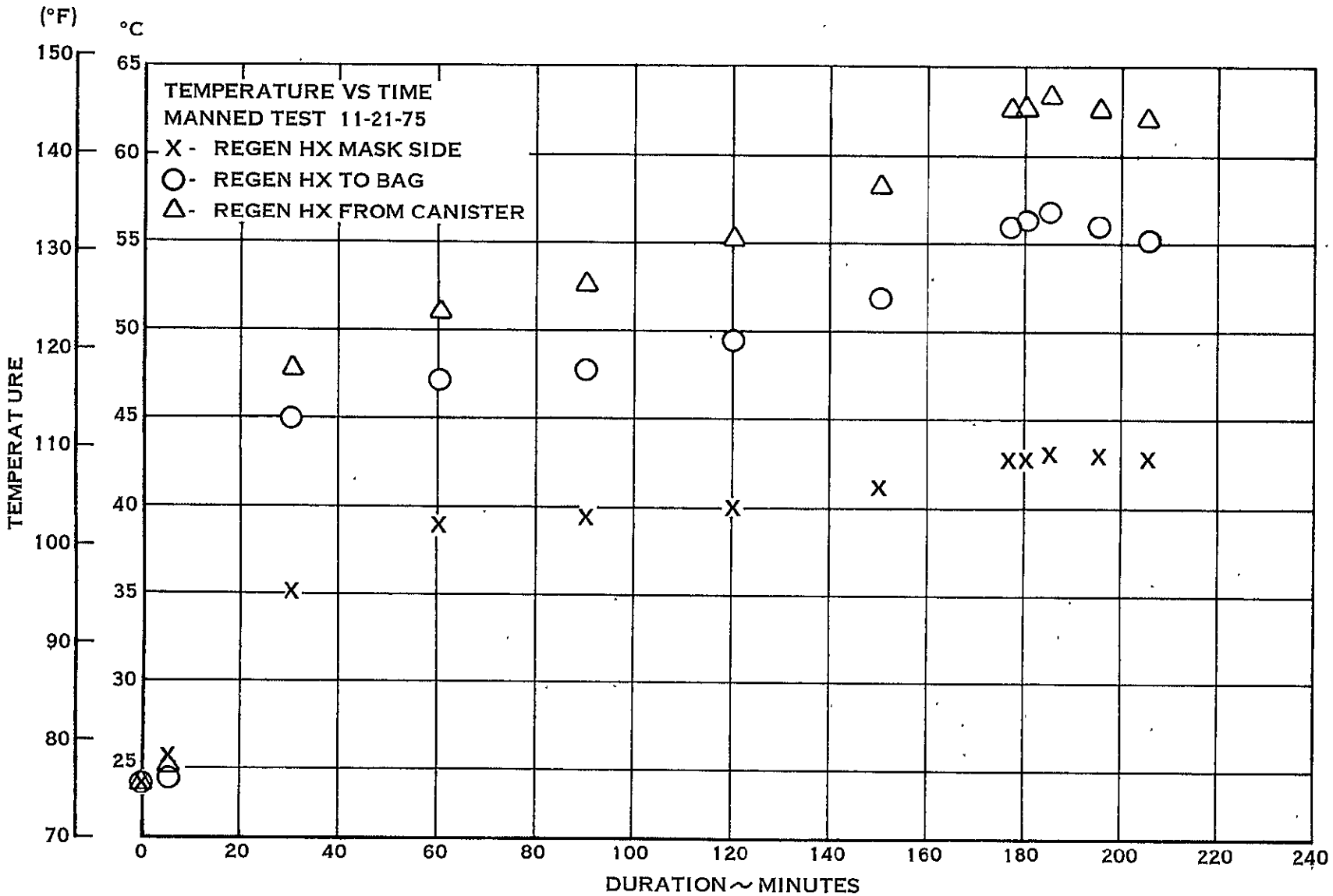


FIGURE 4-6-28 TEMPERATURE VS TIME

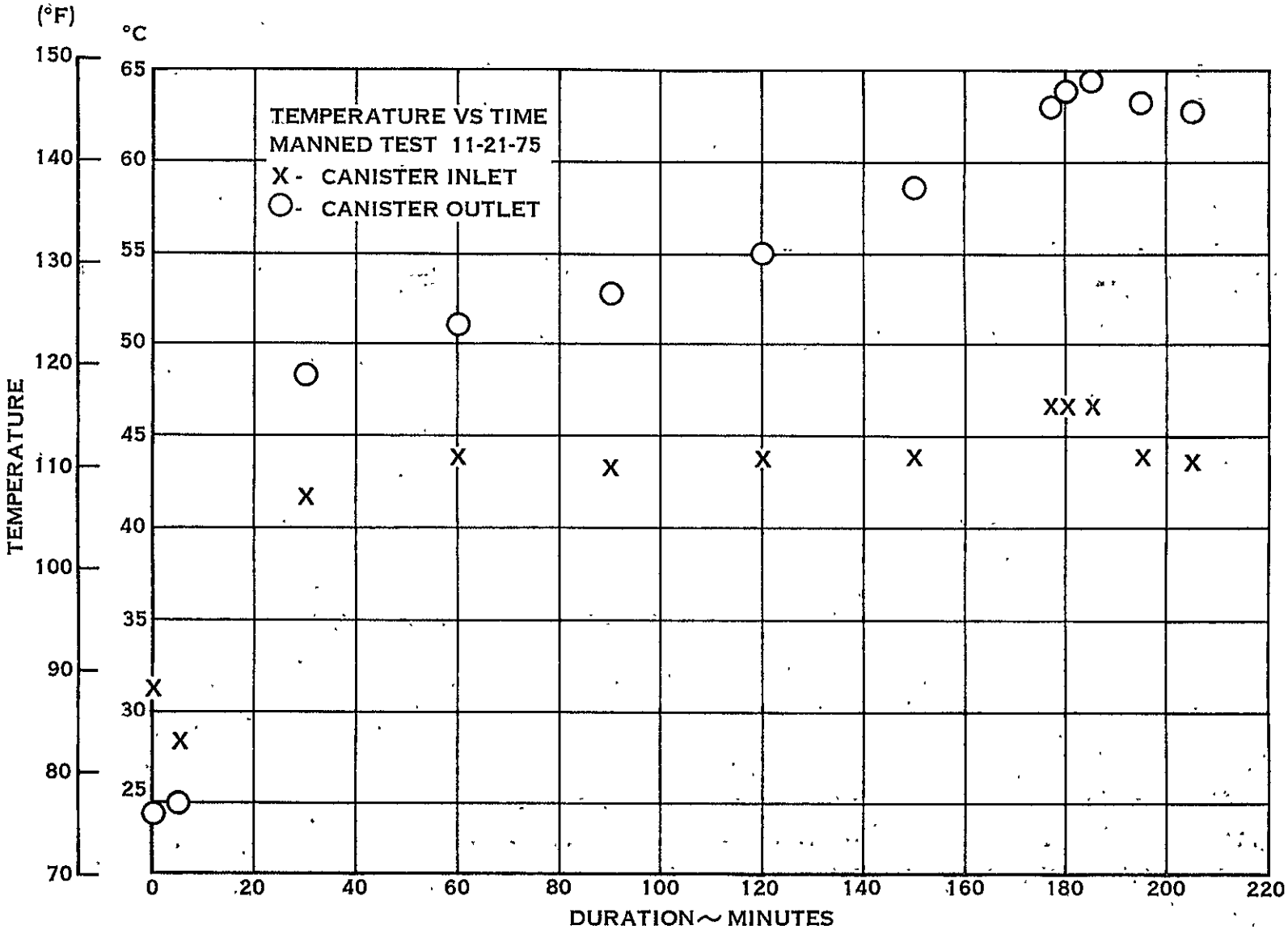


FIGURE 4-6-29 TEMPERATURE VS TIME

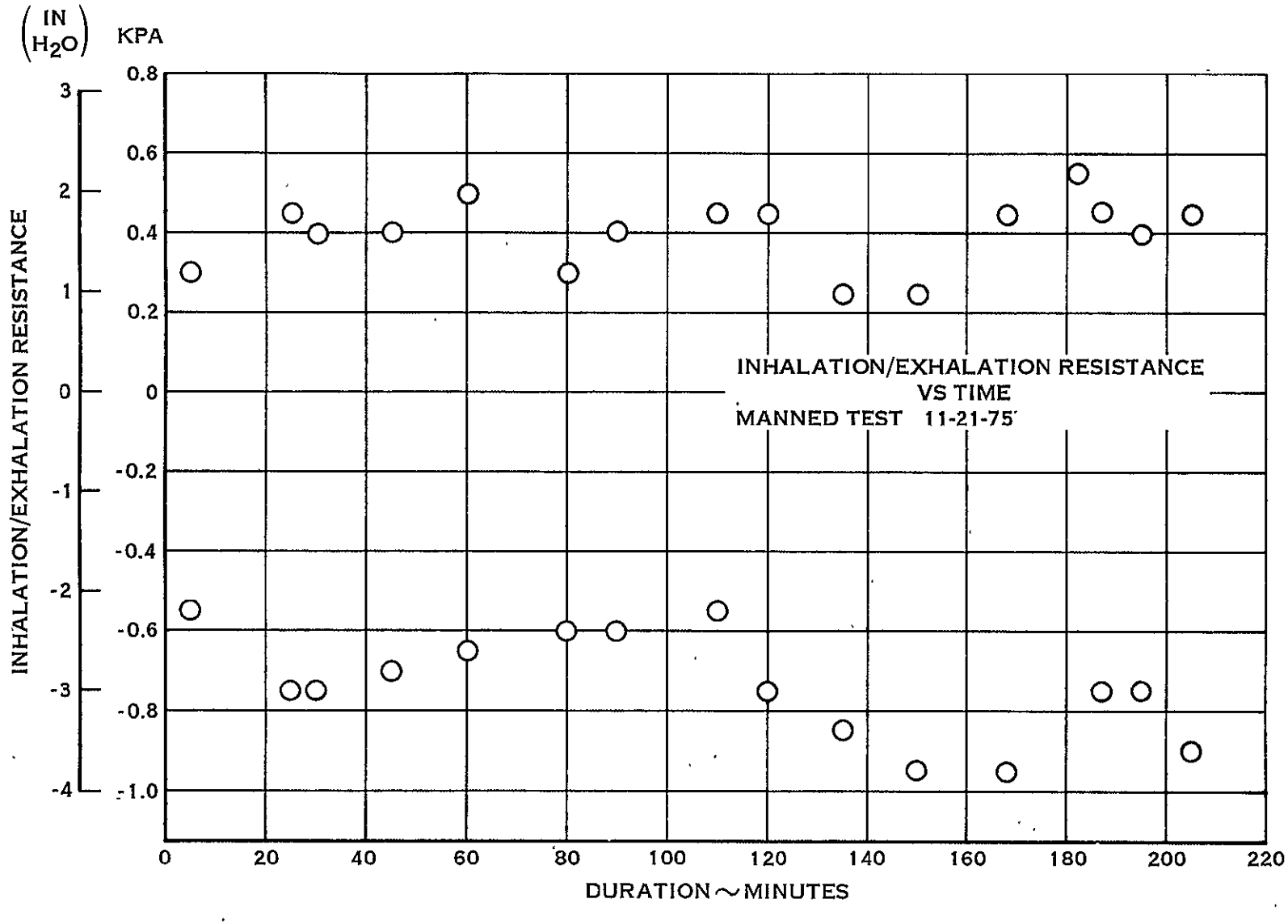


FIGURE 4-6-30 INHALATION/EXHALATION RESISTANCE VS TIME

4.6.2 (Continued)

187 minutes of operation, however, the test was not terminated until 240 minutes in order to gain a second test point for review of LiOH performance. The chemical analysis of the cartridge confirmed that the subject had worked at a rate equal to or slightly above an average of 235 watts (800 Btu/hr). The data from this test is shown in Figures 4-6-31 through 4-3-39.

After about 160 minutes of operation, the subject reported feeling as though the bag was collapsing but was able to continue without the demand regulator by changing his breathing cycle. As before, the exhalation pressure had dropped, and the bag did not appear to fully inflate. After 190 minutes of operation, the clamp isolating the demand regulator was removed, and the subject, as directed, exhaled sharply blowing water from the relief valve. This was repeated about five times. The subject did require the demand regulator several times while blowing water from the system. Once the water was blown out of the system, the subject did not bottom the breathing bag or use the demand regulator for the remainder of the run. This confirmed that water buildup on the valve was affecting its performance. This situation would not occur in 0 'g' operation and could be eliminated in subsequent units by locating the valve vertically with respect to gravity instead of horizontally as in the prototype system.

The system steady state inhalation resistance was determined to assist in evaluation of the higher than expected inhalation resistance observed during the manned test. This information is provided in Figure 4-6-40. At the peak flow used for designing the system, the inhalation resistance was as had been predicted, thus indicating that the peak flow was higher than used in the design of the system. The actual flow experienced during the manned tests were estimated using the LiOH canister inlet CO_2 level and inlet and outlet temperatures assuming that the work rate was 235 watts (800 Btu/hr). Using the resistance versus peak flow data shown in Figure 4-6-40, the estimated resistance versus time was established. This is shown in Figures 4-6-41 and 4-5-42 which show the inhalation resistance versus test duration for the first and second tests respectively. These Figures are composites showing the originally estimated resistance, the estimated resistance based on CO_2 level, the high and low limits of the actual inhalation resistance, and inhalation resistance recorded most often during the test. The proximity of the actual resistance and the resistance estimated from the CO_2 level confirms that the subject was ventilating at a higher rate than used in the system design. This was due in part to the subject's normal breathing pattern. A number of factors influence the difference between the actual resistance and the estimated resistance

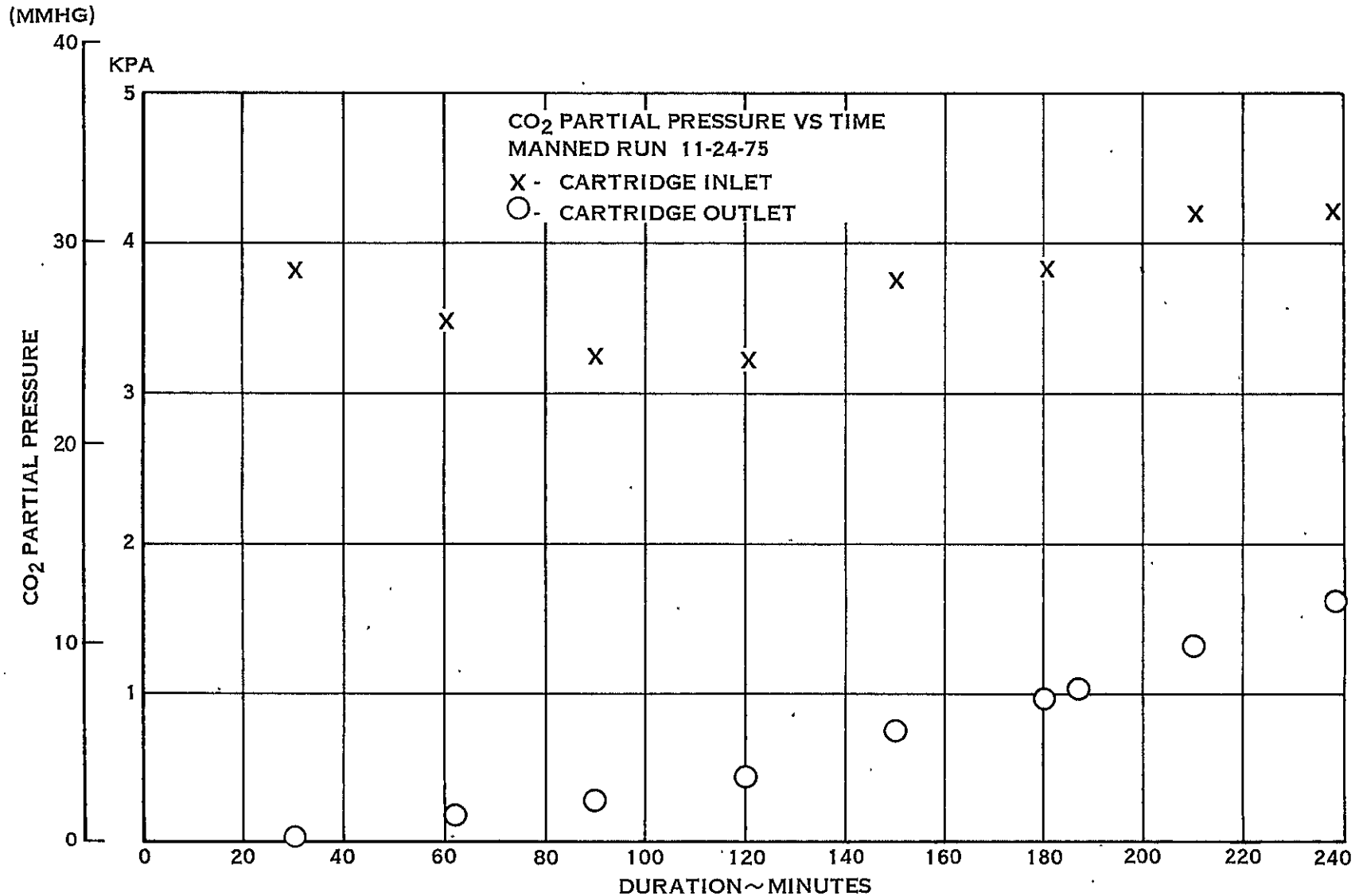


FIGURE 4-6-31 CO_2 PARTIAL PRESSURE VS TIME

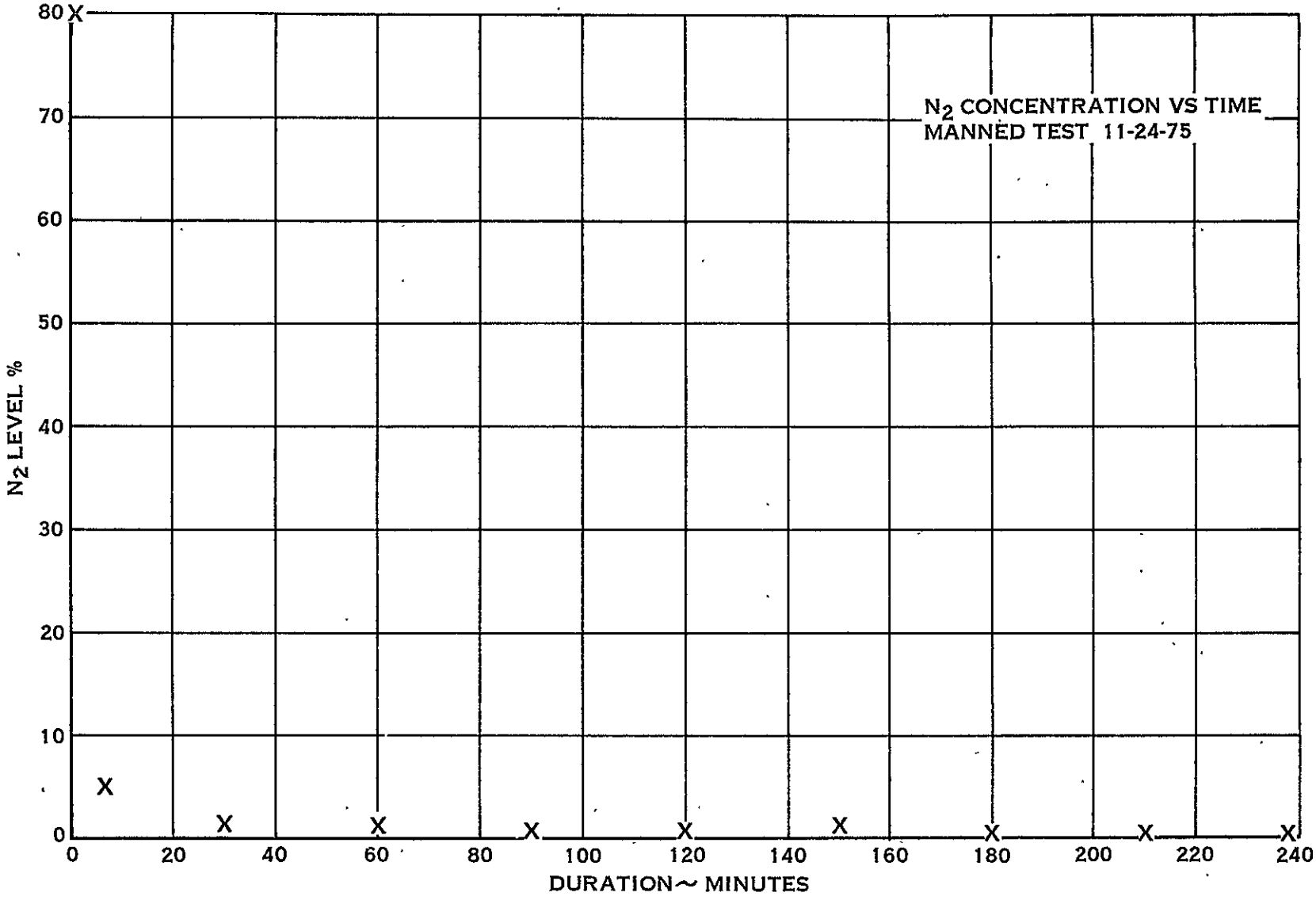


FIGURE 4-6-32 N_2 CONCENTRATION VS TIME

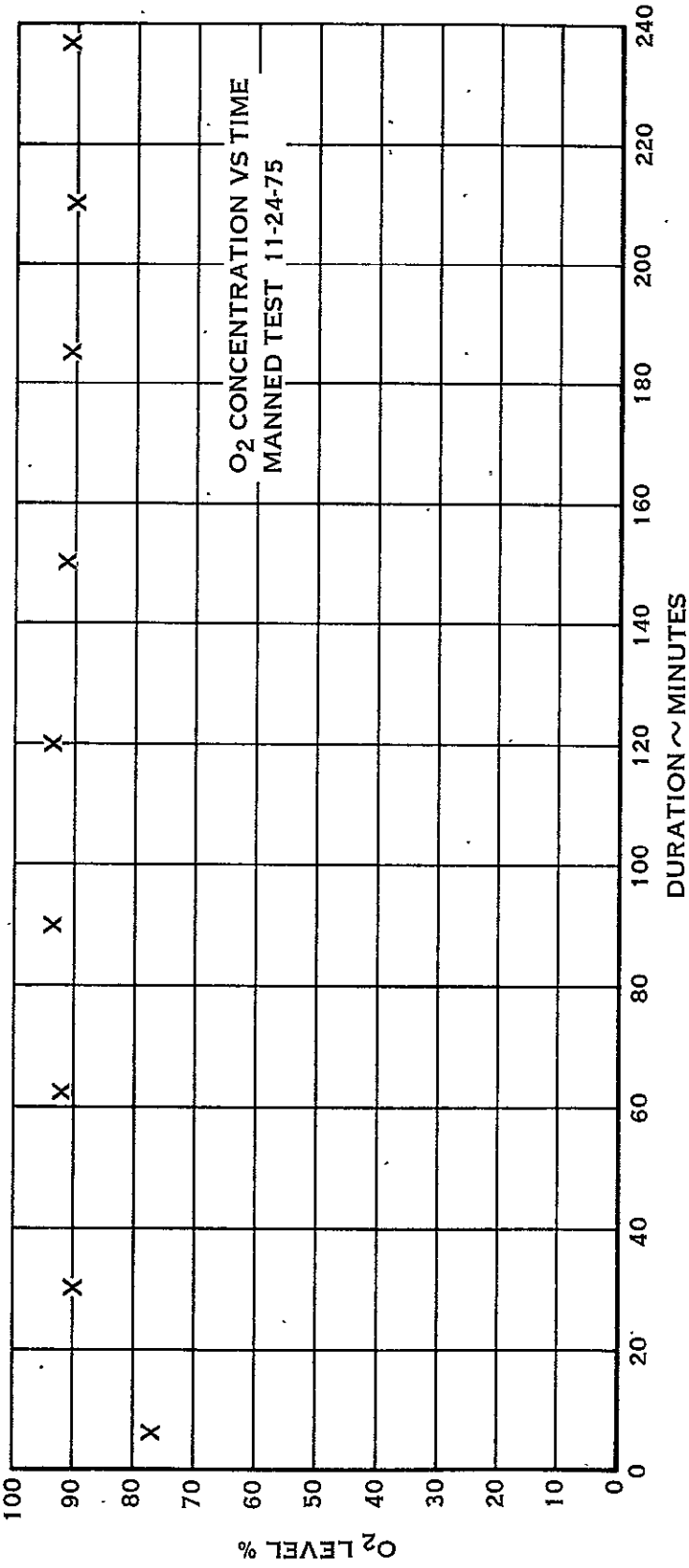


FIGURE 4-6-33 O_2 CONCENTRATION VS TIME

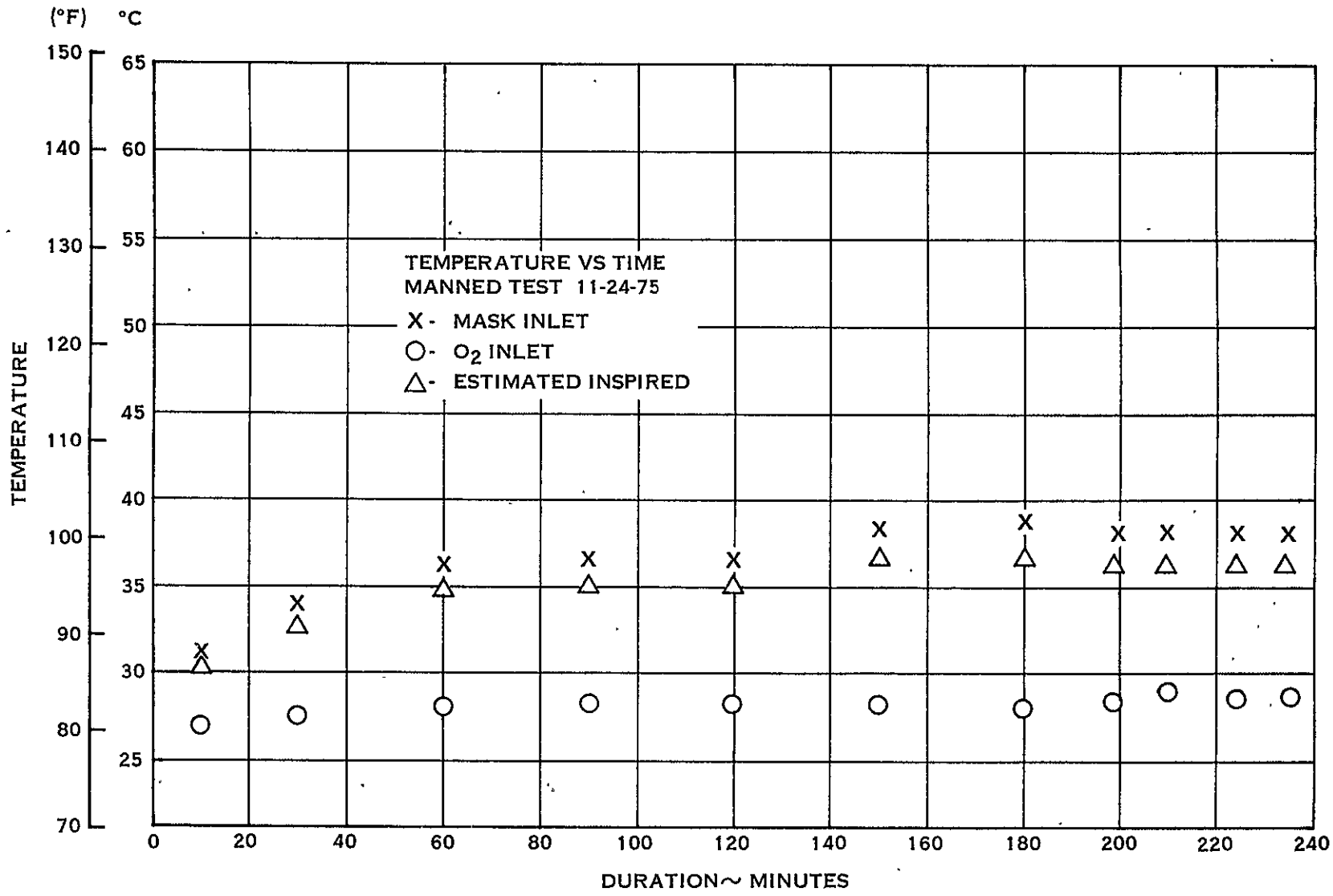


FIGURE 4-6-34 TEMPERATURE VS TIME

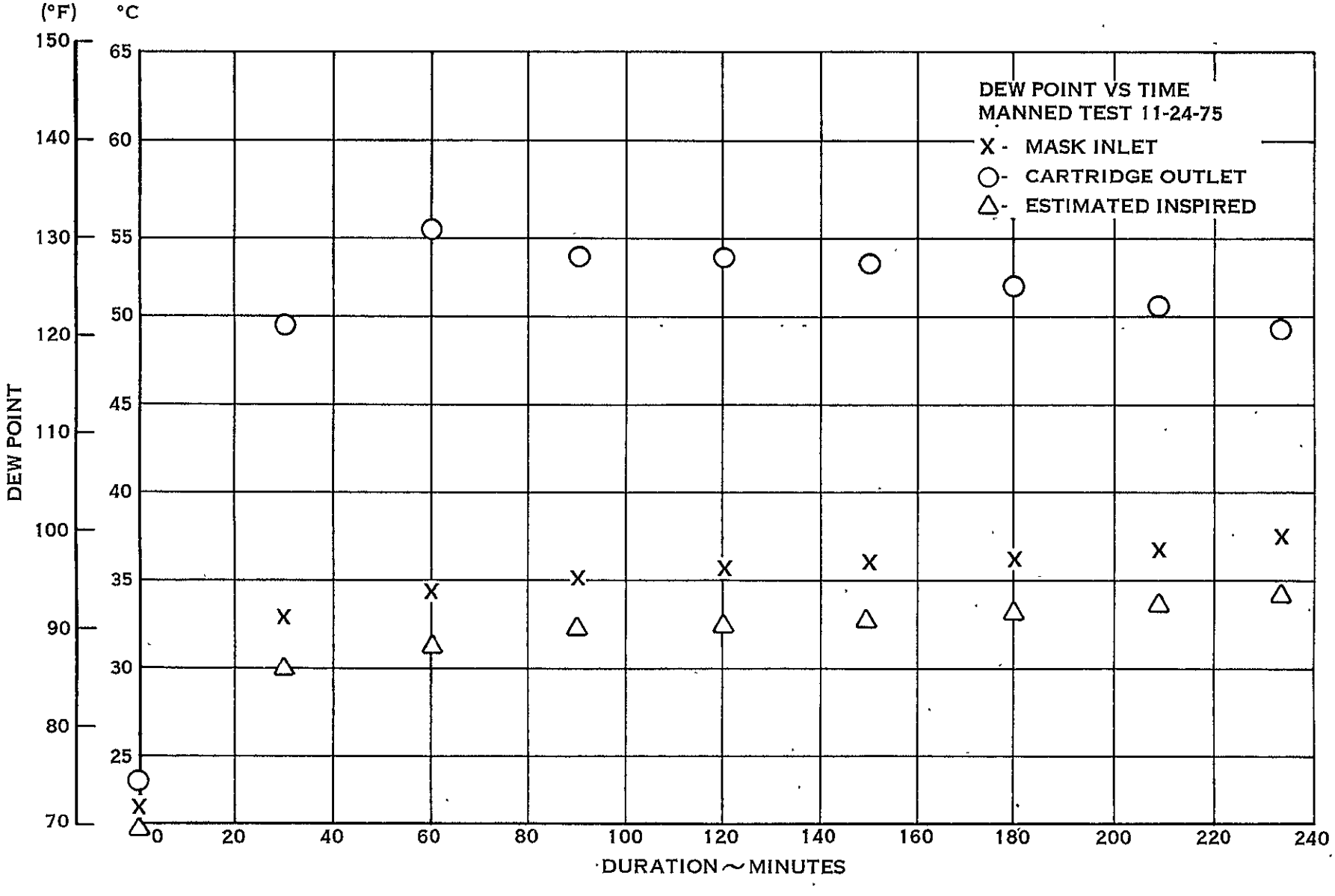


FIGURE 4-6-35 DEW POINT VS TIME

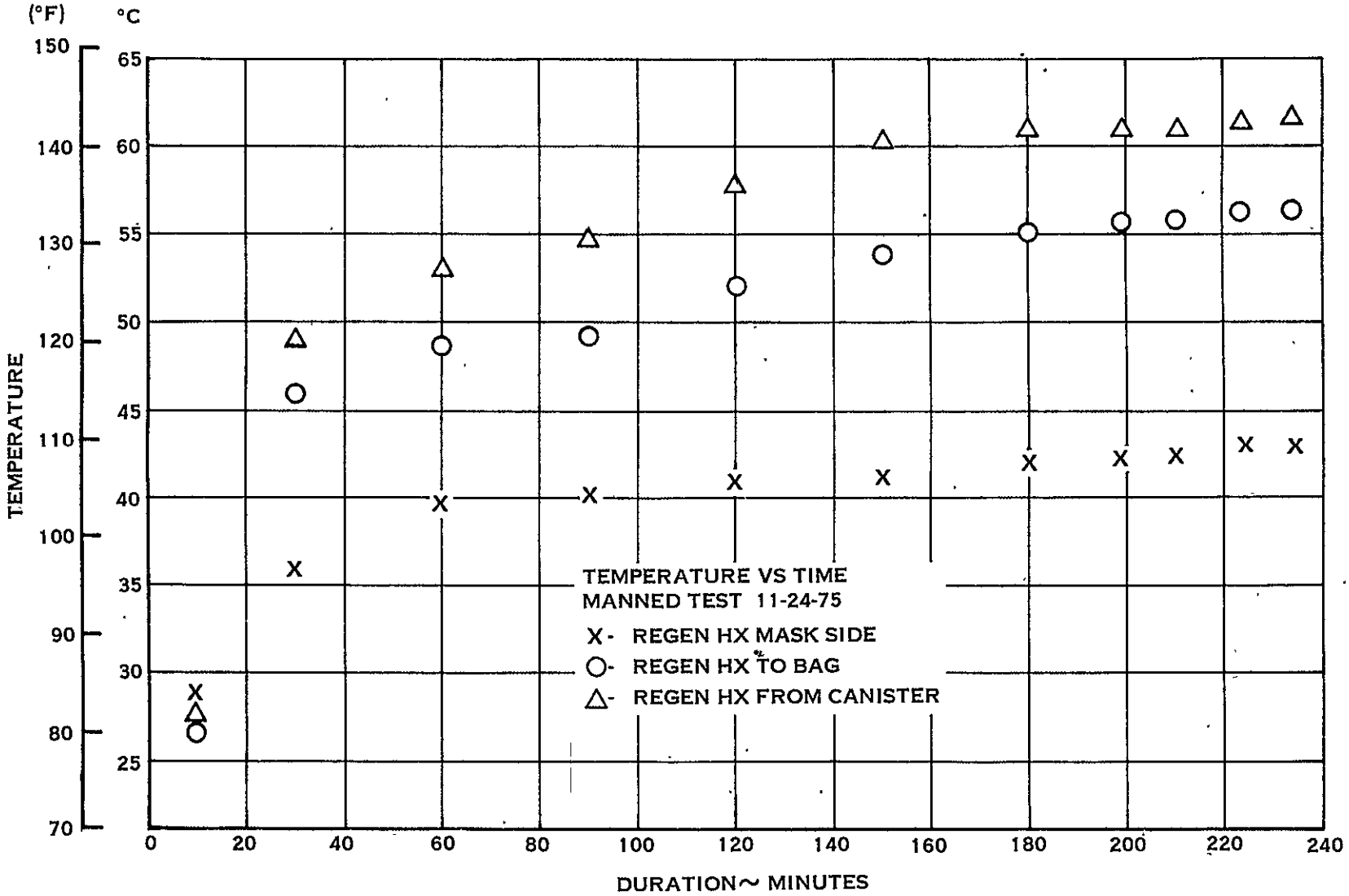


FIGURE 4-6-36 TEMPERATURE VS TIME

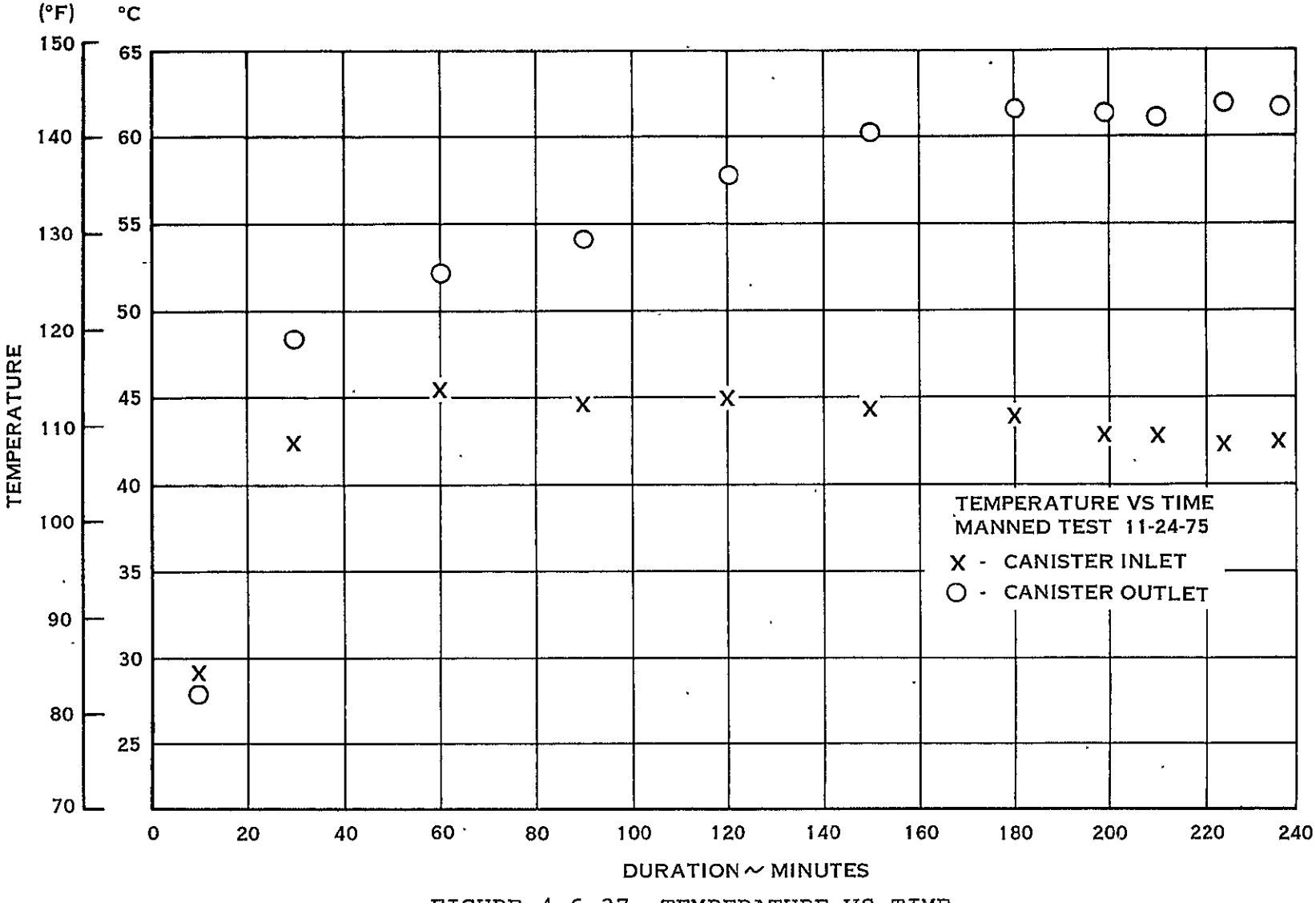


FIGURE 4-6-37 TEMPERATURE VS TIME

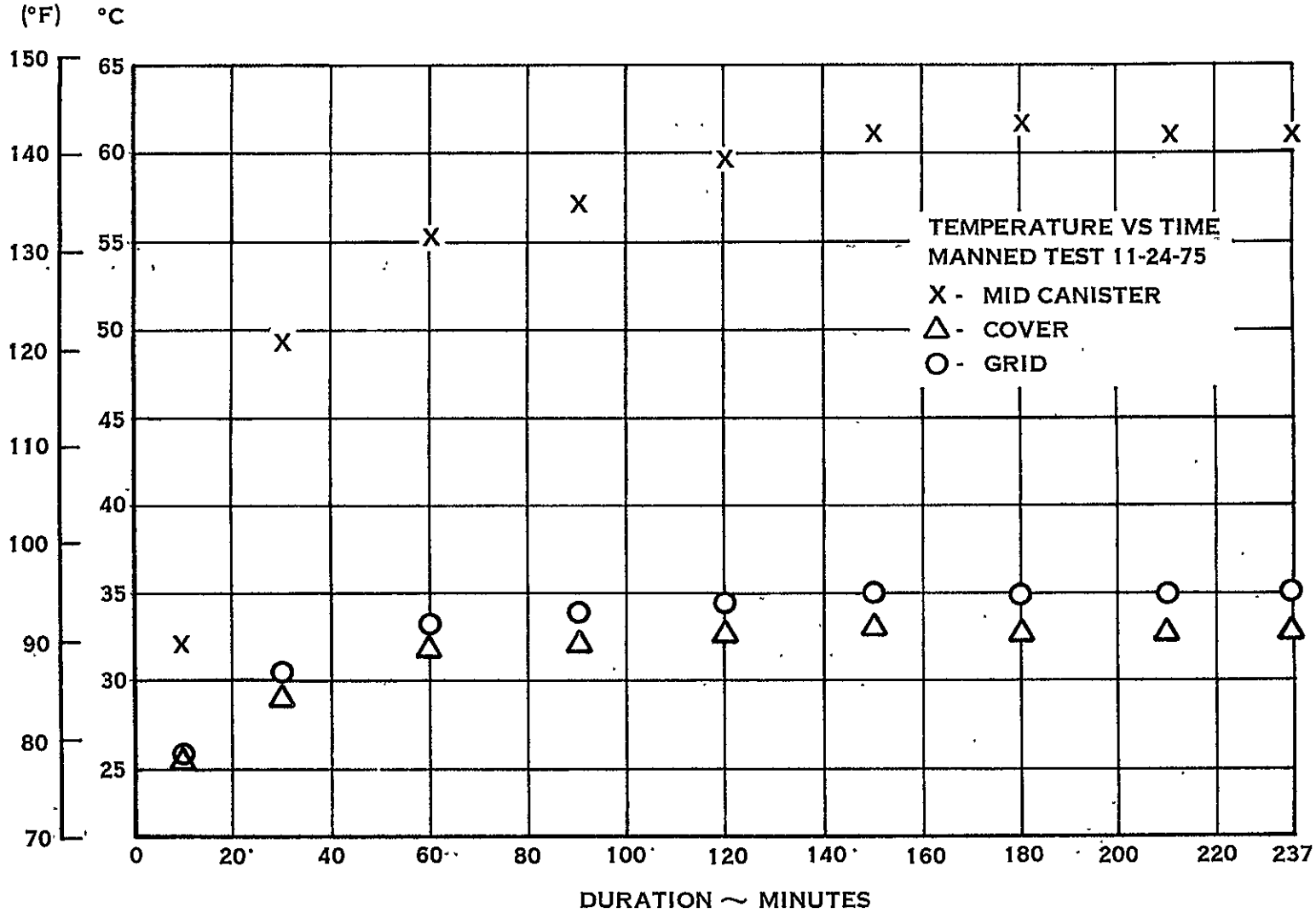


FIGURE 4-6-38 TEMPERATURE VS TIME

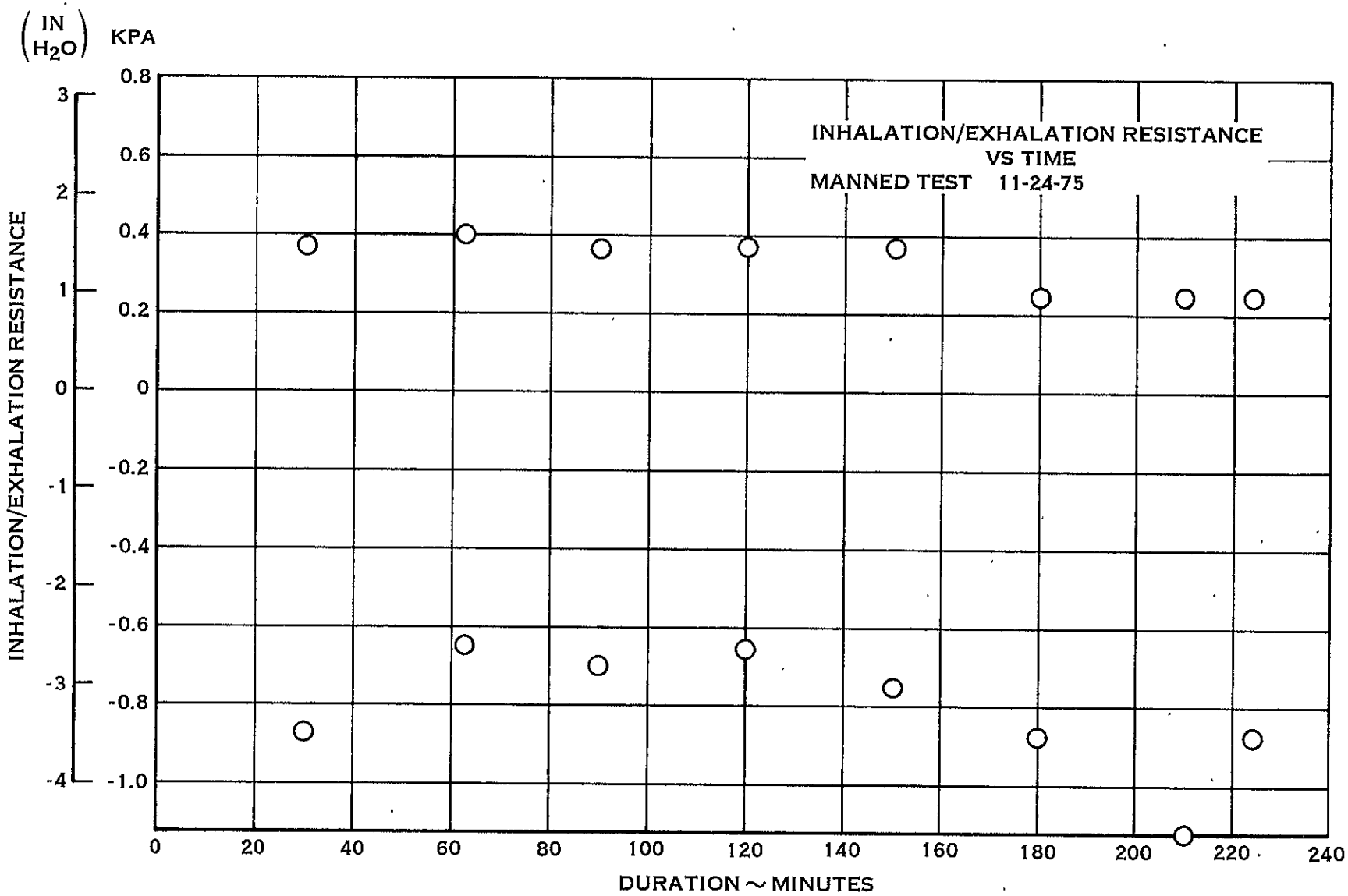


FIGURE 4-6-39 INHALATION/EXHALATION RESISTANCE VS TIME

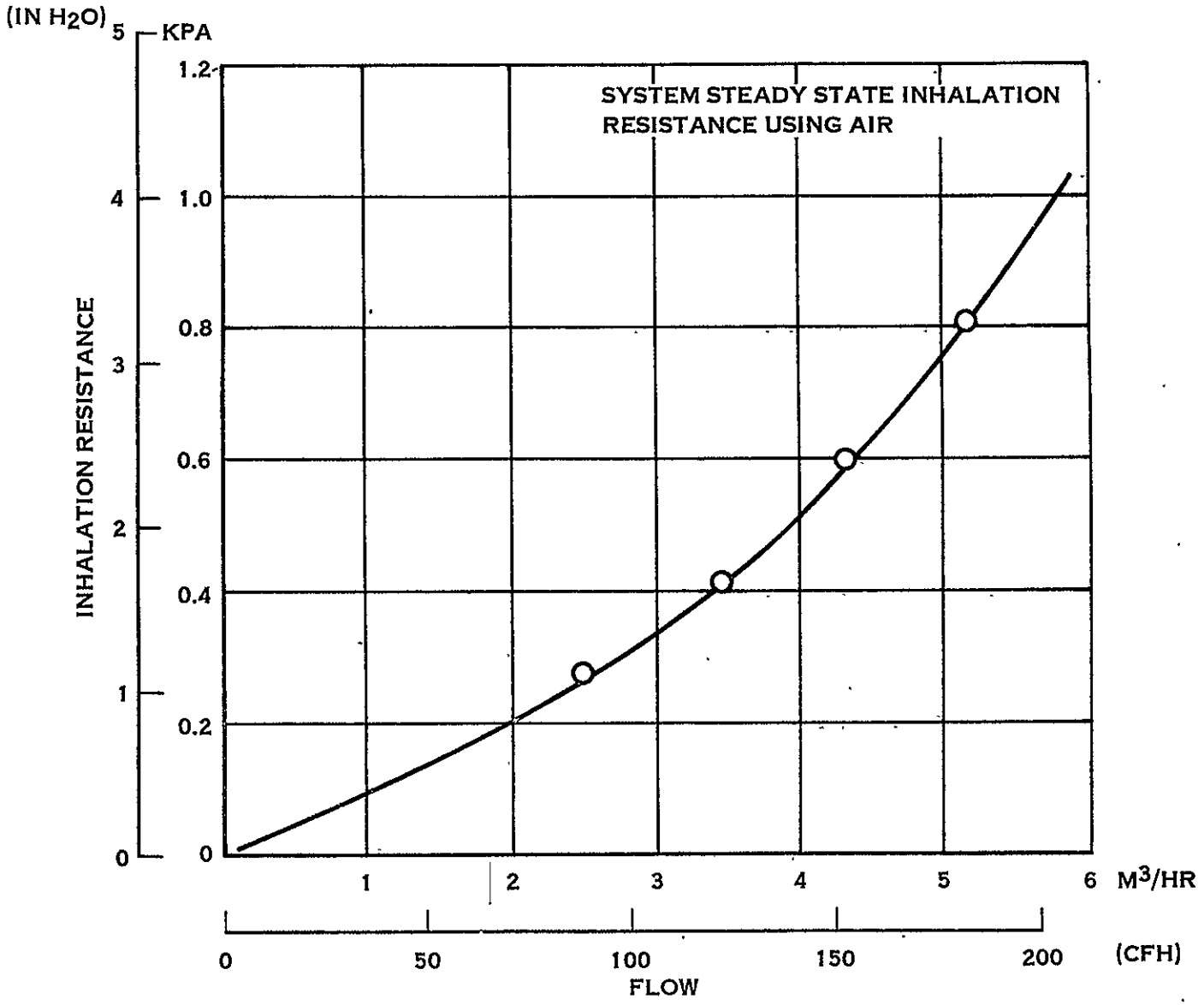


FIGURE 4-6-40 SYSTEM STEADY STATE INHALATION RESISTANCE USING AIR

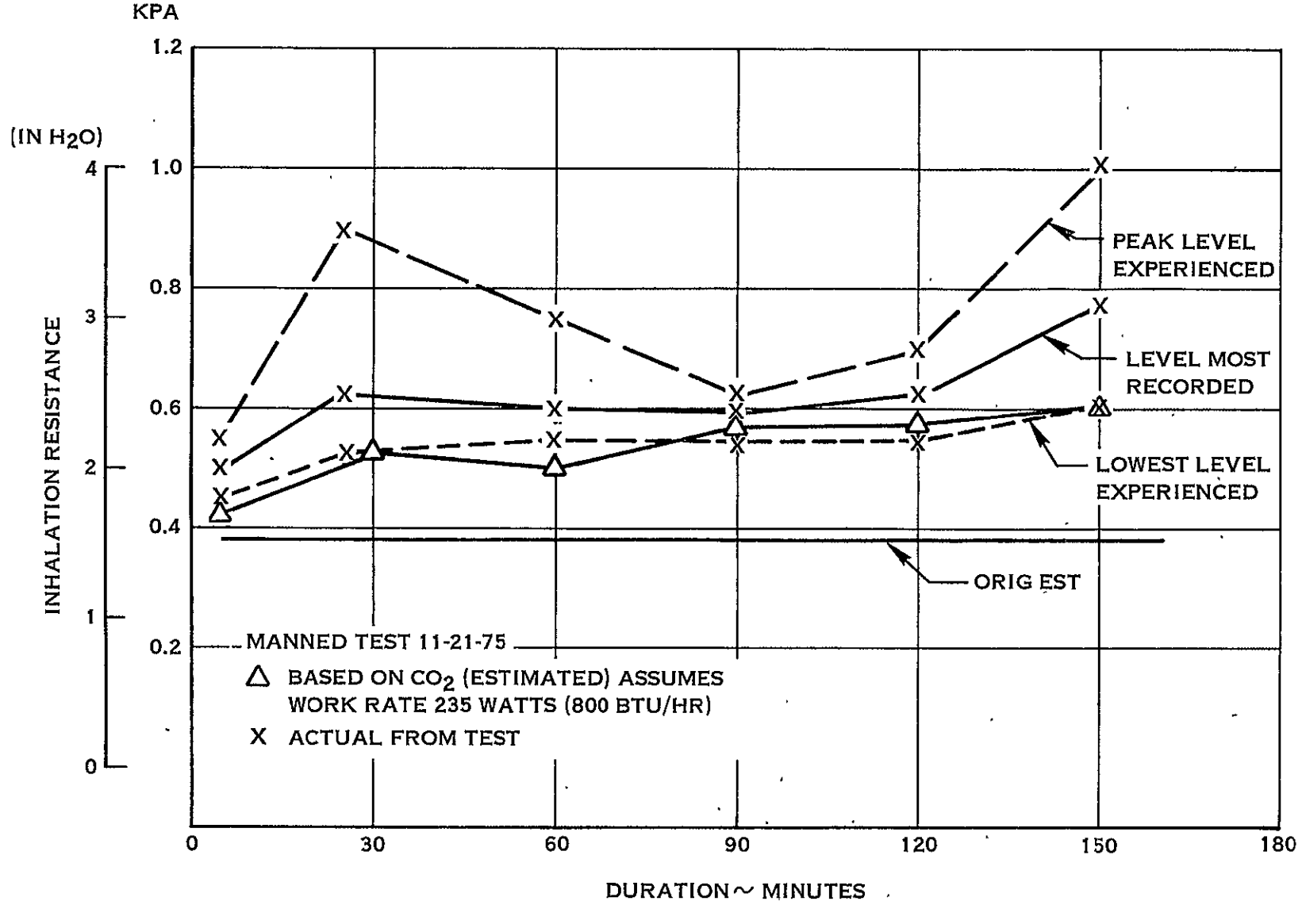


FIGURE 4-6-41 MANNED TEST

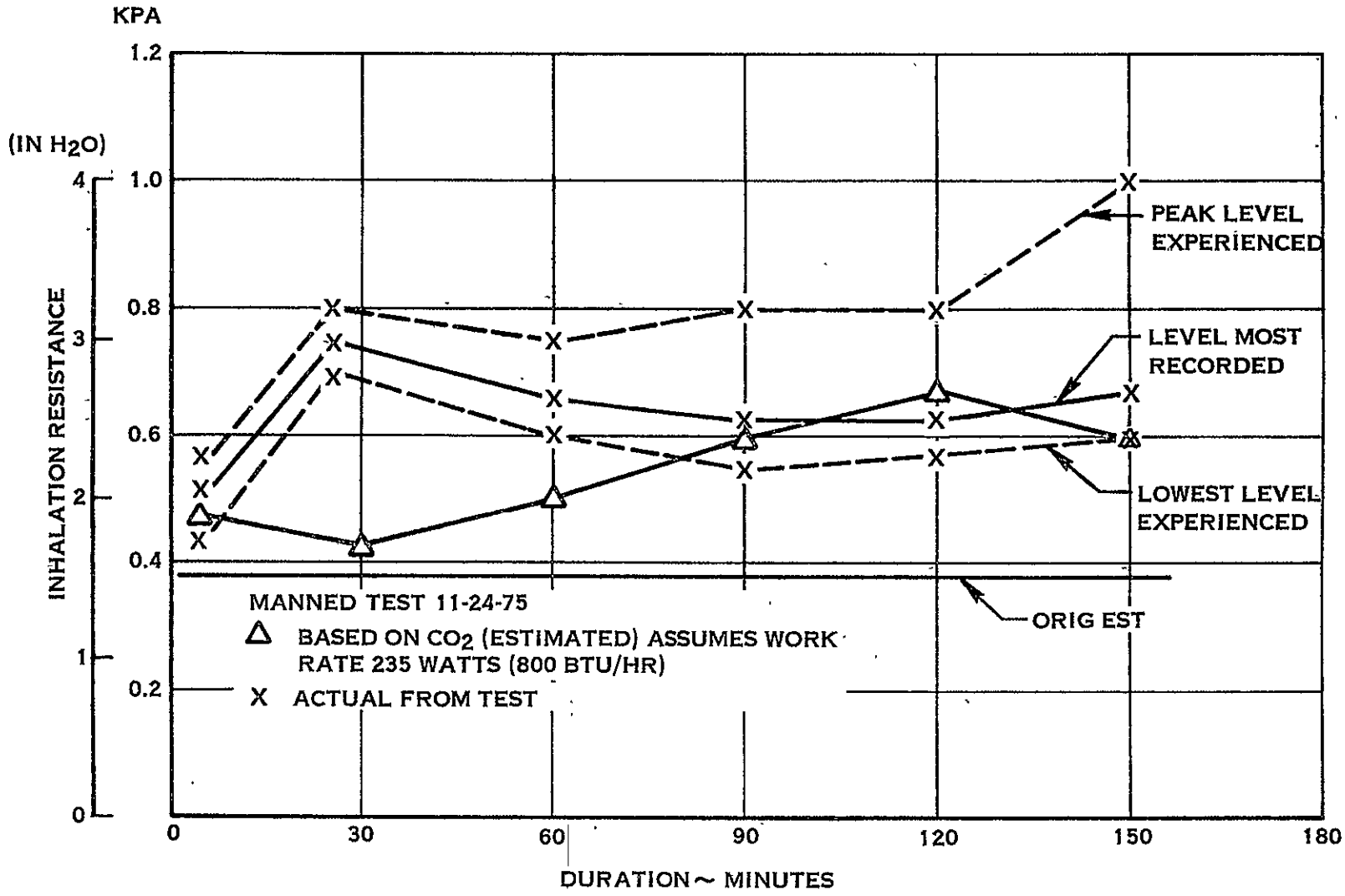


FIGURE 4-6-42 MANNED TEST

4.6.2 (Continued)

based on CO_2 level. These include a) subjects breathing pattern (peak levels shown at 25 and 60 minutes on Figure 4-6-41 resulted from 2 to 3 short deep breaths, whereas most other inhalations were of longer duration); b) subjects work rate (estimated resistance based on CO_2 level assumes 235 watts (800 Btu/hr) work rate, higher work rate would decrease estimated resistance); c) water collection in regenerative heat exchanger (it is estimated that the bed collects about 10 cc of water which contributes ~ 50 Pa (.2 in H_2O) to breathing resistance; and d) breathing bag bottoming (late in run, subject reported feeling the bag bottom - this supported by inhalation resistance pattern for peak levels experienced). The number of variables which occur during manned test make it impossible to isolate and quantify factors influencing the results of the test. As a result of this test series, it is apparent that unmanned testing is mandatory to allow control of the variables in order to properly engineer a system of this type.

From review of the system test results and system design, it is believed that a system of this type could be designed to operate with an inhalation resistance of 373 Pa (1.5 in H_2O) at a work rate of 235 watts (800 Btu/hr). Attempting to achieve this resistance level at higher work rates would impose significant penalties on the system not believed justified because of the short operation of durations at the higher work rates.

The prototype POS, provided under this contract, meets the requirements of the Work Statement and is suitable for further unmanned and manned testing.

5.0 CONCLUSIONS

The POS program has defined a breathing system usable for denitrogenization, emergency intravehicular operation and for emergency rescue operation. The system meets the Space Shuttle objectives of low cost, minimum maintenance, long life, low weight, and low volume. The POS evolved during this contract is also simple, reliable, and easy to operate. The prototype portable oxygen subsystem fabricated and tested during this program meets the requirements of the Work Statement and is suitable for additional manned and unmanned testing.

APPENDIX A

POS ANALYTICAL MODEL

SUMMARY

POS ANALYTICAL MODEL SUMMARY

The POS was modeled using a combination of the IBM Continuous System Modeling Program (CSMP) and Fortran IV and is operational on Hamilton Standard IBM 370 computer.

The basic nodes, shown in Figure A-1, were utilized to describe the various components of the system. There was also a regenerative heat exchanger subroutine to subdivide this component into any desired number of sections.

Each node is convectively linked to the internal gas and (in one "g") the external environment. Operation in one "g" and zero "g" are simulated by changing the convective heat transfer coefficient. Radiation to the environment is considered as is radiative transfer between the LiOH cartridge O.D. and the canister which serves as the outer radiator. Conduction between the LiOH chemical bed and the outer containment is also considered.

Mathematically, each inhalation or exhalation is treated as a separate transient with initial conditions taken from the previous breath. With a breathing rate of 15 breaths per minute, or two seconds per inhalation and two seconds per exhalation, a total of 1,800 transient solutions are obtained for each hour of real time run. A total of 136 output variables are available at a frequency of up to five times per inhalation or exhalation. Management of this volume of data would be at best a difficult task if normal computer print out were utilized. This has been eased by storing all run output on tape. Either print or plot output may be recalled for any desired parameters or time frame and in frequency required as shown by the sample plots shown in Figure A-2 through A-7. The program flow chart is shown starting on page A-9.

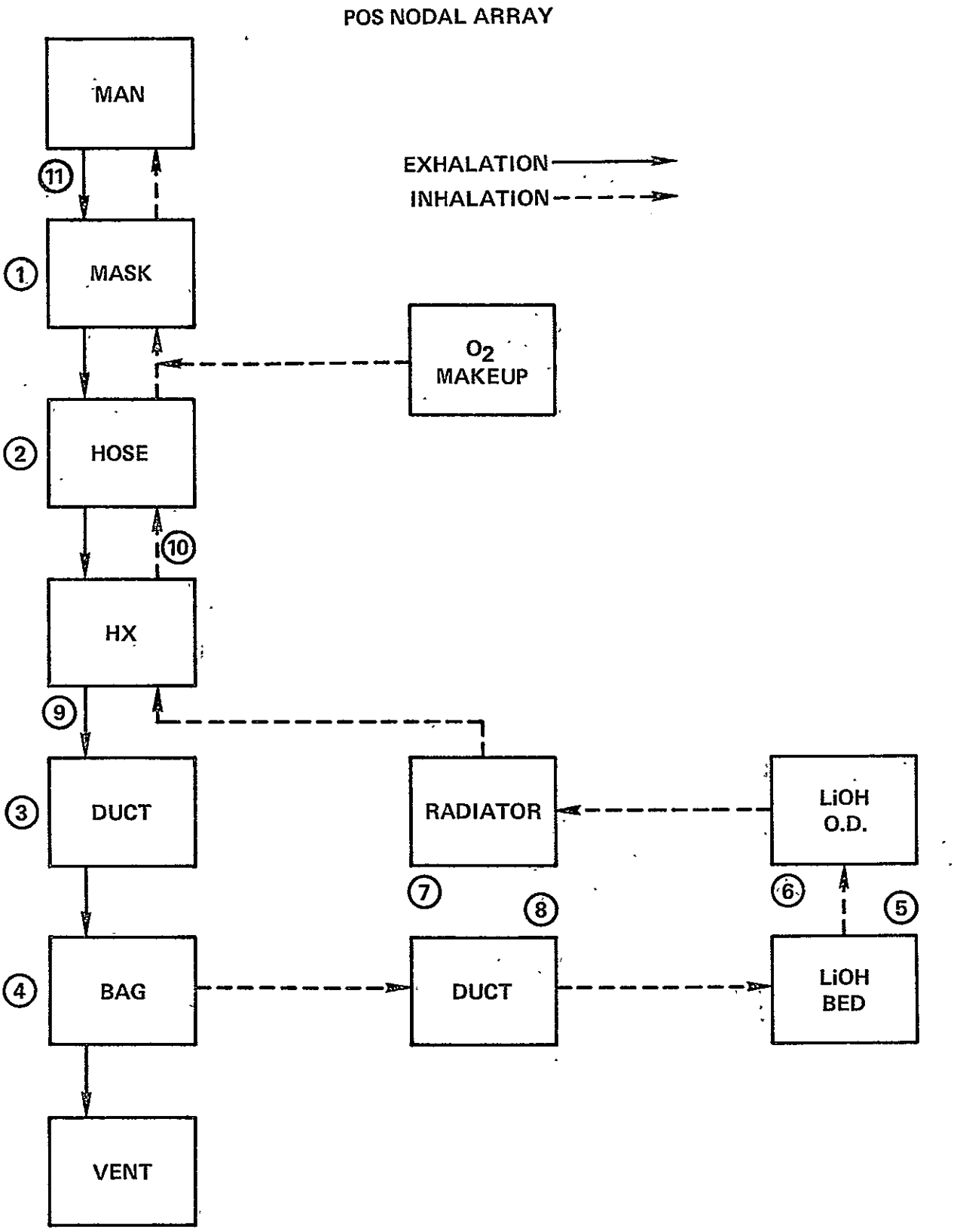

POS NODAL ARRAY
MAN
11
EXHALATION
INHALATION
1
MASK
O_2 MAKEUP
2
HOSE
10
HX
9
3
DUCT
RADIATOR
LiOH O.D.
7
8
6
5
4
BAG
DUCT
LiOH BED
VENT

Figure A-1

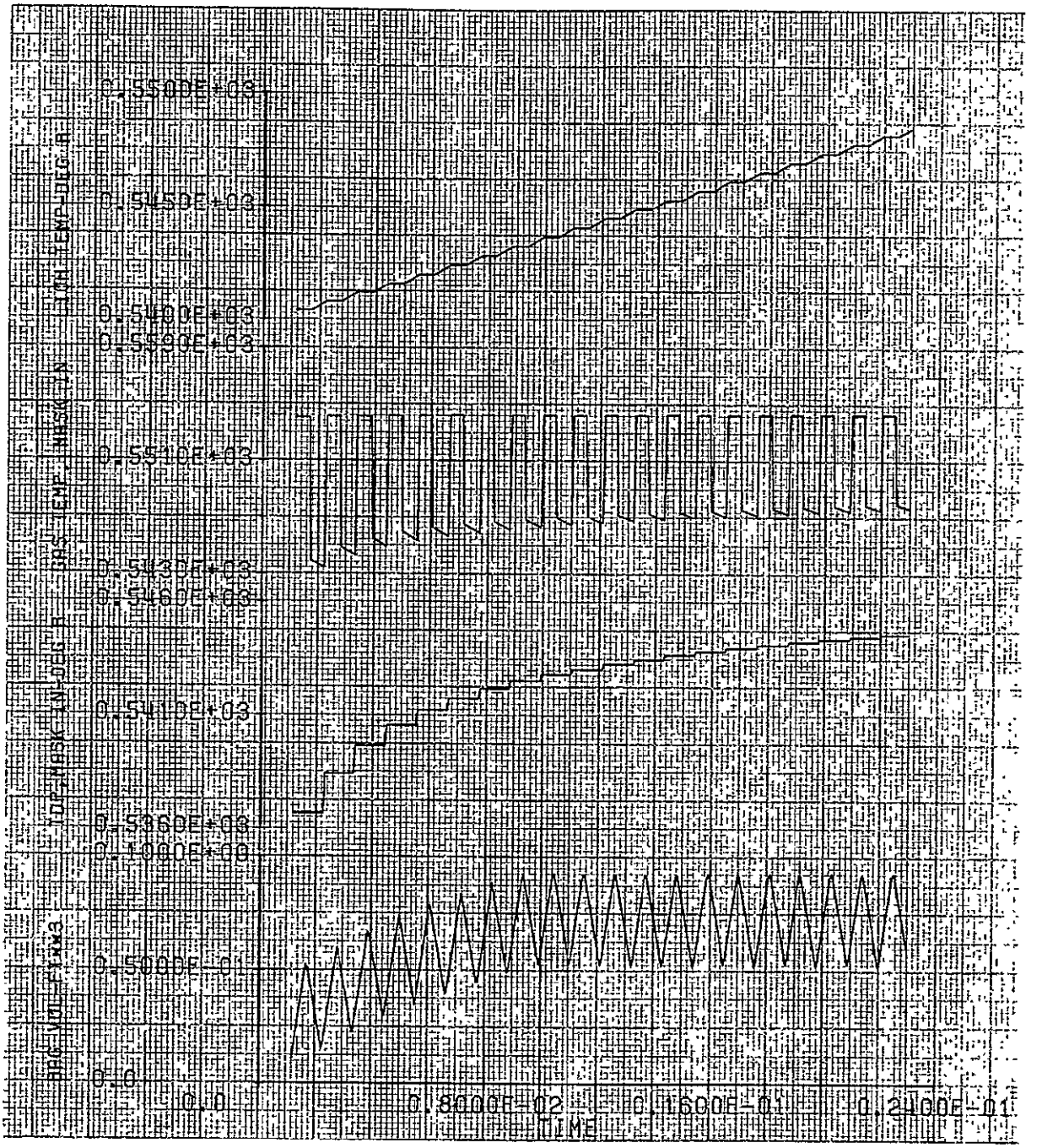


Figure A-2

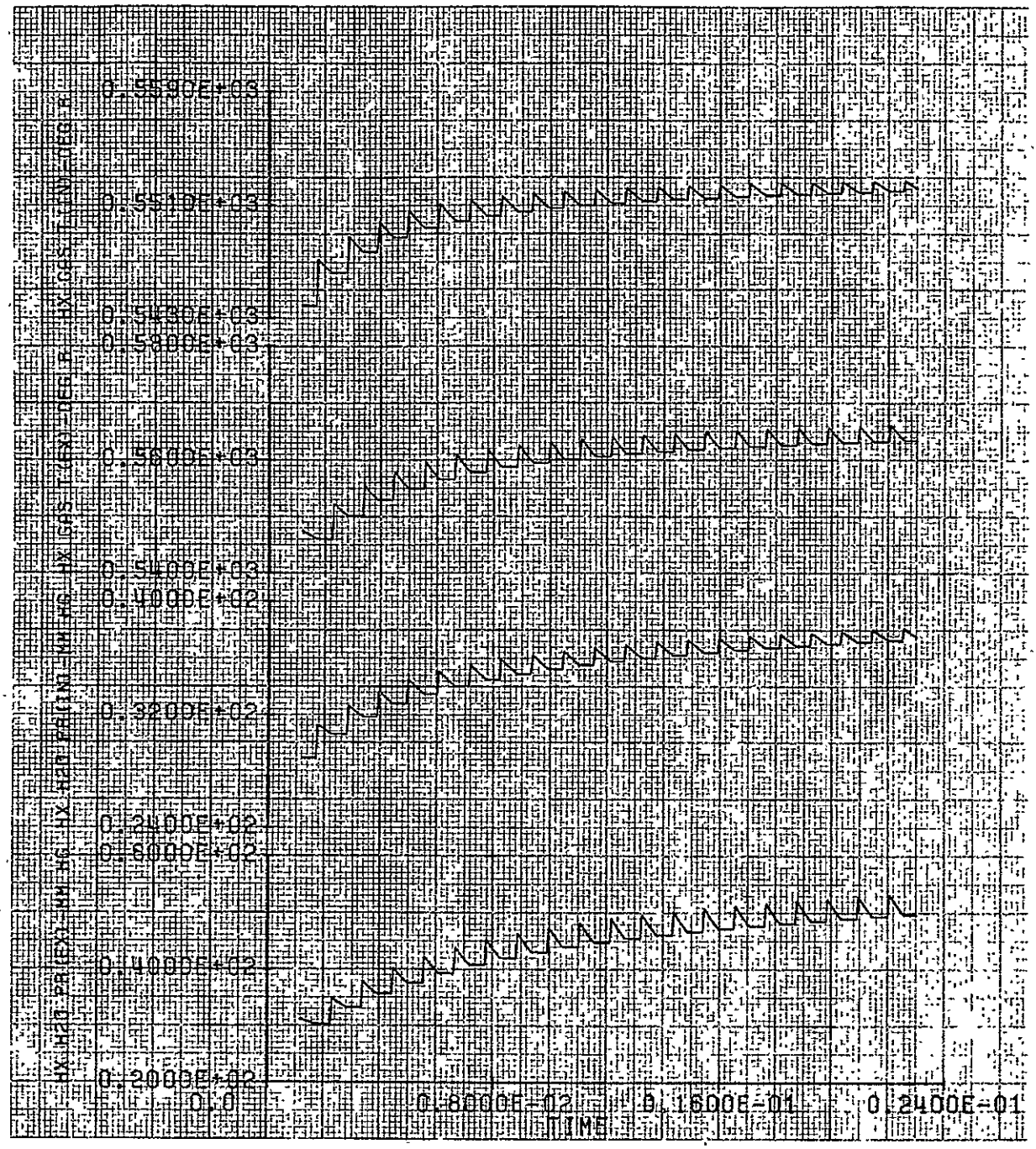

0.5590E+03
0.5510E+03
0.5430E+03
0.5300E+03
0.5800E+03
0.5400E+03
0.4000E+02
0.3200E+02
0.2400E+02
0.1600E+02
0.8000E+01
0.0
0.8000E-02
0.1600E-01
0.2400E-01
TIME

Figure A-3

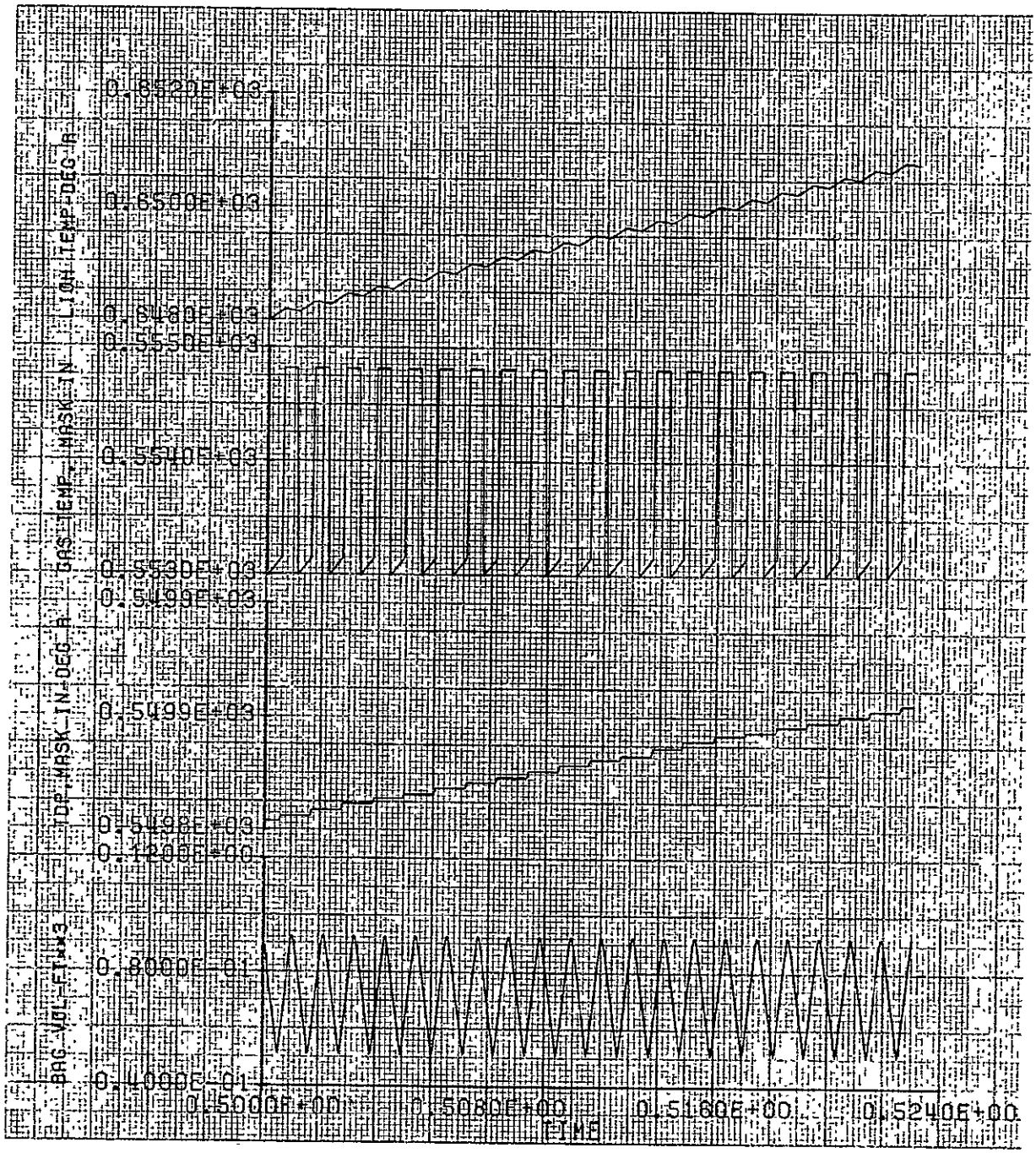


Figure A-4

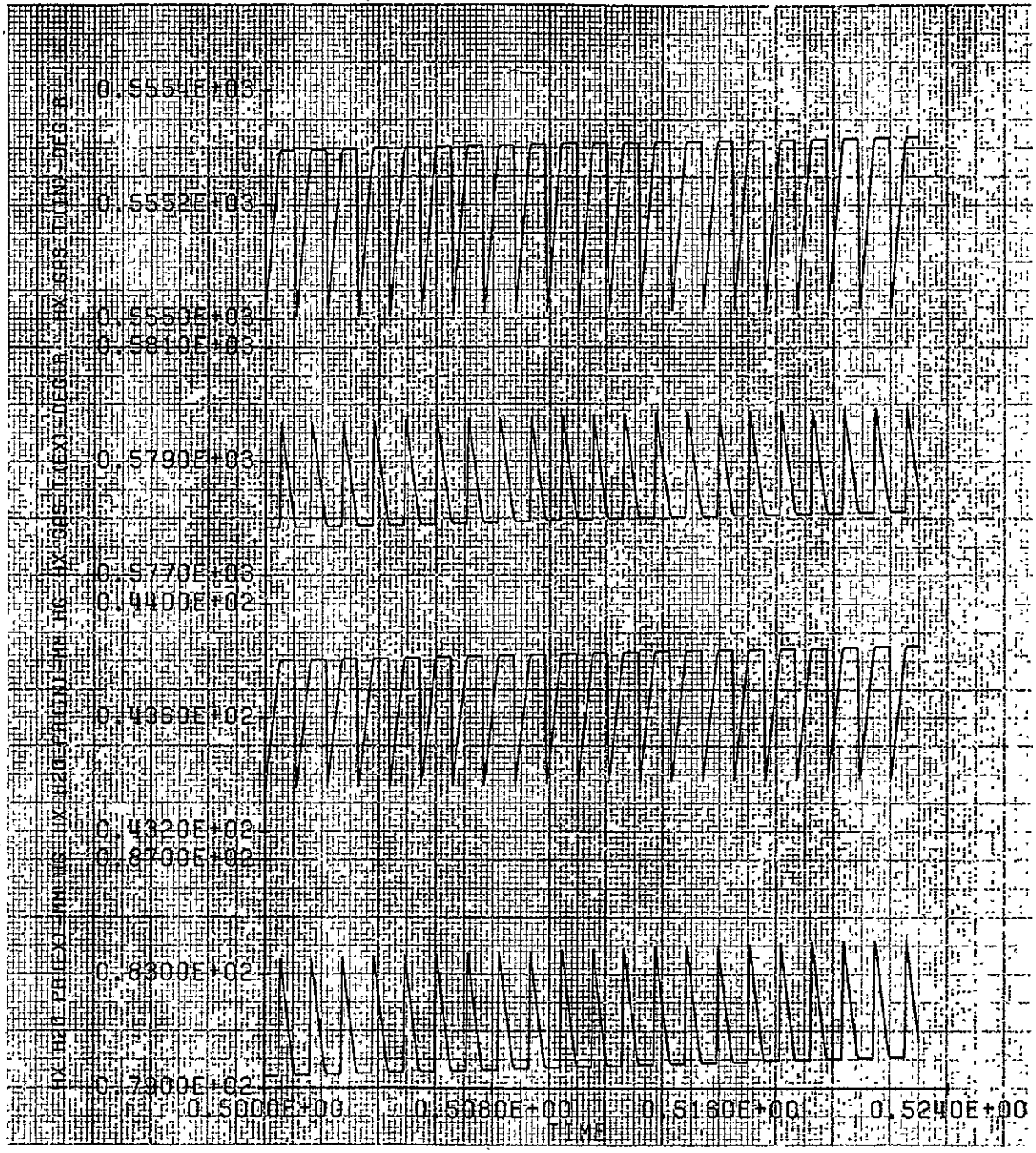

0.5554E+03
0.5552E+03
0.5550E+03
0.5810E+03
0.5790E+03
0.5770E+03
0.4400E+02
0.4360E+02
0.4320E+02
0.8700E+02
0.8300E+02
0.7900E+02
0.5000E+00
0.5080E+00
0.5160E+00
0.5240E+00
TIME

Figure A-5

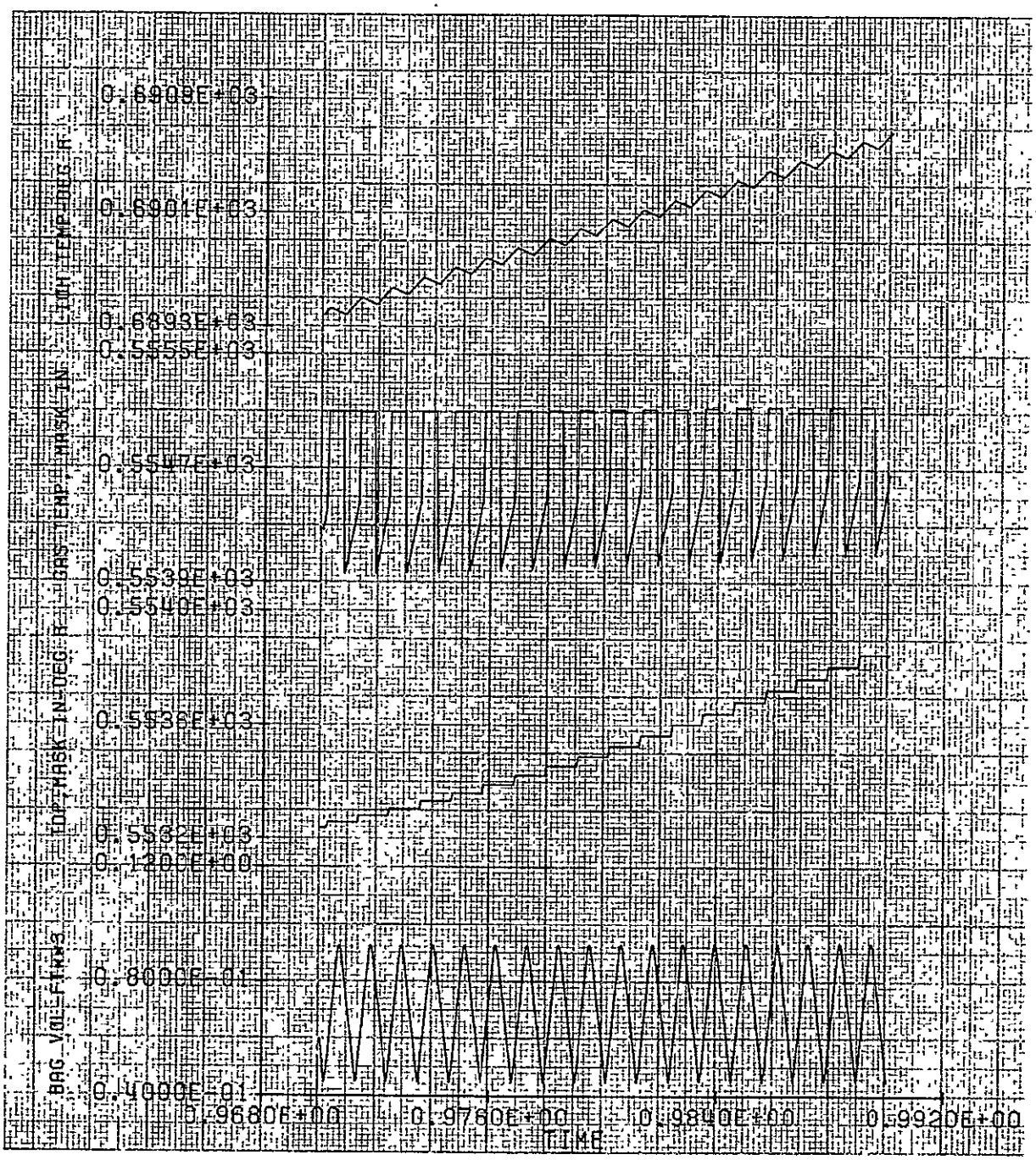

0.6900E+03
0.6901E+03
0.6893E+03
0.5555E+03
0.5547E+03
0.5539E+03
0.5540E+03
0.5536E+03
0.5532E+03
0.1200E+00
0.8000E-01
0.4000E-01
0.9680E+00
0.9760E+00
0.9840E+00
0.9920E+00
TIME
BAG VOLFLOWS
EDP TMASK IN DEG R
GAS TEMP, MASK IN

Figure A-6

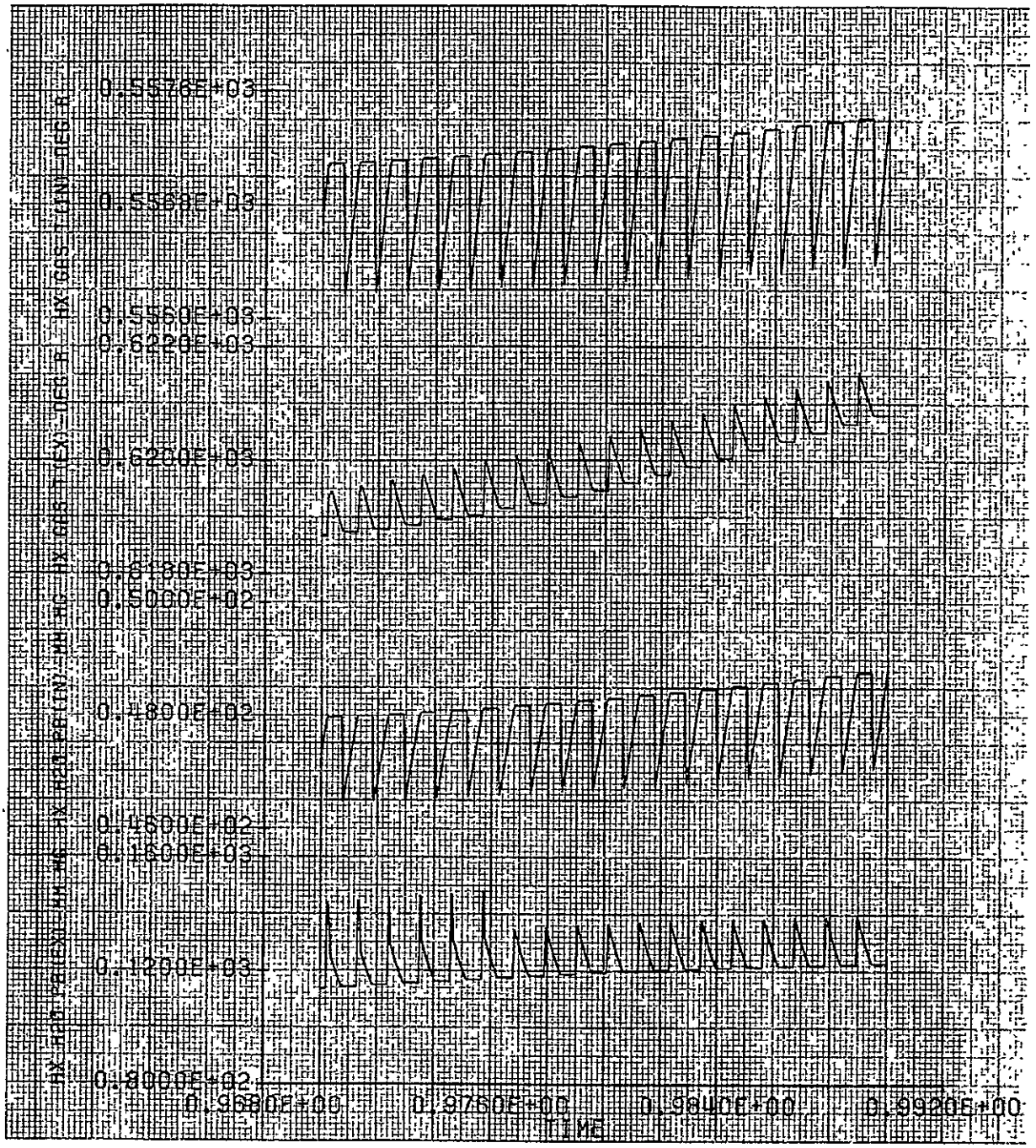


Figure A-7

PROGRAM NOMENCLATURE

C_{ij}	–	THERMAL CONDUCTIVE CONDUCTANCE BETWEEN NODES i AND j
D_{ij}	–	RADIATION CONDUCTANCE BETWEEN NODES i AND j
$CGAS_i$	–	CONVECTIVE CONDUCTANCE BETWEEN FLOWING GAS AND NODE i
$CAMB_i$	–	CONVECTIVE CONDUCTANCE BETWEEN NODE i AND AMBIENT
$DAMB_i$	–	RADIATIVE CONDUCTANCE BETWEEN NODE i AND AMBIENT
Q_i	–	INTERNAL HEAT GENERATION IN NODE i
ZM	–	NODAL THERMAL MASS
PH2OZO	–	HEAT EXCHANGER OUTLET CONDITION DURING INHALATION
PH2OXO	–	HEAT EXCHANGER OUTLET CONDITION DURING EXHALATION
PH2OMO	–	MAN OUTLET CONDITION
PH2OLO	–	LiOH OUTLET CONDITION
Σ	–	HEAT EXCHANGER EFFECTIVENESS
KANDK	–	STEAM TABLE SUBROUTINE

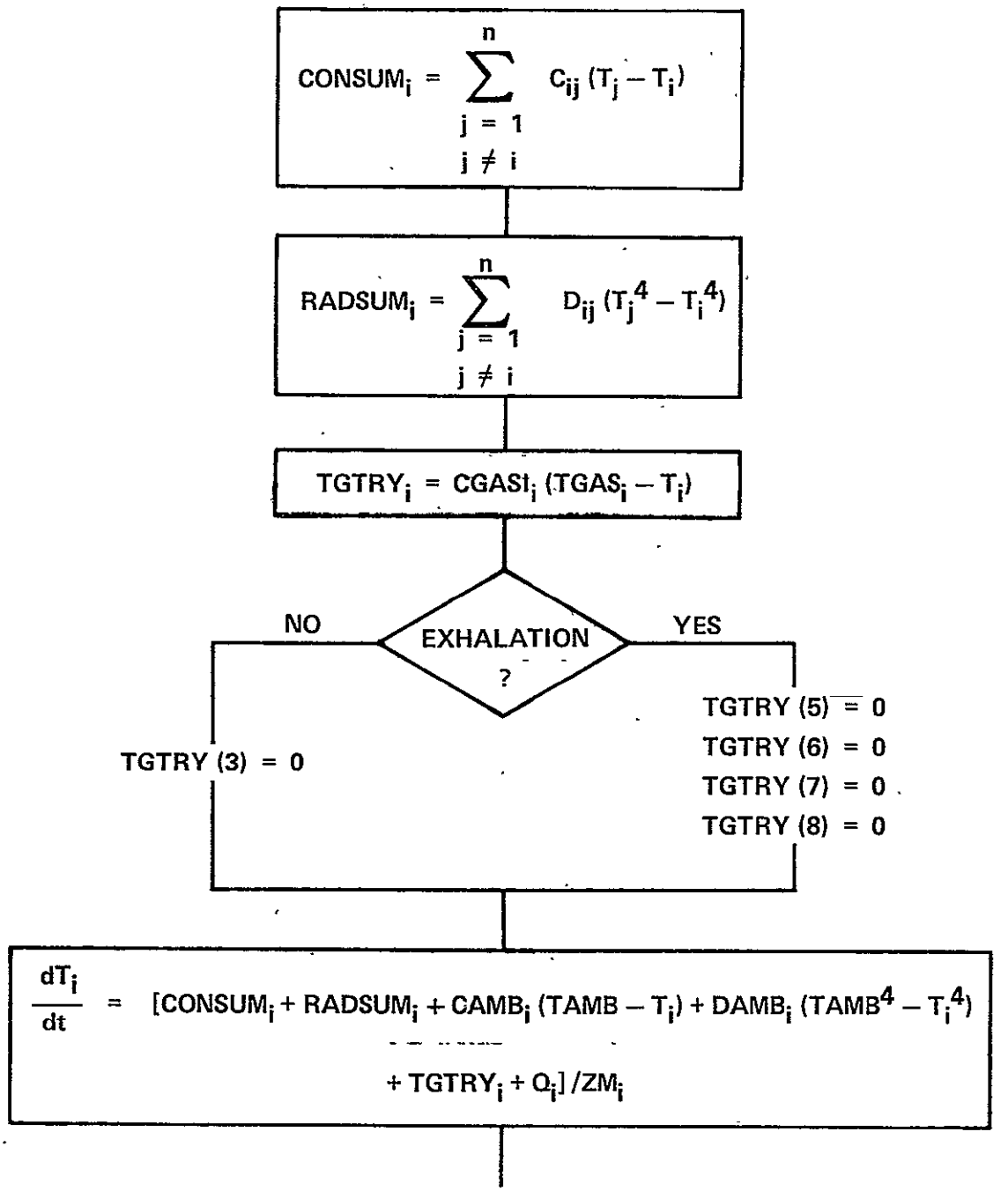
OUTPUT VARIABLES

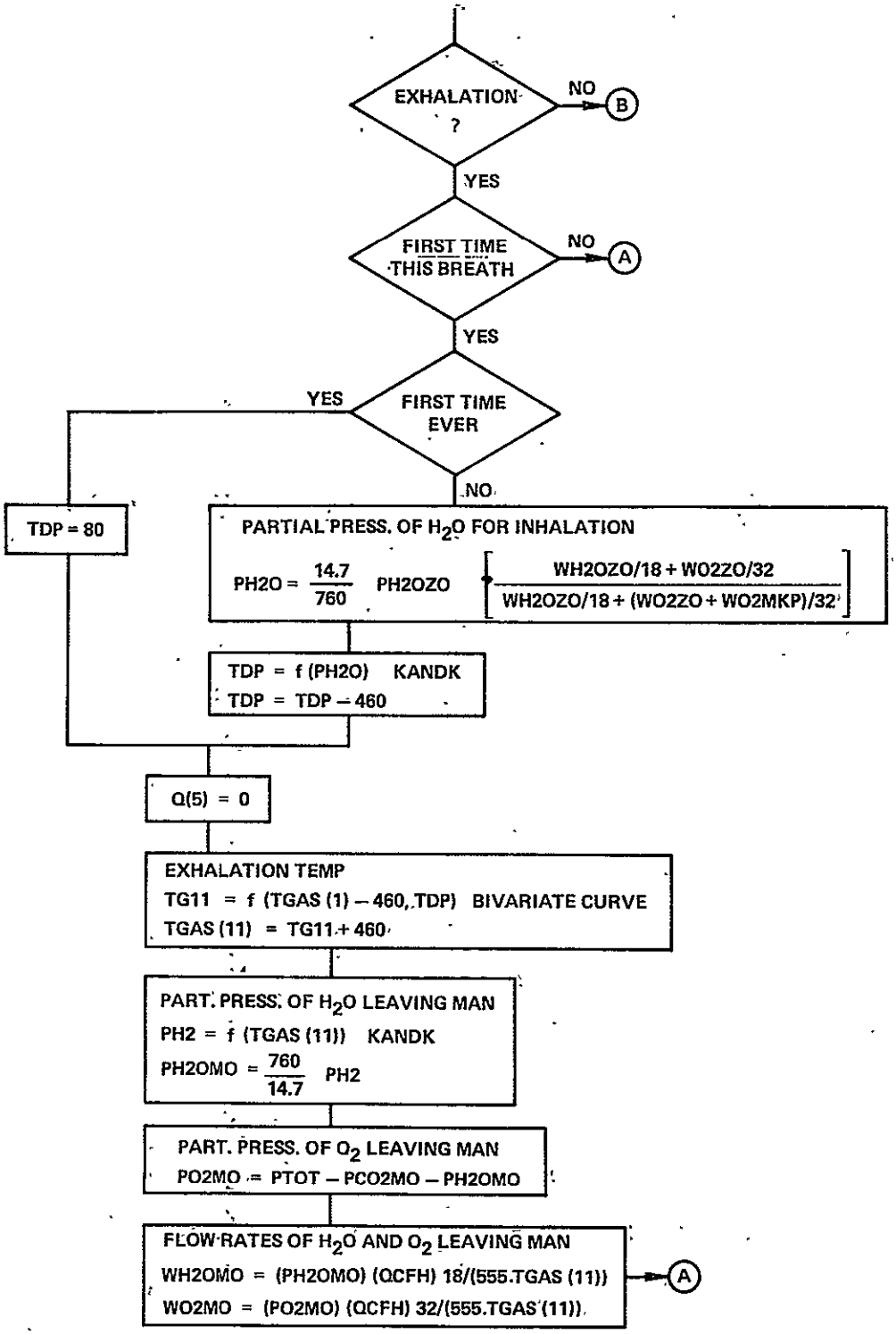
NODES (1) THRU (8)

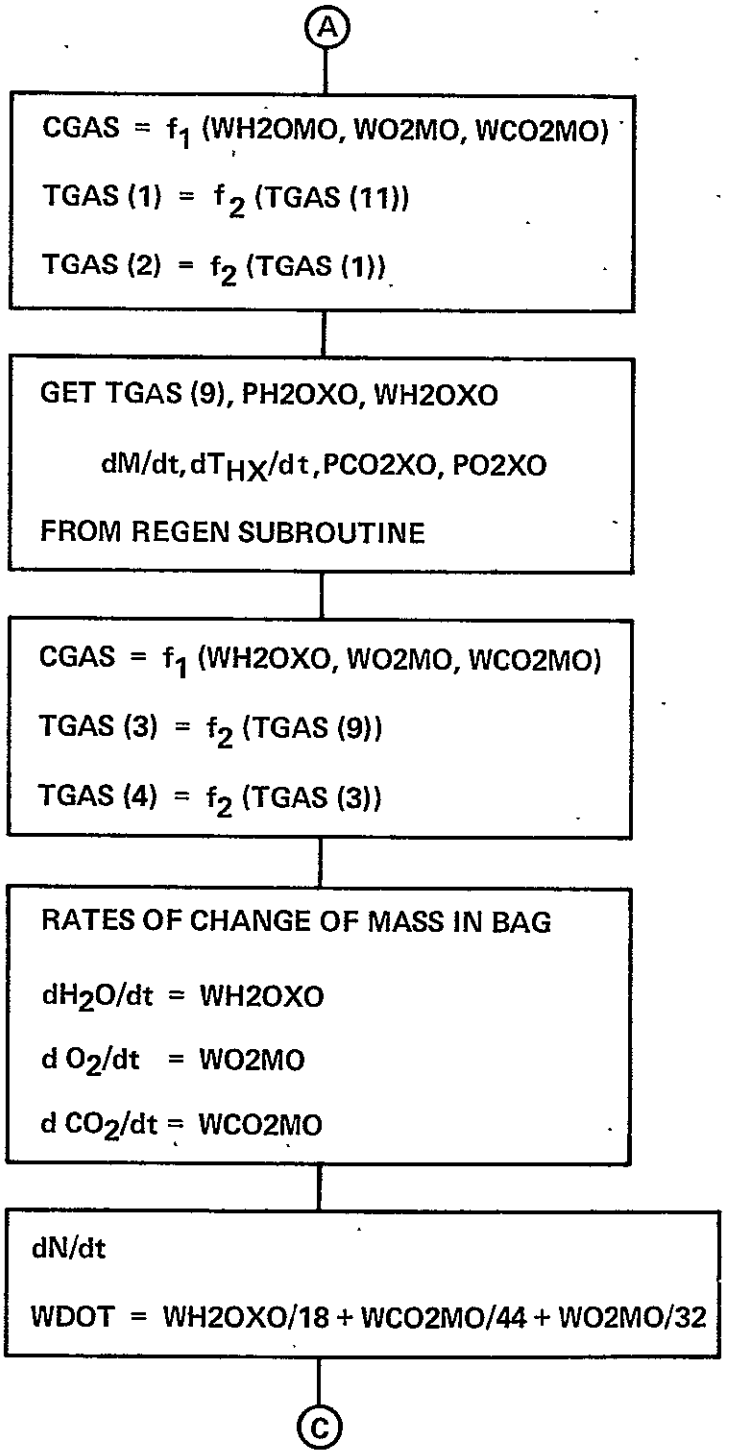
- NODAL TEMPERATURE
- d T_{NODE}/dt
- GAS TEMPERATURE OUT
- PARTIAL PRESSURE (H_2O, CO_2, O_2)
- WEIGHT FLOW (H_2O, CO_2, O_2)
- TOTAL MOLAR FLOW
- BAG VOLUME
- d V_{BAG}/dt
- MASS IN BAG (H_2O, CO_2, O_2)
- dM_{BAG}/dt (H_2O, CO_2, O_2)

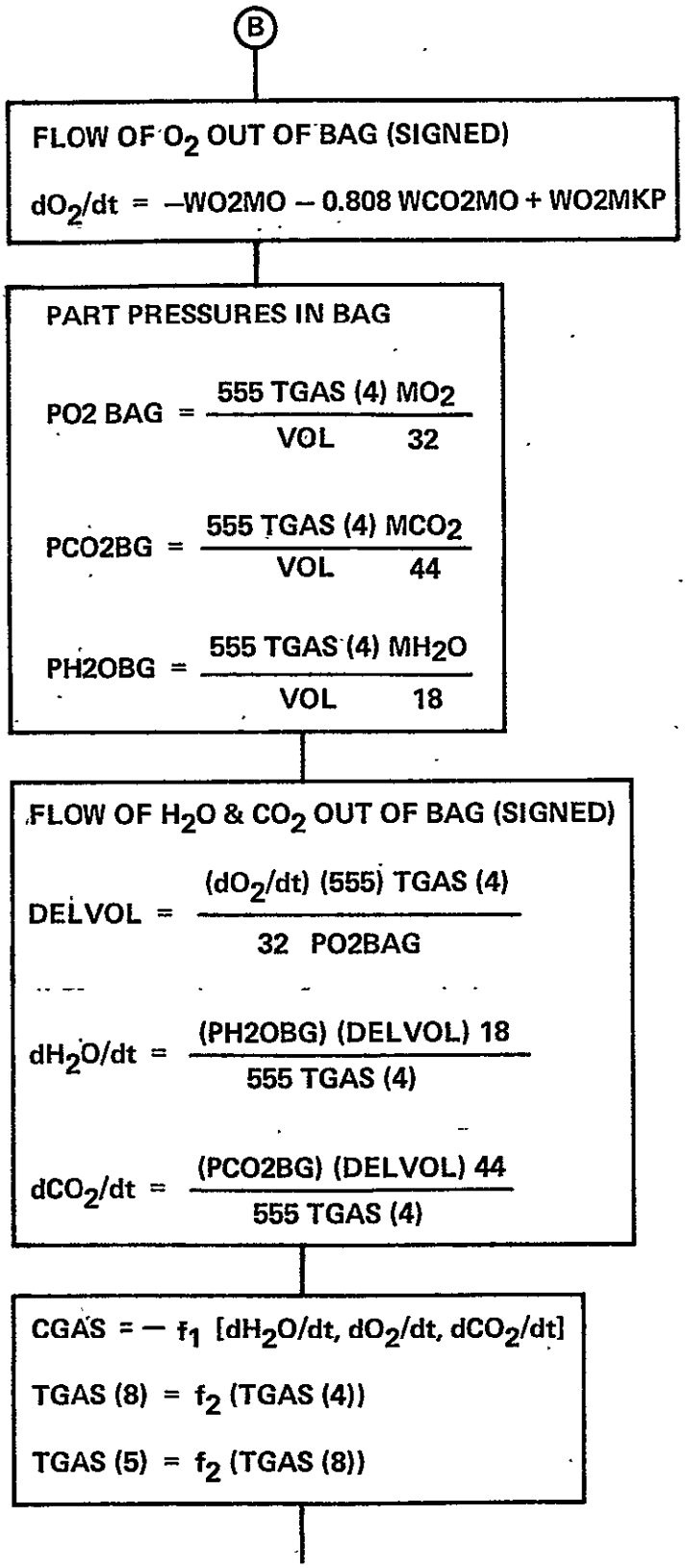
HEAT EXCHANGER (10 SECTIONS)

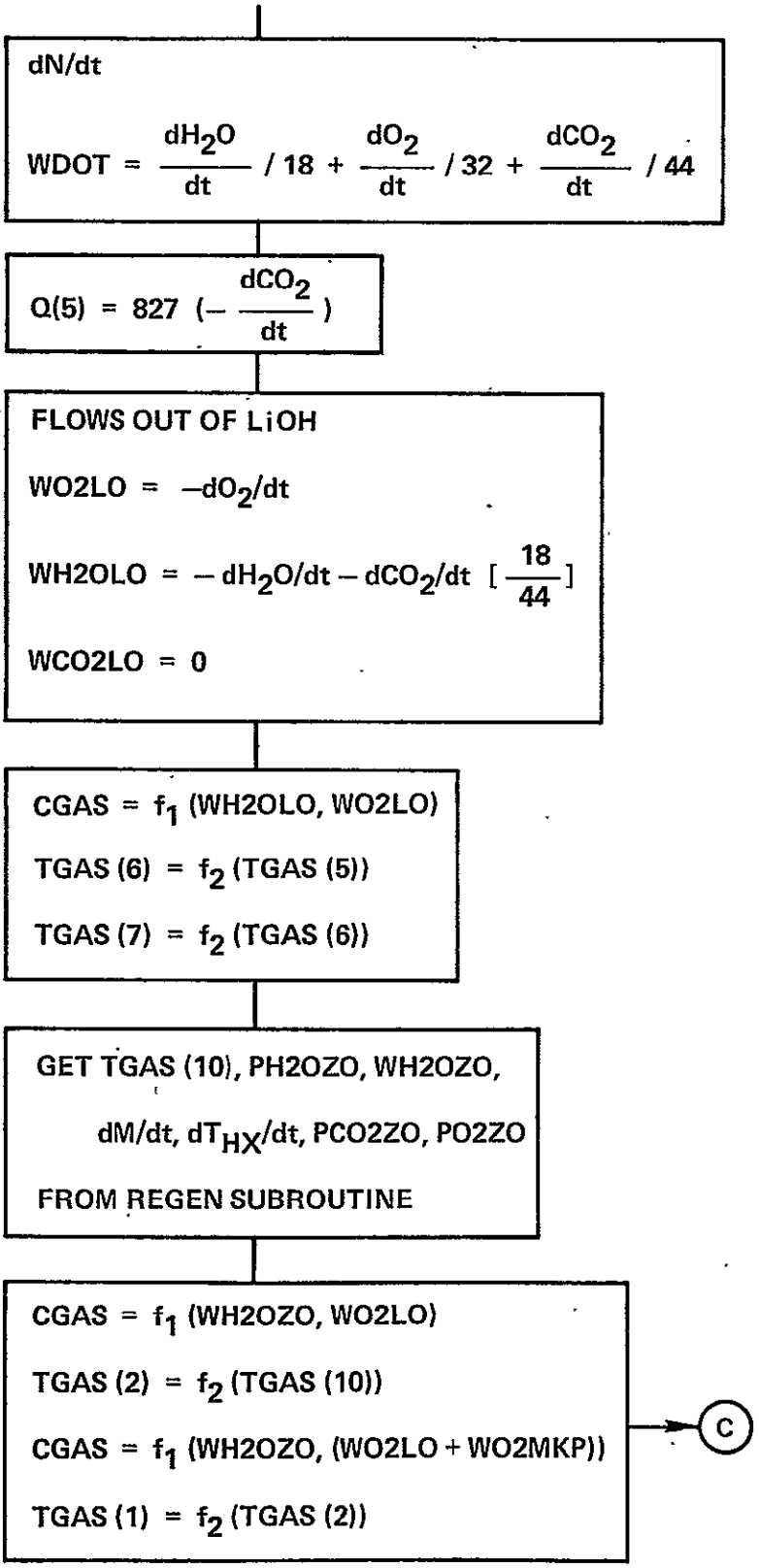
- SECTION TEMPERATURE
- dT_{SEC}/dt
- MASS H_2O IN SECTION
- dM_{SEC}/dt
- TOTAL MASS H_2O IN HX
- PARTIAL PRESSURE OUT (H_2O, CO_2, O_2)
- WEIGHT FLOW OUT (H_2O, CO_2, O_2)
- GAS TEMPERATURE OUT

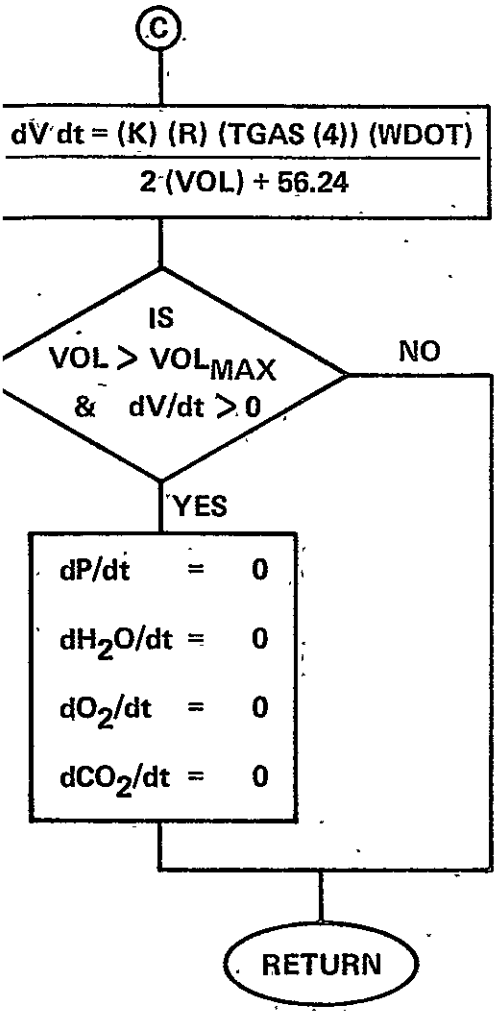

$CONSUM_i = \sum_{\substack{j=1 \\ j \neq i}}^{n} C_{ij} (T_j - T_i)$
$RADSUM_i = \sum_{\substack{j=1 \\ j \neq i}}^{n} D_{ij} (T_j^4 - T_i^4)$
$TGTRY_i = CGAST_i (TGAS_i - T_i)$
EXHALATION ?
NO
YES
TGTRY (3) = 0
TGTRY (5) = 0
TGTRY (6) = 0
TGTRY (7) = 0
TGTRY (8) = 0
$\frac{dT_i}{dt} = [CONSUM_i + RADSUM_i + CAMB_i (TAMB - T_i) + DAMB_i (TAMB^4 - T_i^4) + TGTRY_i + Q_i] / ZM_i$


EXHALATION ?
NO
B
YES
FIRST TIME THIS BREATH
NO
A
YES
FIRST TIME EVER
YES
NO
TDP = 80
PARTIAL PRESS. OF H_2O FOR INHALATION
PH2O = 14.7/760 PH2OZO [WH2OZO/18 + WO2ZO/32 / WH2OZO/18 + (WO2ZO + WO2MKP)/32]
TDP = f (PH2O) KANDK
TDP = TDP – 460
Q(5) = 0
EXHALATION TEMP
TG11 = f (TGAS (1) – 460, TDP) BIVARIATE CURVE
TGAS (11) = TG11 + 460
PART. PRESS. OF H_2O LEAVING MAN
PH2 = f (TGAS (11)) KANDK
PH2OMO = 760/14.7 PH2
PART. PRESS. OF O_2 LEAVING MAN
PO2MO = PTOT – PCO2MO – PH2OMO
FLOW RATES OF H_2O AND O_2 LEAVING MAN
WH2OMO = (PH2OMO) (QCFH) 18/(555.TGAS (11))
WO2MO = (PO2MO) (QCFH) 32/(555.TGAS (11))
A


A
CGAS = f1 (WH2OMO, WO2MO, WCO2MO)
TGAS (1) = f2 (TGAS (11))
TGAS (2) = f2 (TGAS (1))
GET TGAS (9), PH2OXO, WH2OXO
dM/dt, dTHX/dt, PCO2XO, PO2XO
FROM REGEN SUBROUTINE
CGAS = f1 (WH2OXO, WO2MO, WCO2MO)
TGAS (3) = f2 (TGAS (9))
TGAS (4) = f2 (TGAS (3))
RATES OF CHANGE OF MASS IN BAG
dH2O/dt = WH2OXO
d O2/dt = WO2MO
d CO2/dt = WCO2MO
dN/dt
WDOT = WH2OXO/18 + WCO2MO/44 + WO2MO/32
C


B
FLOW OF O_2 OUT OF BAG (SIGNED)
$dO_2/dt = -WO2MO - 0.808\ WCO2MO + WO2MKP$
PART PRESSURES IN BAG
$PO2\ BAG = \frac{555\ TGAS\ (4)\ MO_2}{VOL\quad 32}$
$PCO2BG = \frac{555\ TGAS\ (4)\ MCO_2}{VOL\quad 44}$
$PH2OBG = \frac{555\ TGAS\ (4)\ MH_2O}{VOL\quad 18}$
FLOW OF H_2O & CO_2 OUT OF BAG (SIGNED)
$DELVOL = \frac{(dO_2/dt)\ (555)\ TGAS\ (4)}{32\quad PO2BAG}$
$dH_2O/dt = \frac{(PH2OBG)\ (DELVOL)\ 18}{555\ TGAS\ (4)}$
$dCO_2/dt = \frac{(PCO2BG)\ (DELVOL)\ 44}{555\ TGAS\ (4)}$
$CGAS = -f_1\ [dH_2O/dt, dO_2/dt, dCO_2/dt]$
$TGAS\ (8) = f_2\ (TGAS\ (4))$
$TGAS\ (5) = f_2\ (TGAS\ (8))$


dN/dt
WDOT = dH2O/dt / 18 + dO2/dt / 32 + dCO2/dt / 44
Q(5) = 827 (– dCO2/dt)
FLOWS OUT OF LiOH
WO2LO = –dO2/dt
WH2OLO = – dH2O/dt – dCO2/dt [18/44]
WCO2LO = 0
CGAS = f1 (WH2OLO, WO2LO)
TGAS (6) = f2 (TGAS (5))
TGAS (7) = f2 (TGAS (6))
GET TGAS (10), PH2OZO, WH2OZO,
dM/dt, dTHX/dt, PCO2ZO, PO2ZO
FROM REGEN SUBROUTINE
CGAS = f1 (WH2OZO, WO2LO)
TGAS (2) = f2 (TGAS (10))
CGAS = f1 (WH2OZO, (WO2LO + WO2MKP))
TGAS (1) = f2 (TGAS (2))
C


C
dV/dt = (K) (R) (TGAS (4)) (WDOT)
2 (VOL) + 56.24
IS
VOL > VOL_MAX
& dV/dt > 0
NO
YES
dP/dt = 0
dH2O/dt = 0
dO2/dt = 0
dCO2/dt = 0
RETURN

REGENERATOR (REPEAT FOR EACH NODE)

$$T_{OUT} = \epsilon (T_{HX} - T_{IN}) + T_{IN}$$

$$P_{H2O} = f(T_{OUT}) \quad K \text{ AND } K$$

$$\dot{V} = \left(\frac{W_{CO2}}{44} + \frac{W_{O2}}{32}\right)(555)\, T_{OUT}\,(P_{TOT} - P_{H2O})$$

$$W_{H2O} = \frac{(P_{H2O})\,(\dot{V})\,(18)}{(555)\quad (T_{OUT})}$$

$$\frac{dM}{dt} = W_{H2O\ IN} - W_{H2O} \quad \left[\text{IF } MH2O < 0 \ \&\ \frac{dM}{dt} < 0, \text{ THEN } \frac{dM}{dt} = 0 \ \&\ PH2O = f(T_{IN})\right]$$

$$\frac{d\,T_{HX}}{dt} = -\left[(W_{O2})\,(0.22)(T_{OUT} - T_{IN}) - (1020)\,\frac{dM}{dt}\right] / MHX$$

$$P_{CO_2} = \frac{(W_{CO_2})\,(555)\,(T_{OUT})}{(44)\,(\dot{V})}$$

$$P_{O2} = \frac{(W_{O_2})\,(555)\,(T_{OUT})}{(32)\quad \dot{V}}$$

$$f_1 = WH2O\ (0.45) + WO2\ (0.22) + WCO2MO\ (0.22)$$

$$f_2 = \frac{(CGASI_i)\ (T_i) + (CGAS)\ (TGAS_{IN})}{CGASI_i + CGAS}$$

APPENDIX B

FAILURE MODES AND EFFECTS ANALYSIS

CRITICAL ITEM LIST

SAFETY STUDY AND HAZARD ANALYSIS

GROUNDRULES FOR FMEA/CIL

This FMECA is organized to meet the POS Statement of Work, paragraph 7E(2) and DRL Item 9, 338T. The criticalities are:

1. Loss of life or vehicle
2. Aborted or scrubbed mission
3. All others

It is reasoned that failure of a POS cannot cause a scrubbed mission since the failed unit could be replaced during launch preparation. Further, a failed POS cannot result in aborting a POS mission because at any time prior to Independent Rescue Operation the spare POS can be substituted, and because it is not possible to abort a committed Independent Rescue Operation. Accordingly, criticalities appearing in the analysis are either (1) or (3).

Consideration should be given to placing a spare POS on each deck. If this were done, quick access to a spare POS in the event of failure during Independent IV may decrease the criticality of numerous failure modes.

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM: MAN/POS OR MAN/POS/VEHICLE
SUBSYSTEM: POS
ASSEMBLY:

PREPARED BY:
APPROVED BY:

DATE
SUPERSEDING

NAME AND ID NO. ITEM NO.	FUNCTION	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON: ASSEMBLY	SUBSYSTEM	SYSTEM	FAILURE DETECTION METHOD	TIME AVAIL	CORRECTIVE ACTION	FAIL MODE CRIT	REV
O_2 Bottle (1)	storage for independent POS operation.	Rupture due to flaw or overheating.	Storage	Loss of function.	Loss of function.	Loss of function.	Visual observation of pressure gage or none.	Yes	Use spare POS.	3	
			Denitrogenization	"	"	"	"	No	None	1	
			Independent IV Operation	"	"	"	"	No	None	1	
			Independent Rescue Operation	"	"	"	"	No	None	1	
			Recharge in Vehicle	"	"	"	"	Yes	Use spare POS.	3	
		Leakage due to flaw.	Storage	"	"	"	"	Yes	Use spare POS.	3	
			Denitrogenization	"	"	"	"	Yes	Use spare POS.	3	
			Independent IV Operation	"	"	"	"	No	None	1	
			Independent Rescue Operation	"	"	"	"	Note 1 No	Special breathing procedure.	1	
			Recharge in Vehicle	"	"	"	"	Yes	Use spare POS.	3	
			Note 1: In those cases where special breathing procedure is feasible, there is sufficient time to employ.								
Pressure Gage (2)	Monitor bottle pressure	Rupture due to flaw or overheating.	Storage	Loss of function and stored O_2.	Loss of function and stored O_2.	Loss of function and stored O_2.	Visual observation of pressure gage or none.	Yes	Use spare POS.	3	
			Denitrogenization	"	"	"	"	No	None	1	
			Independent IV Operation	"	"	"	"	No	None	1	
			Independent Rescue Operation	"	"	"	"	No	None	1	
			Recharge in Vehicle	"	"	"	"	Yes	Use spare POS.	3	

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM: MAN/POS OR MAN/POS/VEHICLE
SUBSYSTEM: POS
ASSEMBLY:

PREPARED BY:
APPROVED BY:

DATE
SUPERSEDING

NAME AND ID NO. ITEM NO.	FUNCTION	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON: ASSEMBLY	SUBSYSTEM	SYSTEM	FAILURE DETECTION METHOD	TIME AVAIL	CORRECTIVE ACTION	FAIL MODE CRIT	REV
Pressure Gage (2) (Cont'd)		Leakage due to flaw.	Storage	Loss of function and stored O_2.	Loss of function and stored O_2.	Loss of function and stored O_2.	Visual observation of pressure gage or none.	Yes	Use spare POS.	3	
			Denitrogenization	"	"	"	"	Yes	Use spare POS.	3	
			Independent IV Operation	"	"	"	"	No	None	1	
			Indpendent Rescue Operation	"	"	"	"	Note 1 No	Special breathing procedure.	1	
			Recharge in Vehicle	"	"	"	"	Yes	Use spare POS.	3	
		Movement sticks.	Storage	Loss of function.	Loss of function.	Loss of function.	None	Yes	None required. Top the gage.	3	
			Denitrogenization	"	"	"	"	Yes	"	3	
			Independent IV Operation	"	"	"	Visual observation of gage.	Yes	"	3	
			Independent Rescue Operation	"	"	"	"	Yes	"	3	
			Recharge in Vehicle	"	"	"	"	Yes	"	3	
O_2 Shutoff Valve (3)	Isolates bottle during storage and while using vehicle O_2.	Cannot be closed due to jamming.	Recharge	"	"	"	Crew observation.	Yes	Use spare POS.	3	
			Independent IV Operation	"	"	"	"	Yes	Use spare POS.	3	
		Cannot be opended due to jamming.	Recharge	"	"	"	"	Yes	Use spare POS.	3	
			Independent IV Operation	"	"	"	"	No	None	1	
			Independent Rescue Operation	Note: Valve to be opened before committing to transfer.				Yes	Use spare POS.	3	
		External leak due to housing defect or seal malfunction.	Storage	"	"	"	Pressure Gage	Yes	Use spare POS.	3	
			Independent IV Operation	"	"	"	"	No	None	1	
			Independent Rescue Operation	"	"	"	"	Note 1 No	Special breathing procedure.	1	

SYSTEM: MAN/POS OR MAN/POS/VEHICLE
SUBSYSTEM: POS
ASSEMBLY:

PREPARED BY:
APPROVED BY:

PAGE 3 OF
DATE
SUPERSEDING

NAME AND ID NO. ITEM NO.	FUNCTION	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON: ASSEMBLY	SUBSYSTEM	SYSTEM	FAILURE DETECTION METHOD	TIME AVAIL	CORRECTIVE ACTION	FAIL MODE CRIT	REV
O_2 Shut-off Valve (3) (Cont'd)		Seat Leakage	Storage	Loss of function.	Loss of function.	Loss of function.	Pressure Gage	Yes	Use spare POS.	3	
Check Valve (4)	Prevent back flow from POS to vehicle O_2 supply in the event POS O_2 shutoff is left open.	Fails closed due to jamming.	Denitrogenization	Won't allow flow to POS from vehicle O_2 supply.	Loss of function.	Loss of function.	Crew observation can't inhale and/or breathing bag does not inflate.	Yes	Use spare POS.	3	
		Fails open due to jamming.	Independent IV Operation	Fails to check flow from POS to vehicle.	Loss of POS oxygen.	Bottle sized to provide 10 min. independent operation when charged to vehicle supply pressure.	Bottle pressure drops when connection to vehicle O_2 supply.	Not Req'd	Not required.	3	
			Independent Rescue Operation	"	"	Rescue duration limited to 15 minutes.	"	Yes	Use spare POS.	3	
O_2 Disconnect (5)	Connect POS to vehicle O_2 supply.	Fail to connect due to jamming or distortion.	Denitrogenization	Loss of function.	Loss of function.	Loss of function.	Crew observation.	Yes	Use spare POS.	3	
			Independent IV Operation	"	Can't recharge bottle	"	"	Yes	Use spare POS.	3	
		Fails to disconnect due to jamming.	At end of denitrogenization.	Cannot be disconnected	Loss of function.	"	"	Yes	Use spare POS. Note: There must be at least one extra vehicle connector.	3	
		Leakage while connected.	Denitrogenization	None	Requires excess vehicle O_2.	Excess use of vehicle O_2.	None in POS. Rate of vehicle O_2 use.	Yes	Use spare POS.	3	
		Leakage while disconnected.	Independent IV Operation	None	Loss of stored O_2.	Reduced duration of independent operation.	POS pressure gage or none.	No	If detected, use spare POS.	1	
			Independent Rescue Operation	None	"	"	"	Note 1 No	Special breathing procedure.	1	

SYSTEM: MAN/POS OR MAN/POS/VEHICLE
SUBSYSTEM: POS
ASSEMBLY:

PREPARED BY:
APPROVED BY:

NAME AND ID NO. ITEM NO.	FUNCTION	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON: ASSEMBLY	SUBSYSTEM	SYSTEM	FAILURE DETECTION METHOD	TIME AVAIL	CORRECTIVE ACTION	FAIL MODE CRIT	REV
Pressure Reducer (6)	Control orifice and demand regulator inlet pressure to a fixed value.	Fails open due to spring failure.	Denitrogenization	Loss of function.	Loss of function.	Excessive use of vehicle O_2.	Interstage Pressure Gage	Yes	Use spare POS.	3	
			Independent IV Operation	"	"	Loss of function.	Interstage pressure gage and bottle pressure gage or none.	No	None	1	
			Independent Rescue Operation	"	"	"	"	No	None	1	
		Regulator above. Set point or excessive internal leakage.	Denitrogenization	"	"	Excessive use of vehicle O_2.	Interstage Pressure Gage	Yes	Use spare POS.	3	
			Emergency IV Operation	"	"	Loss of function.	Interstage pressure gage and bottle pressure gage or none.	No	None	1	
			Rescue EV Operation	"	"	"	"	No	Same as for fail open.	1	
		Failed closed	Denitrogenization	"	"	"	Can't inhale and no pressure indication on interstage pressure gage.	Yes	Use spare POS.	3	
			Independent IV Operation	"	"	"	"	No	None	1	
			Independent Rescue Operation	"	"	"	"	No	None	1	
		Regulate below set point (flow in excess of metabolic requirement).	Denitrogenization	"		Higher than normal inlet temperature.	Higher than normal inlet gas temp. and interstage pressure gage or none.	Not Req'd	Not req'd.	3	
			Independent IV Operation and Independent Rescue Operation	"		"	"	Not Req'd	Not req'd.	3	

SYSTEM: MAN/POS OR MAN/POS/VEHICLE
SUBSYSTEM: POS
ASSEMBLY:

PREPARED BY:
APPROVED BY:

DATE
SUPERSEDING

NAME AND ID NO. ITEM NO.	FUNCTION	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON: ASSEMBLY	SUBSYSTEM	SYSTEM	FAILURE DETECTION METHOD	TIME AVAIL	CORRECTIVE ACTION	FAIL MODE CRIT	REV
Pressure Reducer (6) (Cont'd)		Flow less than metabolic requirements.	Denitrogenization	Loss of function.		Loss of function.	Interstage pressure gage. Also breathing bag collapses.	Yes	Use spare POS.	3	
			Independent IV Operation and Independent Rescue Operation	"		Degraded performance.	"	No	None	1	
		External Leakage	Denitrogenization	"		"	None	Yes	Use spare POS.	3	
			Independent IV Operation	"		"	Drop in bottle pressure or none.	No	None	1	
			Independent Rescue Operation					Note 1 No	Special breathing procedure.	1	
High Pressure Relief Valve (7)	Prevent overpressure of breathing circuit in the event of a failed open pressure reducer.	Opens when it should not or leaks.	Denitrogenization	Loss of function.	Loss of function.	Excessive use vehicle O_2.	None	No	None	1	
			Independent IV Operation	"	"	Loss of function.	Bottle pressure gage drops or none.	No	None	1	
			Independent Rescue Operation	"	"	"	"	No	None	1	
Demand Regulator (8)	Provide additional O_2 on demand if requirement exceeds orifice flow	Fails closed due to jamming.	Denitrogenization	"	"	"	Total collapse of breathing bag on inhalation.	Not Req'd	Not req'd.	3	
			Independent IV Operation or Independent Rescue Operation	"	"	"	"	"	"	3	
		Fails open and leaks internally.	Denitrogenization	"	"	Excess use of vehicle O_2.	None	"	"	3	
			Independent IV Operation	"	"	Loss of function.	Abnormal drop in bottle pressure or none.	No	None	1	
			Independent Rescue Operation	"	"	"	"	No	None	1	

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM: MAN/POS OR MAN/POS/VEHICLE
SUBSYSTEM: POS
ASSEMBLY:

PREPARED BY:
APPROVED BY:

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NAME AND ID NO. ITEM NO.	FUNCTION	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON: ASSEMBLY	SUBSYSTEM	SYSTEM	FAILURE DETECTION METHOD	TIME AVAIL	CORRECTIVE ACTION	FAIL MODE CRIT	REV
Demand Regulator (8) (Cont'd)		External Leakage	Denitrogen-tion	Loss of function.	Loss of function.	Excess use of vehicle O_2.	None	Not Req'd.	Not req'd.	3	
			Independent IV Operation	"	"	Loss of function.	Abnormal drop in bottle pressure.	Yes	Use spare POS.	3	
			Independent Rescue Operation	"	"	"	"	Note 1 No	Special breathing procedure.	1	
Orifice (9)	Restrict O_2 flow to a specified range.	Clogs	Denitrogen-ization	"	"	Degraded performance.	Breathing bag would collapse and crewman would have to inhale deeply to get flow through demand regulator. Inlet gas temp. and dewpoint would be higher than normal.	Yes	Use spare POS.	3	
			Independent IV Operation or Indepen-dent Rescue Operation	"	"	"	"	Not Req'd	Not req'd.	3	
Flow Compensa-ting Bag (10)	Store make-up O_2 dur-ing exhala-tion and supplement makeup O_2 during inhalation.	Leakage due to tear or flaw.	Denitrogen-ization and Independent IV Operation	"	"	Loss of function.	None	No	None	1	
			Independent Rescue Operation	"	"	Slightly de-graded function.	None	Not	Not req'd.	3	
Flow Matching Orifice (11)	Control makeup flow during inhalation.	Clogging	Denitrogen-ization	"	"	Loss of function.	Increase in breathing resistance.	Not Req'd	Not req'd.	3	
			Independent IV Operation or Indepen-dent Rescue Operation	"	"	"	"	"	"	3	

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM: MAN/POS OR MAN/POS/VEHICLE
SUBSYSTEM: POS
ASSEMBLY:

PREPARED BY:
APPROVED BY:

DATE
SUPERSEDING

NAME AND ID NO. ITEM NO.	FUNCTION	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON: ASSEMBLY	SUBSYSTEM	SYSTEM	FAILURE DETECTION METHOD	TIME AVAIL	CORRECTIVE ACTION	FAIL MODE CRIT	REV
Makeup Flow Check Valve (12)	To prevent exhaling into flow compensating bag.	Fail closed.		Umbrella Type Valve - Cannot Fail Closed							
		Fail open.	All	Loss of function.	Slightly degraded performance.	Slightly degraded performance.	None	Not Req'd	Not req'd.	3	
O_2 Inlet Hose (13)	Supply duct for mask O_2	Clogged		Same as Item 9.							
		External leak	Denitrogenization and Independent IV Operation	Loss of function.	Loss of function.	Loss of function.	Breathing bag would collapse.	No	None	1	
			Independent Rescue Operation	"	Degraded performance.	Degraded performance.	None	Not Req'd	Not req'd.	3	
Mask (14)	Isolates eyes and oral/nasal area from ambient.	Leakage	Denitrogenization and Independent IV Operation	"	Loss of function.	Loss of function.	None	No	None	1	
			Independent Rescue Operation	"	Degraded performance.	Degraded performance.	None	Not Req'd	Not req'd.	3	
		O_2 inlet line clogged.		Same as Item 9.							
Breathing Hose (15)	Connect mask with recirculating portion of the system.	External Leakage		Same as Face Mask Item 14.							
Regenerative Heat Exchanger (16)	Provide thermal and humidity control to gas delivered to mask.	External leakage; screen broken at mask end or clogged, as with vomit.		Same as Face Mask Item 14.							
Canister Outlet Valve (17)	Prevent reverse flow through cartridge.	Fail closed.		Umbrella Type Valve - Cannot Fail Closed							
		Fail open.	All	Loss of function.	Slightly degraded performance.	Slightly degraded performance.	None	Not Req'd	Not req'd.	3	

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM: MAN/POS OR MAN/POS/VEHICLE
SUBSYSTEM: POS
ASSEMBLY:

PREPARED BY:
APPROVED BY:

DATE
SUPERSEDING

NAME AND ID NO. ITEM NO.	FUNCTION	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON: ASSEMBLY	SUBSYSTEM	SYSTEM	FAILURE DETECTION METHOD	TIME AVAIL	CORRECTIVE ACTION	FAIL MODE CRIT	REV
Exhalation Valve (18)	Prevent reverse flow through breathing bag.	Fail closed.		Umbrella Type Valve - Cannot Fail Closed							
		Fail open.	Denitrogenization and Independent IV Operation	Loss of function.	Loss of function.	Loss of function.	Crewman develops headache.	No	None	1	
			Independent Rescue Operation	"	"	"	"	No	None	1	
Breathing Bag (19)	Breathing gas accumulator	External Leakage	Denitrogenization and Independent IV Operation	"	"	"	None	No	None	1	
			Independent Rescue Operation	"	Slightly Degraded Performance.	Slightly Degraded Performance	None	Not Req'd	Not req'd.	3	
Relief Valve (20)	Provide a means of nitrogen purging.	Fail closed.		Umbrella Type Valve - Cannot Fail Closed							
		Fail open or leaks.	Denitrogenization and Independent IV Operation	"	Loss of function.	Loss of function.	None	No	None	1	
			Independent Rescue Operation	"	Degraded Performance	Degraded Performance	None	Not Req'd	Not req'd.	3	
LiOH Canister and Cartridge (21)	Scrub CO_2 from the gas to be inhaled.	Shortened life due to contamination.	All	"	Loss of function.	Loss of function.	Headache	No	None	1	
		Dusting	All	"	"	"	Oral/Nasal Irritation	Not Req'd	Not req'd.	3	
		Channeling	All	"	"	"	Headache	No	None	1	
Rupture Disc (22)	Prevent catastropic bottle failure in event of overpressurization.	External Leakage	Denitrogenization	None	None	None	Low bottle pressure.	Not Req'd	Not req'd.	3	
			Independent IV Operation or Independent Rescue Operation	Loss of function.	Loss of function.	Loss of function.	"	No	None	1	

FAILURE MODE AND EFFECT ANALYSIS

SYSTEM: MAN/POS OR MAN/POS/VEHICLE
SUBSYSTEM: POS
ASSEMBLY:

PREPARED BY:
APPROVED BY:

DATE
SUPERSEDING

NAME AND ID NO. ITEM NO.	FUNCTION	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON: ASSEMBLY	SUBSYSTEM	SYSTEM	FAILURE DETECTION METHOD	TIME AVAIL	CORRECTIVE ACTION	FAIL MODE CRIT	REV
Inter-stage Pressure Gage (23)	Provide verification of pressure reducer performance.	Rupture due to flaw or overheating.	Denitrogen-ization	Loss of function.	Loss of function.	Loss of function.	Visual obser-vation of pressure gage or none	Yes	Use spare POS.	3	
			Independent IV Operation	"	"	"	"	No	None	1	
			Independent Rescue Operation	"	"	"	"	"	"	1	
		Leakage due to flaw.	Denitrogen-ization	"	"	"	"	Yes	Use spare POS.	3	
			Independent IV Operation	"	"	"	"	No	None	1	
			Independent Rescue Operation	"	"	"	"	Note 1 No	Special breathing procedure.	1	
		Movement sticks.	Denitrogen-ization	"	"	"	"	Not Req'd	Not req'd.	3	
			Independent IV Operation	"	"	"	Visual obser-vation of gage.	"	"	3	
			Independent Rescue Operation	"	"	"	"	"	"	3	

The following Critical Item List (CIL) lists and provides acceptance rationale for all criticality 1 and 3_I failures identified in the FMEA. The CIL was prepared using the following guidelines.

A) Criticalities are defined per paragraph 7.0e of the Statement of Work:

1) Loss of life, injury, or loss of vehicle.

2) Loss of mission, which includes post-launch aborts and launch delays sufficient to cause mission scrub.

3) All others.

Subscript I refers to failure to pass one or more redundancy screens per NASA DRD RA-338T.

B) Corrective Action/Retention categories are:

1) Item for which analysis and test results support acceptability and adequate procedures exist to minimize the effect of occurrence or eliminate problem.

2) Item involving passive equipment characteristics. Adequate safety margins exist and test results prove acceptable.

C) Headings are per NASA DRD RA-339T.

LIST, CRITICAL ITEM (CIL)

SYSTEM MAN/POS OR MAN/POS/VEHICLE
SUBSYSTEM POS
ASSEMBLY

PREPARED BY
APPROVED BY

DATE
SUPERSEDING

NOTE: FMEA REFERENCE IS VIA NAME AND ITEM NUMBER

NAME AND ID NO. (ITEM NO.)	CRITICALITY	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON SYSTEM	CORRECTIVE ACTION/ RETENTION CLASSIFICATION	NO. OF CRITICAL ITEMS	RATIONALE FOR ACCEPTANCE
O_2 Bottle (1)	1	Rupture or leakage due to flaw or overheating	Denitrogenization, Independent IV Operation, Independent Rescue Operation	Possible Loss of Life	*C or B (See f) See Hazard Analyses 1A-06-POS-4	1	Low Probability of Occurrence a) Bottle will be of "fail safe" design by fracture mechanics - failure mode is leakage not catastrophic rupture. b) System contains a burst disc to prevent over-pressurization due to heating. c) Non-destructive testing to be used to verify no flaws. d) Leakage due to a flaw is cyclic induced; would be detected during ground charge. Should not occur during discharge. Stress on bottle induced by recharge in vehicle is approx. 25% of stress induced by ground charge pressure, therefore, unlikely this will induce leakage. e) Loss of pressure should be detected prior to independent use. Use spare POS. f) If leakage does occur during Independent Rescue Operation, it may be possible to continue the transfer by a special routine of breathing, lifting the mask during part of the inhalation/exhalation cycle. Assume O_2 pressure gage not being monitored.
Pressure Gage (2)	1	Rupture of leakage due to flaw or overheating	Denitrogenization, Independent IV Operation, Independent Rescue Operation	Possible Loss of Life	C or B (See i) See 1A-06-POS-4		Low Probability of Occurrence a) Gage uses a helical element having a cycle life in excess of 100,000 cycles. b) Design is low stress using high factors of safety. c) Actual experience indicates gages leak not rupture. d) Gage is of "fail safe" design by fracture mechanics.

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NAME AND ID NO. (ITEM NO.)	CRITICALITY	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON SYSTEM	CORRECTIVE ACTION/ RETENTION CLASSIFICATION	NO. OF CRITICAL ITEMS	RATIONALE FOR ACCEPTANCE
							e) Gage case vented to prevent rupture. f) Non-destructive testing to be use to verify no flaws. g) Leakage due to a flaw is detected during ground charge. Should not occur during discharge. 25% of stress induced by ground charge pressure, therefore, unlikely thi will induce leakage. h) Loss of pressure should be detect ed prior to independent use. Use in spare POS. i) If leakage does occur during In- dependent Rescue Operation, it ma be possible to continue the trans fer by a special routine of breathing, lifting the mask durin part of the inhalation/exhalation cycle.
O_2 Shutoff Valve (3)	1	External leak due to housing defect or seal malfunction.	Independent IV Operation, Independent Rescue Operation	Possible Loss of Life	C or B (See Rationale) See 1A-06-POS-5A	1	Low Probability of Occurrence If leakage does occur during Indepen dent Rescue Operation, it may be pos sible to contine the transfer by a special routine of breathing, liftin the mask during part of the inhalati exhalation cycle.
	1	Jammed closed.	Independent IV Operation		C See 1A-06-POS-5A	1	Low Probability of Occurrence a) Cyclic operation required to in- duce jamming-increased resistance of valve would be detected during ground checkout. b) Storage environment does not in- duce cold welding or corrosive seizure.

LIST, CRITICAL ITEM (CIL)

SYSTEM MAN/POS OR MAN/POS/VEHICLE
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ASSEMBLY

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NAME AND ID NO. (ITEM NO.)	CRITICALITY	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON SYSTEM	CORRECTIVE ACTION/ RETENTION CLASSIFICATION	NO. OF CRITICAL ITEMS	RATIONALE FOR ACCEPTANCE
O_2 Disconnect (5)	1	Leakage while disconnected.	Independent IV Operation, Independent Rescue Operation	Possible Loss of Life	C or B (See c) See 1A-06-POS-5A	1	Low Probability of Occurrence a) Check valve upstream limits leakage. b) Connector had redundant sealing cap. c) If leakage does occur during Independent Rescue Operation, it ma be possible to continue the trans fer by a special routine of breathing, lifting the mask durin part of the inhalation/exhalation cycle.
Pressure Reducer (6)	1	Fails open, due to spring failure, regulates above set point, leaks internally excessively, fails closed or flows less than metabolic requirements, or leaks internally.	Independent IV Operation, Independent Rescue Operation	Possible Loss of Life	C or B (See d) See 1A-06-POS-5A	1	Low Probability of Occurrence a) All of the stressed components are subject to low stress levels. b) A fail open condition requires failure of the control spring which sees no cyclic stress and is designed for infinite life when fully compressed. c) In the event of a malfunction, the spare POS can be used. d) If leakage does occur during Independent Rescue Operation, it ma be possible to continue the transfer by a special routine of breathing, lifting the mask during part of the inhalation/exhalation cycle. A shift in set point is not likely failure (see above). Based on experience, leakage failures occur when unit is first turned on. This can be detected and crewman can use spare POS.
Hi Pressure Relief Valve (7)	1	Opens when it should not, or leaks.	Independent IV Operation, Independent Rescue Operation	Possible Loss of Life	C See 1A-06-POS-5A	1	Low Probability of Occurrence Setting well above normal operating pressure. No reason for valve to open or leak. Normal operating pressure is not high enough to cause seal extrusion.

LIST, CRITICAL ITEM (CIL)

SYSTEM MAN/POS OR MAN/POS/VEHICLE
SUBSYSTEM POS
ASSEMBLY

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NAME AND ID NO. (ITEM NO.)	CRITICALITY	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON SYSTEM	CORRECTIVE ACTION/ RETENTION CLASSIFICATION	NO. OF CRITICAL ITEMS	RATIONALE FOR ACCEPTANCE
Demand Regulator (8)	1	Fails open or leaks internally.	Independent IV Operation, Independent Rescue Operation	Possible Loss of Life	C or B (See d) See 1A-06-POS-5A	1	Low Probability of Occurrence a) Requires failure of a low stressed spring. b) Regulator can be checked prior to use of the system. c) If found leaking, use spare POS. Also, if checkout is okay, its not likely to failure during next use. d) If leakage does occur during Independent Rescue Operation, it may be possible to continue the transfer by a special routine of breathing, lifting the mask during part of the inhalation/exhalation cycle.
	1	External Leakage	Independent IV Operation Independent Rescue Operation	Possible Loss of Life	C or B See 1A-06-POS-5A	1	Same as Shutoff Valve.
Flow Compensating Bag (10)	1	Leakage due to tear or flaw.	Independent IV or Denitrogenization	Possible Loss of Life	C See 1A-06-POS-5A	1	Low probability of occurrence. Bag capable of operating at pressures many times normal operating pressure. Bag will be protected and can be checked prior to use. If found leaking, use spare POS.
O_2 Inlet Hose (13)	1	External Leak	Denitrogenization and Independent IV Operation	Possible Loss of Life	C See 1A-06-POS-5A	1	Can be checked for leakage prior to use - if leaking, use spare POS.
Mask (14) and Breathing Hose (15)	1	Leakage	Denitrogenization and Independent IV Operation	Possible Loss of Life	B See 1A-06-POS-5A	1	Must check out to verify seal integrity prior to use. Once checked, not probable that leak will develop.

NOTE: FMEA REFERENCE IS VIA NAME AND ITEM NUMBER

NAME AND ID NO. (ITEM NO.)	CRITICALITY	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON SYSTEM	CORRECTIVE ACTION/ RETENTION CLASSIFICATION	NO. OF CRITICAL ITEMS	RATIONALE FOR ACCEPTANCE
Regenera-tive Heat Exchanger (16)	1	Screen broken at mask end.	Denitrogenization Independent IV Operation and Independent Rescue Operation	Possible In-halation of Loose Balls	C See 1A-06-POS-7	1	Screen has high strength margin.
	1	Clogged, as with vomit.	Denitrogenization Independent IV Operation and Independent Rescue Operation	Cannot exhale without lifting mask, thus pos-sible injury.	C See 1A-06-POS-8	1	If nauseous, astronaut shall be prepared to doff mask while vomiting.
	1	External Leakage	Denitrogenization and Independent IV Operation	Possible Loss of Life	B See 1A-06-POS-6	1	Check out to verify integrity prior to use. Once checked, not probable that leak will develop.
Exhalation Valve (18)	1	Fails Open	Independent Operation	Possible CO_2 Poisoning	B See 1A-06-POS-1A	1	Must be and can be checked by user prior to use. Not a likely failure subsequent to check out.
Breathing Bag (19)	1	External Leakage	Denitrogenization and Independent IV Operation	Possible loss of life due to loss of O_2 or ingestion of contaminating atmosphere.	B See 1A-06-POS-6	1	Must be and can be checked by user prior to use.
Relief Valve (20)	1	Fails Open or Leaks	Denitrogenization and Independent IV Operation	Same as above.	B See 1A-06-POS-6	1	Same as above.
LiOH Cartridge and Canister (20)		Contamina-tion or Channeling	All	Possible CO_2 Poisoning	C See 1A-06-POS-1A	1	Low probability of occurrence due to processing controls and use of sen-sors to verify integrity upon instal-lation. The preload pads plus ad-herence to assembly procedures will prevent channeling.

LIST, CRITICAL ITEM (CIL)

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NAME AND ID NO. (ITEM NO.)	CRITICALITY	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON SYSTEM	CORRECTIVE ACTION/ RETENTION CLASSIFICATION	NO. OF CRITICAL ITEMS	RATIONALE FOR ACCEPTANCE
Rupture Disc (32)		External Leakage	Independent IV and Independent Rescue Operation	Possible Loss of Life	B See 1A-06-POS-5A	1	Low probability of occurrence. If disc were to leak, it would do so during storage, and this would be detected prior to use of the system. The spare POS could be used.
Interstage Pressure Gage (23)	1	Rupture	Independent IV and Independent Rescue Operation	Possible Loss of Life	C or B (See f) See 1A-06-POS-5A	1	Low Probability of Occurrence a) Gage uses a helical element having a cycle life in excess of 100,000. b) Design is low stress using high factors of safety. c) Actual experience indicates gages leak, not rupture. d) Gage is of "fail safe" design by Fracture Mechanics. e) Gage case vented to prevent rupture. f) If leakage does occur during Independent Rescue Operation, it may be possible to continue the transfer by a special routine of breathing, lifting the mask during part of the inhalation/exhalation cycle.
Makeup Flow Check Valve (12)	3_I	Fails Open	All	Degraded Performance	C	1	Integrity of valve verified during periodic ground check out. Fails redundancy screen b).
Pressure Reducer (6)	3_I	External Leakage	Denitrogenization	Loss of Function	C	1	Low probability of occurrence. Fails redundancy screen b).
High Pressure Relief (7)	3_I	Opens when it should not or leaks.	Denitrogenization	Excessive use of vehicle O_2	C	1	Low probability of occurrence. Setting well above normal operating pressure. No reason for valve to open or leak. Normal operating pressure is not high enough to cause seal extrustion.

LIST, CRITICAL ITEM (CIL)

SYSTEM MAN/POS OR MAN/POS/VEHICLE
SUBSYSTEM POS
ASSEMBLY

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NAME AND ID NO. (ITEM NO.)	CRITICALITY	FAILURE MODE AND CAUSE	MISSION PHASE	FAILURE EFFECT ON SYSTEM	CORRECTIVE ACTION/ RETENTION CLASSIFICATION	NO. OF CRITICAL ITEMS	RATIONALE FOR ACCEPTANCE
Demand Regulator (8)	3_I	External leakage or fails open or leaks internally.	Denitrogenization	Same as above.	C	1	Low probability of occurrence. Open failure requires failure of a low stressed spring. Regulator can be checked prior to use of the system. If check out okay, not likely to fail during next use.
Flow Compensating Bag (10)	3_I	Leakage due to tear or flake.	Independent Rescue Operation	Slightly Degraded Function	C	1	Slightly degraded performance would not affect mission.
O_2 Inlet Hose (13)	3_I	External Leakage	Same as above.	Degraded Performance	B	1	Can be checked for leakage prior to use.
Mask (14) and Breathing Hose (15) and Regenerative Heat Exchanger (16)	3_I	Leakage	Same as above.	Same as above.	B	1	Same as above.
Canister Outlet Check Valve (17)	3_I	Fail Open	All	Slightly Degraded Performance	C	1	Slightly higher inlet CO_2 PP to mask
Breathing Bag (19)	3_I	External Leakage	Independent Rescue Operation	Slightly Degraded Performance	C	1	Can be checked for leakage prior to use.
Relief Valve (20)	3_I	Fail open or leaks.	Same as above.	Degraded Performance	C	1	Same as above.

SAFETY GUIDELINES, CONSTRAINTS, AND REQUIREMENTS

The safety approach has been to search out safety concerns and to use foreknowledge to eliminate, suppress, or control them. This search has been applied actively.

The basic safety requirements are established by Specification CSD-SH-025 and Exhibit A, the Statement of Work. The POS is to a) supply life support under all required conditions and modes, b) to be self donning, c) to provide eye protection, d) to preclude any condition in which with a collapsed bag the oxygen supply should be blocked, and 3) to prevent lack of visibility by condensate on the face plate. In addition, SE-R-0006 was invoked to control flammability, odor, and off-gassing; and JSCM 8080 Manned Spacecraft Criteria & Standards were invoked as guideline in order to minimize inherent, interface or human factors hazards.

Requirements (a) through (e) above are met by the POS design. The provisions of SE-R-0006 can be satisfied for flight versions of the POS design, but with mutual agreement have been deviated for some of the materials, such as face mask and hoses, to permit use of appropriate available substitutes.

CSD-SH025, paragraph 3.1.3.1, points out that redundancy shall be provided at spacecraft level by providing one more POS than the total number of crew and passengers. This partial redundancy may be applied if a POS anomaly occurs and is revealed at predonning check out, or if one occurs and is detected during IV use. Certain failure modes now classified as criticality 1 may be correctable by this redundancy if the crewman observes the oxygen pressure gages while on IV independent operation. In connection with the spacecraft level redundancy approach and assuming stowage is in the cabin, a possible limitation is that part of the crew may be isolated from the spare POS by the airlock in event of an emergency in the space lab. A spare POS in both cabin and space lab would remove this limitation.

Much of the POS usage which can credibly experience a criticality 1 failure is emergency usage. Thus, in an overall spacecraft sense, the failure would not be a single point failure and would not violate the usual spacecraft prohibition against single failure points. Such failures would not necessarily meet requirement 2 of JSCM 8080 Standard No. 12 which states that "During an abort the single failure or malfunction in a subsystem or component shall not cause loss of life." However, justification has been provided as required by the Standard. Also, the normal denitrogenization missions involve several possible single failure points, and the POS does not meet JSCM Standard 143 and CO_2 detection. Justification of the above conditions is the capability

to check out the POS, the low failure rates of components, and the short exposure. The FMEA and Hazard Analyses cover criticality 1 failures modes and their justification in detail.

Results

The safety approach described above including study of detailed alternatives in the design has led to positive safety features. Among these, the following are prominent:

1) The O_2 bottle is designed for infinite life, i.e., unlimited cycles of charge and discharge.

2. There is a positive means to determine that a canister/cartridge is fresh.

3. Relief provision in event of a failed open regulator is adequate to prevent excess breathing pressure.

4. The unit is protected from incidental physical damage by its cover and is not prone to snagging by external objects.

5. Crewmen are positively isolated from touch temperatures over 113°F.

6. Crewmen are protected against breathing temperatures above 110°F dry bulb and from excessively cold temperatures, even in event of a failure.

7. Provision is made for continuous ventilation to prevent condensation and maintain visibility through the face plate.

8. The mask is capable of being lifted from the face quickly, if necessary.

9. The face plate is shatterproof, and gage faces are vented.

10. The POS is designed to be washable in the areas where exhaled gases flow or are contained, thus preventing bacterial buildup or infection.

Hazard Analyses

Hazards have been searched from the FMEA criticality 1 items by review relative to intended procedures and handling, by reflection of the design against the guidelines and constraints, and by reflection of the design against the MSC Space Flight Hazards Catalog, MSC00134, and against the Skylab System Safety Checklist.

The analysis was conducted using the Rockwell "Reliability and Safety Desk Instruction No. 400-1, Hazards Analyses Procedures" which amplifies on applicable portions of NHB5300.4 (ID) and MIL-STD-882.

In accordance with 400-1, all hazards which are physically possible were considered irrespective of probability of occurrence, means existing in the design to control the hazard, number of failures required to cause damage or loss, redundancy, etc. The hazards are either in Residual or Controlled Status.

SPACE SHUTTLE HAZARD ANALYSIS

HAZARD GROUP	HAZARD CODE	HAZARD NO.
Loss of/Unsafe Environment	DD	1A-06-POS-1A

SUBSYSTEM/OPERATION	MISSION PHASE
POS	

REFERENCES

HAZARD

CO_2 Poisoning

HAZARD DESCRIPTION

An improperly charged canister (i.e., with poisoned or exhausted LiOH) could result in CO_2 poisoning even though the pressure indicator showed it to be fresh.

CAUSES

Failure to observe procedures for storage and charging of LiOH.

Note: See also two modes of failure on page 5 of the Critical Item List and their Rationale for Acceptance.

EFFECTS

Possible loss of life.

HAZARD LEVEL	HAZARD CATEGORY	PREPARED BY	DATE
I	A		Revision 10/30/75

1A-06-POS-1A

REQUIREMENTS	RESPONSIBLE ENGINEER	VERIFICATION*	
		REQUIREMENTS	IMPLEMENTATION

Controls of procurement, storage, and handling are adequate for the hazard to be considered controlled. The controls are summarized as follows:

Activity Covered	Procedure for POS Prototype	Procedure for Flight POS
Procurement	Procured to MIL Specification, with requirement for certification and analysis.	Same as for prototype.
Packaging	Shipped in sealed plastic bag in can with sealed cover.	Same as for prototype.
Receipt at HS	Verification of presence of Lot Number plus presence and correctness of Part Number and analysis.	Same as for prototype plus verification of chemical composition of sample from each lot.
Storage at HS	Stored in shipping container.	Same as for prototype.
Charging of POS	Bag opened only in LiOH charge rig after complete purge of rig with N_2. Cartridge charged and assembled in charge rig; then put in plastic bag. Bag is heat sealed immediately upon removal from rig and placed in 2nd bag.	Same as for prototype.

HAZARD STATUS

OPEN		CLOSED			CLOSURE DOCUMENT		CONCURRENCE	
IN-WORK	RESIDUAL	ELIMINATED	CONTROLLED	ACCEPTED	REFERENCE	DATE	SAFETY	RESP. GROUP
			X					

*IF REQUIREMENT IS NOT IMPLEMENTED PROVIDE RATIONALE FOR NON-COMPLIANCE INSTEAD.

FORM 3981-F REV. 10-73 (BACK)

REQUIREMENTS			RESPONSIBLE ENGINEER	VERIFICATION*	
				REQUIREMENTS	IMPLEMENTATION
Activity Covered	Procedure for POS Prototype	Procedure for Flight POS			
Cartridge Acceptance Test	Cartridge removed from bags while in LiOH charge rig and installed in canister. Delta P checked with N_2 or O_2. Canister then charged to 2 psi with O_2 and sealed on cartridge removed and resealed in plastic bags.	Same as for prototype.			
Storage of Cartridge	Cartridge stored either in charged canister with indicator or in double plastic bags.	Same as for prototype.			
Manned Evaluation Test	Above procedures plus redundant CO_2 sensing in the loop.	N/A			
In the event of a headache during IV operation, the spare POS should be substituted.					

HAZARD STATUS							CONCURRENCE	
OPEN		CLOSED			CLOSURE DOCUMENT			
IN-WORK	RESIDUAL	ELIMINATED	CONTROLLED	ACCEPTED	REFERENCE	DATE	SAFETY	RESP. GROUP
			X					

*IF REQUIREMENT IS NOT IMPLEMENTED PROVIDE RATIONALE FOR NON-COMPLIANCE INSTEAD.

FORM 3981-F REV. 10-73 (BACK)

SPACE SHUTTLE HAZARD ANALYSIS

HAZARD GROUP	HAZARD CODE	HAZARD NO.
Fire Explosion	DD	1A-06-POS-2A

SUBSYSTEM/OPERATION	MISSION PHASE
POS	All

REFERENCES

HAZARD

Fire in high pressure O_2 system.

HAZARD DESCRIPTION

Organic contaminant particles driven against valve seats, etc. can initiate combustion.

CAUSES

Lack of cleanliness disciplines.

EFFECTS

Injury to crewman.

HAZARD LEVEL	HAZARD CATEGORY	PREPARED BY	DATE
I	A		Revision 10/30/75

1A-06-POS-2A

REQUIREMENTS	RESPONSIBLE ENGINEER	VERIFICATION*	
		REQUIREMENTS	IMPLEMENTATION

Cleanliness of the system and the O_2 charge is the key to prevention of fire.

Parts or Activity Covered	Procedure for Flight and Prototype POS
Procured Components	Cleaned per MIL-STD-1246A, Level 100A. Packaged in double plastic bags. Unpackaged and handled only in clean work station.
Detail Parts	Cleaned per HS 3150, CD-3. Packaged in plastic bags. Unpackaged and handled only in clean work station.
Assembly	Use only details cleaned as above. Assembly completed within clean work station. Unit not removed from work station until the assembly is complete and all ports are covered.
Test	Test rig completely cleaned per HS 3150 CD-3. Gas supplied to system through a filter. Oxygen is certified MIL-O-27210 oxygen.
Storage	POS stored with all ports covered.
Recharge in Flight	Dependent on vehicle gas supply and procedures.

The controls, through storage, are adequate for the hazard to be considered "controlled". Flight safety depends on NASA procedures. Therefore, overall status must be "Residual" pending adoption of flight procedures by NASA.

HAZARD STATUS

OPEN		CLOSED			CLOSURE DOCUMENT		CONCURRENCE	
IN-WORK	RESIDUAL	ELIMINATED	CONTROLLED	ACCEPTED	REFERENCE	DATE	SAFETY	RESP. GROUP
	X							

*IF REQUIREMENT IS NOT IMPLEMENTED PROVIDE RATIONALE FOR NON-COMPLIANCE INSTEAD.

FORM 3981-F REV. 10-73 (BACK)

SPACE SHUTTLE HAZARD ANALYSIS

HAZARD GROUP	HAZARD CODE	HAZARD NO.
Burn (Hot Surface Contact)	AA	10-06-POS-3A

SUBSYSTEM/OPERATION	MISSION PHASE
POS	All Operational

REFERENCES

HAZARD

Burn by contact with hot container.

HAZARD DESCRIPTION

In operation the LiOH cartridge gets up to 200°F. Normal contact is prevented by a cover. If cover is ineffective or if cartridge is removed before cooldown and without protective gloves, burns may occur.

CAUSES

Ineffective cover due to contamination of the gold plated inner surface or removal of a cartridge before cooldown.

EFFECTS

Skin burns.

HAZARD LEVEL	HAZARD CATEGORY	PREPARED BY	DATE
III	A		Revision 10/31/75

REQUIREMENTS	RESPONSIBLE ENGINEER	VERIFICATION*	
		REQUIREMENTS	IMPLEMENTATION
There must be handling cautions for the gold plate cover and strict procedures for removal of cartridges. This hazard is classed as residual until NASA generated instructions deal with it.			

HAZARD STATUS							CONCURRENCE	
OPEN		CLOSED			CLOSURE DOCUMENT			
IN-WORK	RESIDUAL	ELIMINATED	CONTROLLED	ACCEPTED	REFERENCE	DATE	SAFETY	RESP. GROUP
	X							

*IF REQUIREMENT IS NOT IMPLEMENTED PROVIDE RATIONALE FOR NON-COMPLIANCE INSTEAD.

FORM 3981-F REV. 10-73 (BACK)

SPACE SHUTTLE HAZARD ANALYSIS

HAZARD GROUP	HAZARD CODE	HAZARD NO.
Flying Debris	BB	1A-06-POS-4

SUBSYSTEM/OPERATION	MISSION PHASE
POS	All with charged bottle.

REFERENCES

HAZARD

Explosive Rupture

HAZARD DESCRIPTION

A high pressure bottle, pressure gage, etc. if not designed and proved with respect to facture characteristics can create high velocity debris upon rupture.

CAUSES

Flaw or corrosion, coupled with design deficiency. This hazard is a prominent category of hazard for pressure vessels and is documented even though eliminated by design.

EFFECTS

Injury

HAZARD LEVEL	HAZARD CATEGORY	PREPARED BY	DATE
I	A		Revision 10/31/75

1A-06-POS-4

REQUIREMENTS	RESPONSIBLE ENGINEER	VERIFICATION*	
		REQUIREMENTS	IMPLEMENTATION
The bottle is designed to leak rather than burst, under all possible combinations of loading, both static and fatique, both pressure loading and vibration, shock and acceleration.			

HAZARD STATUS								
OPEN		CLOSED			CLOSURE DOCUMENT		CONCURRENCE	
IN-WORK	RESIDUAL	ELIMINATED	CONTROLLED	ACCEPTED	REFERENCE	DATE	SAFETY	RESP. GROUP
			X					

*IF REQUIREMENT IS NOT IMPLEMENTED PROVIDE RATIONALE FOR NON-COMPLIANCE INSTEAD.

FORM 3981-F REV. 10-73 (BACK)

SPACE SHUTTLE HAZARD ANALYSIS

HAZARD GROUP	HAZARD CODE	HAZARD NO.
Loss of Oxygen	DD	1A-06-POS-5A

SUBSYSTEM/OPERATION	MISSION PHASE
POS	Mission Operations Independent Operation

REFERENCES

HAZARD

Loss of oxygen from the POS.

HAZARD DESCRIPTION

Exhaustion of oxygen before completion of usage during independent operation due to leakage.

CAUSES

Failed seals, cracked or torn flow compensator, porous housings, loose fittings, pinhole corrosion, fatique cracks, etc.

EFFECTS

Possible loss of life.

HAZARD LEVEL	HAZARD CATEGORY	PREPARED BY	DATE
I	A		Revision 10/31/75

1A-06-POS-5A

REQUIREMENTS	RESPONSIBLE ENGINEER	VERIFICATION*	
		REQUIREMENTS	IMPLEMENTATION
Provide leakage check out prior to use. Provide for astronaut monitoring of pressure gage to permit timely action in event of leakage, such as switch to spare POS when IV or to accelerate transfer and minimize demand during EV. This hazard is classed as residual pending adoption of flight procedures by NASA.			

HAZARD STATUS							CONCURRENCE	
OPEN		CLOSED			CLOSURE DOCUMENT			
IN-WORK	RESIDUAL	ELIMINATED	CONTROLLED	ACCEPTED	REFERENCE	DATE	SAFETY	RESP. GROUP
	X							

*IF REQUIREMENT IS NOT IMPLEMENTED PROVIDE RATIONALE FOR NON-COMPLIANCE INSTEAD.

FORM 3981-F REV. 10-73 (BACK)

SPACE SHUTTLE HAZARD ANALYSIS

HAZARD GROUP	HAZARD CODE	HAZARD NO.
Toxicity	DD	1A-06-POS-6A

SUBSYSTEM/OPERATION	MISSION PHASE
POS	Mission Operations Independent Operation

REFERENCES

HAZARD

Ingestion of foul or toxic gas.

HAZARD DESCRIPTION

During inhalation, system pressure in the regenerative loop is slightly below ambient. If leaking occurs, the POS would not protect against possible toxic gases.

CAUSES

A leak in the breathing bag or any other portion of the regenerative loop.

EFFECTS

Possible loss of life or injury.

HAZARD LEVEL	HAZARD CATEGORY	PREPARED BY	DATE
I	A		Revision 10/31/75

REQUIREMENTS	RESPONSIBLE ENGINEER	VERIFICATION*	
		REQUIREMENTS	IMPLEMENTATION
The POS should be checked for tightness after any usage. The low exposure times and the low failure rates justify acceptance of this hazard.			

HAZARD STATUS							CONCURRENCE	
OPEN		CLOSED			CLOSURE DOCUMENT			
IN-WORK	RESIDUAL	ELIMINATED	CONTROLLED	ACCEPTED	REFERENCE	DATE	SAFETY	RESP. GROUP
	X							

*IF REQUIREMENT IS NOT IMPLEMENTED PROVIDE RATIONALE FOR NON-COMPLIANCE INSTEAD.

FORM 3981-F REV. 10-73 (BACK)

SPACE SHUTTLE HAZARD ANALYSIS

HAZARD GROUP	HAZARD CODE	HAZARD NO.
Contamination	DD	1A-06-POS-7

SUBSYSTEM/OPERATION	MISSION PHASE
POS	Mission Operations

REFERENCES

HAZARD

Choking from foreign object ingestion.

HAZARD DESCRIPTION

If the "pebbles" in the regenerative heat exchanger come loose, they could be swept into the breathing stream and cause choking.

CAUSES

Failure of the retaining screen.

EFFECTS

Possible suffocation.

HAZARD LEVEL	HAZARD CATEGORY	PREPARED BY	DATE
I	A		

REQUIREMENTS	RESPONSIBLE ENGINEER	VERIFICATION*	
		REQUIREMENTS	IMPLEMENTATION
The strength of the screen is such that this hazard is reduced to a controlled level.			

HAZARD STATUS						
OPEN		CLOSED			CLOSURE DOCUMENT	
IN-WORK	RESIDUAL	ELIMINATED	CONTROLLED	ACCEPTED	REFERENCE	DATE
			X			

CONCURRENCE	
SAFETY	RESP. GROUP

*IF REQUIREMENT IS NOT IMPLEMENTED PROVIDE RATIONALE FOR NON-COMPLIANCE INSTEAD.

SPACE SHUTTLE HAZARD ANALYSIS

HAZARD GROUP	HAZARD CODE	HAZARD NO.
Loss of Unsafe Environment	DD	1A-06-POS-8

SUBSYSTEM/OPERATION	MISSION PHASE
POS	Independent Rescue Operation

REFERENCES

HAZARD

Loss of regenerative function.

HAZARD DESCRIPTION

A) If the astronaut should vomit into the regenerative heat exchanger, it could be clogged, and the regenerative feature of the POS would be lost, limiting the time available for transfer.

B) If the exhalation check valve, item 18, fails open, the regenerative feature would be lost.

CAUSES

EFFECTS

CO_2 Poisoning

HAZARD LEVEL	HAZARD CATEGORY	PREPARED BY	DATE
II	A		

REQUIREMENTS	RESPONSIBLE ENGINEER	VERIFICATION*	
		REQUIREMENTS	IMPLEMENTATION
A) If nauseous, the crew member in the Rescue Ball must be prepared to pull off the mask before vomiting. B) The regenerative action can be partially restored by holding the breathing bag in a collapsed position. Note: Without the regenerative function, CO_2 concentration would reach in the Rescue Ball.			

HAZARD STATUS

OPEN		CLOSED			CLOSURE DOCUMENT		CONCURRENCE	
IN-WORK	RESIDUAL	ELIMINATED	CONTROLLED	ACCEPTED	REFERENCE	DATE	SAFETY	RESP. GROUP
			X					

*IF REQUIREMENT IS NOT IMPLEMENTED PROVIDE RATIONALE FOR NON-COMPLIANCE INSTEAD.

FORM 3981-F REV. 10-73 (BACK)

APPENDIX C

POS CHECK OUT PROCEDURE

The POS FMEA has identified several criticality 1 failure modes which are not readily detectable or obvious to the crewman. These are failure of the check valve at the inlet to the breathing bag and inward leakage any where in the breathing circuit. The following procedure specifically checks for these two failures and provides any indications that the system is operational.

	Check Point	Procedure
a)	Bottle Pressure	Verify bottle pressure gage reading at proper level.
b)	LiOH Verification	Verify indicator pin on side of LiOH canister is visible.
c)	Exhalation Check Valve	Place mask on face and exhale. Attempt to inhale from system. Breathing bag should not collapse and crewman should not be able to inhale.
d)	Inward Leakage	Open canister. Place mask to face inhale from system and exhale to ambient. Once bag is collapsed, crewman should not be able to inhale.
e)	O_2 Supply Check Out	With canister closed, connect to O_2 supply. Verify that interstage pressure is 33.5 $\pm$ 6 psi. Place mask to face and inhale. Crewman should feel flow from demand regulator.

In the event of emergency use in a contaminated cabin, the crewman should only do steps (a) and (b) prior to donning the system. Once the system is operational, the crewman can check for inward leakage by shutting off the O_2 supply (close valve on POS or disconnect fill line as applicable) and breathing until the bag is depleted. The crewman should attempt to inhale slowly and should not be able to. The O_2 supply should then be reestablished and the canisters shut off. If the crewman can inhale without opening the demand regulator, the exhalation check valve is not functioning and the system should be replaced.

APPENDIX D

PROTOTYPE PORTABLE OXYGEN SUBSYSTEM

LIMITED LIFE LIST

SVHS 7016

Hamilton Standard
DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT · U.S.A.

CODE IDENT NO.	SPECIFICATION NO.	REV.
73030	SVHS 7016	

SPECIFICATION TITLE Prototype Portable Oxygen Subsystem

Limited Life List

PREPARED BY W Bouchelle 6/17/75 DATE
APPROVED BY A B Hooker 11/5/75 QUALITY DATE
APPROVED BY J Goodwin 11/5/75 PROJECT DATE
APPROVED BY _____ PURCHASING DATE
APPROVED BY _____ TECH. STANDARDS DATE
APPROVED BY _____ MANUFACTURING DATE
APPROVED BY _____ MATERIALS DATE
APPROVED BY _____ DESIGN DATE
APPROVED BY _____ SPEC. CONTROL DATE
APPROVED BY J. Rayle 11/5/75 RELIABILITY DATE
APPROVED BY _____ DATE
APPROVED BY _____ DATE
APPROVED BY _____ DATE
APPROVED BY _____ DATE

CUSTODIAN _____

EXP. RELEASE _____ DATE
PROD. RELEASE _____ DATE

Hamilton Standard
DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

CODE IDENT NO.	SPECIFICATION NO.	REV
73030	SVHS 7016	

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Hamilton Standard
DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

CODE IDENT NO.	SPECIFICATION NO.	REV
73030	SV HS 7016	

1.0 SCOPE

This specification defines the portable oxygen subsystem limit life items and defines requirements for inspection and historical data/records.

2.0 APPLICABLE DOCUMENTS

Drawings

SVSK 90390 - Portable Oxygen Subsystem

Standards

Mil-HDBK-695 - Military Standardization Handbook Rubber Products: Shelf Storage Life

3.0 REQUIREMENTS

3.1 Time/Cycle Items List

All items in the POS are capable of more than 1000 hours of operation and 1000 operating cycles both of which exceed the life requirements of the POS. Therefore, there are no time/cycle limited items in the POS.

3.2 Age - Controlled Items List

The prototype POS utilizes some items containing materials requiring age control as defined by Mil-HDBK-695. The details, materials age control limits are listed in Table I.

4.0 QUALITY ASSURANCE

The acceptance data package for the POS shall contain the cure date (by quarter) of each item containing materials requiring age control. At the expiration of the life specified in Table I, the following actions shall be taken:

Code	Action
A	The item will be carefully examined for cracks, flaws on excessive wear. If found to be free of defects, it will be proof pressure tested and reexamined. If still free of defects, it may be used for one year at which time the inspection will be repeated.

4.0 (Cont'd)

Code	Action
B	Items marked 'B' or found to be defective will be replaced.

The historical record in the acceptance data package will be updated to reflect the results of the age-control inspection and shall include the cure date of all replacement age-controlled materials.

TABLE I
AGE CONTROL MATERIALS LIST

Item No.	Name	Material Requiring Age Control	Minimum Life	Inspection Code	Cure Date	Inspection Date				
10	Flow Compensating Bag	Natural Latex	2	A						
19	Breathing Bag	Conductive Nat'l Latex	2	A						
14	Mask Assembly	Neoprene and Neoprene/Nat'l Rubber	5	A						
15	Flexible Hose	Neoprene	5	A						
12	Check Valve	Ethylene Propylene	5	A						
NA	Tubing	Neoprene	5	A						

APPENDIX E

PORTABLE OXYGEN SUBSYSTEM

ACCEPTANCE TEST SPECIFICATION

SVHS 7015

AND

PREDELIVERY ACCEPTANCE TEST PROCEDURES

FOR

PORTABLE OXYGEN SUBSYSTEM

PDA 7015

Hamilton Standard
DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT • U.S.A.

CODE IDENT NO.	SPECIFICATION NO.	REV.
73030	SVHS 7015	

SPECIFICATION TITLE Portable Oxygen Subsystem Acceptance Test Specification

PREPARED BY W Bouchelle 6-16-75 DATE
APPROVED BY A B Hooker 11/5/75 QUALITY DATE
APPROVED BY J Goodwin 10-1-75 PROJECT DATE
APPROVED BY _____ PURCHASING DATE
APPROVED BY _____ TECH. STANDARDS DATE
APPROVED BY _____ MANUFACTURING DATE
APPROVED BY _____ MATERIALS DATE
APPROVED BY _____ DESIGN DATE
APPROVED BY _____ SPEC. CONTROL DATE
APPROVED BY J. Raye 11/5/75 RELIABILITY DATE
APPROVED BY _____ DATE
APPROVED BY _____ DATE
APPROVED BY _____ DATE
APPROVED BY _____ DATE

CUSTODIAN _____

EXP. RELEASE _____ DATE
PROD. RELEASE _____ DATE

TABLE OF CONTENTS

1.0 SCOPE

This specification establishes the requirements for complete identification and acceptance of the Prototype Portable Oxygen Subsystem (SVSK 90390) to be supplied to the National Aeronautics and Space Administration.

2.0 APPLICABLE DOCUMENTS

NASA

NHB 5300.4 (ID)	Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program
JSCM 5322	JSC Contamination Control Program Requirement Manual

Drawings

SVSK 90390	Portable Oxygen Subsystem
SV 723020-2	Oxygen Fill Connector

Standards

Mil-O-27210	Oxygen Aviators Breathing, Liquid and Gas
Mil-P-27401	Propellant, Pressurizing Agent, Nitrogen

3.0 REQUIREMENTS

This section specifies performance and product configuration requirements of the Portable Oxygen Subsystem.

3.1 Performance

3.1.1 Proof Pressure

The unit shall be capable of meeting the requirements of this specification after subjecting the high pressure circuit to a pressure of 15,773±138 KPa (2288±20 psig) for five minutes with the shutoff valve open and subjecting the interstage to a pressure of 689±69 KPa (100±10 psig) for five minutes.

The unit shall be capable of meeting the requirements of this specification after subjecting the breathing circuit to a pressure of 6.89±.69 KPa (1±.1 psig).

3.1.2 Operational Requirements

3.1.2.1 O_2 Pressure Gage Accuracy

The O_2 pressure gage shall have an accuracy of ±4% of full scale reading.

3.1.2.2 Interstage Pressure Gage Accuracy

The interstage pressure gage shall have an accuracy of ±4% of full scale reading.

3.1.2.3 Make-up Oxygen Supply Performance

Pressure reducer shall maintain the interstage pressure at 231±41 KPa (33.5±6 psid) with with an inlet pressure of 689 KPa (100 psig) to 7,887 KPa (1144 psig). With a supply pressure of 6205±69 KPa (900±10 psig) the O_2 flow to the mask shall be .22 Kg/hr (1.5 ± lb/hr). With a breathing circuit pressure of 746 Pa (-3 in H_2O) the flow through the demand regulator shall be less than 25 cc/hr. With the breathing circuit pressure of 995 Pa (-4 in H_2O) the flow through the demand regulator shall be 3.6 Kg/hr (8 lb/hr) minimum. The O_2 inlet check valve shall permit less than 25 scc/min backflow when the downstream side is pressurized to 498 Pa (2.0 in H_2O).

3.1.2.4 Breathing Circuit Performance

At a flow of 4.1 Kg/hr (9.1 lb/hr) the pressure drop from the mask to the cartridge inlet shall not exceed 348 Pa(1.4 in H_2O) and the pressure drop from the cartridge outlet to the mask shall not exceed 298 Pa (1.2 in H_2O). The exhalation relief valve shall crack at 124 Pa (0.5 in H_2O) max. and shall reset at 50 Pa (0.2 in H_2O) minimum & the pressure drop shall be 498 Pa (2.0 in H_2O) maximum at an O_2 flow of 65 LPM. With a backpressure of 249 Pa (1 in H_2O) the flow through either the exhalation or inhalation check valve shall not exceed 25 scc/min O_2.

3.1.2.5 External Leakage

3.1.2.5.1 High Pressure Circuit

With the bottle charged to 7887±138 KPa (1144±20 psig) and the shutoff valve closed the external leakage shall not exceed 2.0 scc/ hr. With the bottle charged to 7887±138 KPa (1144±20 psig) and the shutoff valve open the external leakage shall not exceed 20 cc/hr.

3.1.2.5.2 Breathing Circuit

With a breathing circuit pressure of 746 Pa (-3 inH_2O) the inward leakage shall not exceed 25 scc/min.

3.1.2.6 Cartridge/Canister Performance

The LiOH cartridge shall contain a minimum of 0.5 Kg (1.1 lb) LiOH after charging. At a flow rate of 4.1 Kg/hr (9.1 lb/hr) the pressure drop from the canister inlet to outlet after installation of the cartridge shall not exceed 99 Pa (.4 in H_2O). The canister pressure indicator shall be visible at an internal pressure of 3.45 KPa (0.5 psig). The canister cartridge assembly shall be sealed with an internal pressure of 13.8 KPa (2 psig).

The external leakage of the sealed canister when pressurized to 13.8 KPa (2 psig) shall not exceed .15 cc/hr.

3.2 Product Configuration

3.2.1 Manufacturing Drawing

The configuration of the Portable Oxygen Subsystem shall be in accordance with Hamilton Standard Drawing SVSK 90390 and the detail drawings.

3.2.2 Government Furnished Property List

The POS shall contain the following GFP hardware:

P/N	Part Name
SV 723020-2	Oxygen Fill Connector

4.0 QUALITY ASSURANCE

A Quality Assurance Program and a Reliability Program in accordance with NASA Document NHB 5300.4 (ID) as modified by contract NAS 9-14458 shall be required.

4.1 Performance and Design Requirements

Verification Cross Reference Index

Manufacturing Drawing 3.2.1	Pretest Inspection 4.2.1
Proof Pressure 3.1.1	Proof Pressure 4.2.2
O_2 Pressure Gage Accuracy 3.1.2.1	Makeup O_2 Supply Perf. 4.2.3
Interstage Pressure Gage Accuracy 3.1.2.2	" " " " 4.2.3
Accuracy 3.1.2.2	
Makeup O_2 Supply	" " " " 4.2.3
Performance 3.1.2.3	

4.1 (Cont'd)

Requirements	Verification
Breathing Circuit Performance 3.1.2.4	Breathing Circuit Perf. 4.2.4 and Proof Pressure 4.2.2
External Leakage 3.1.2.5	External Leakage 4.2.5
Cartridge/Canister Performance 3.1.2.6	Cartridge/Canister Performance 4.2.6

4.2 Tests/Verification

The following tests shall be run on the prototype POS per PDA 7015 to demonstrate the acceptability of the unit. To maintain the internal cleanliness of the unit during testing, the gases used for the test shall be filtered through a 15 absolute filter placed immediately upstream of the connections to the POS. Oxygen conforming to Mil-O-27210, Type I and nitrogen conforming to Mil-P-27401 Type I are the only gases to be used for testing the POS.

4.2.1 Pretest Inspection

The Portable Oxygen Subsystem shall be inspected for compliance with the manufacturing drawings. Assembly and subassembly inspection and manufacturing operation records shall be reviewed for adequate completion of the operation and the records thereof. The quality records shall also be reviewed for completeness. All material review action, to this point, must be completed.

4.2.2 Proof Pressure

The shutoff valve will be in the open position and pressure will be supplied through the fill fittings. The pressure will be maintained at 15,773±138 KPa (2288±20 psig) for five minutes using nitrogen. Pressure will then be supplied to the interstage through a pressurization fitting on the pressure reducer. The interstage pressure will be maintained at 689.±69. KPa (100±10 psig) for five minutes using nitrogen. Ambient conditions shall be room ambient pressure and 4.4 to 38°C (70±30°F). During the test, the gas will flow to the mask continuously.

The breathing circuit relief valve will be capped and the breathing circuit will be pressurized with nitrogen to 6.89±.69 KPa (1±.1 psig) for five minutes. The flow required to maintain a constant pressure shall not exceed 25 cc/min.

4.2.3 Make-up O_2 Supply Performance

The shutoff valve shall be in the open position and oxygen shall be supplied through the fill fittings during the following tests:

The supply pressure shall be set at pressures of 689±69 KPa (100±10 psig) and 7887±138 KPa (1144±20 psig). The O_2 supply pressure gage shall agree with the rig gage within ±1102 KPa (160 psi). The interstage pressure gage shall agree with a rig pressure gage (connected to the pressure port on the pressure reducer) within ±27.8 KPa (4.0 psi). The interstage pressure shall be 231±40 KPa (33.5±6 psid). The supply pressure will then be set at 6205±69 KPa (900±10 psig). The flow to the mask shall be .227±.01 Kg/hr (0.5±.025 lb/hr). The breathing circuit pressure will be reduced 746 Pa (3 in H_2O) below ambient. The flow to vacuum required to maintain this pressure shall not exceed 25 scc/min. The breathing circuit pressure will then be decreased to 995 Pa (4 in H_2O) below ambient. The flow to the mask shall be 3.6 Kg/hr (8 lb/hr) minimum. The oxygen supply will be shut off and the system pressure will be decreased to zero. A mask pressure of 498±50 Pa (2±.2 in H_2O) will be established and the interstage pressure will be observed. The flow required to maintain the interstage pressure at zero shall not exceed 25 scc/min. The ambient condition shall be room ambient pressure and 4.4 to 38°C (70±30°F).

4.2.4 Breathing Circuit Performance

With the canister removed from the POS, the pressure in the mask shall be increased until a flow of 4.1 Kg/hr (9.1 lb/hr) is obtained. The pressure drop between the mask and the canister inlet fitting shall not exceed 348 Pa (1.4 in H_2O). The mask pressure shall be decreased below ambient until a flow of 4.1 Kg/hr (9.1 lb/hr) is established.

The pressure drop between the canister outlet fitting and the mask shall not exceed 298 Pa (1.2 in H_2O). During this test the canister inlet fitting shall be capped. With a pressure gage connected to the canister inlet fitting, the pressure in the mask shall be slowly increased until a flow of 65±1 lPM is obtained.

The pressure difference between the canister inlet fitting pressure and ambient shall not exceed 498 Pa (2.0 in H_2O). The pressure at which flow is initiated shall be greater than 124 Pa (0.5 in H_2O) and the pressure at which flow stops shall be greater than 50 Pa (0.2 in H_2O).

4.2.4 (Cont'd)

A pressure of 249±25 Pa (1±.1 in H_2O) above ambient shall be established at the canister inlet fitting and flow to the mask will be collected. The flow shall be less than 25 scc/min. With the canister inlet fitting capped, the mask pressure shall be increased 249±25 Pa (1±.1 in H_2O) above ambient and flow to the canister outlet fitting will be collected. The flow shall be less than 25 scc/min. The test fluid to be used is oxygen and the ambient conditions shall be room ambient pressure and 4.4 to 38°C (70±30°F).

4.2.5 External Leakage (Prototype Unit Only)

The system shall be charged to 7887±138 KPa (1144±20 psig) with nitrogen and all joints, couplings and fittings in the high pressure and interstage circuit shall be coated with an oxygen compatible leak test fluid. There shall be no evidence of leakage. The shutoff valve will be closed and the gas supply line will be disconnected from the rig and submerged in water. The shutoff valve will be opened and the end of the supply line will be observed. The flow from the line shall not exceed 2 cc/hr.

The canister shall be installed in the POS in the open condition.
The pressure in the POS will be reduced 746 Pa (3 in H_2O) below ambient. The flow to vacuum required to maintain this pressure shall not exceed 25 scc/min. The ambient conditions shall be room ambient pressure and 4.4 to 38°C (70±30°F).

4.2.6 Cartridge/Canister Performance

The cartridge weight including preload pads shall be recorded prior to and after charging with LiOH. The weight increase due to LiOH shall be 0.2 Kg (1.1 lb) Minimum. The cartridge will be installed in the canister. A flow of 4.1 Kg/hr (9.1 lb/hr) using O_2 shall be established flowing from the canister inlet to the canister outlet. The pressure drop across the cartridge shall not exceed 99 Pa (.4 in H_2O). The canister pressure shall be increased to 3.45 KPa (0.5 psig) and then to 13.8 KPa (2.0 psig). The indicator shall be visible at 3.45 KPa (0.5 psig). At 13.8 KPa (2.0 psig) the canister valve shall be closed. The sealed canister will be submerged in water for 30 minutes. There shall be no evidence of leakage. The ambient condition shall be room ambient pressure and 4.4 to 38°C (70±30°F).

4.2.7 Post Test Inspection

After the POS has passed the sequence of tests, it shall have a complete, final visual inspection. The purpose of this inspection shall be to establish the final conditions of the unit and to complete all operation records.

5.0 PREPARATION FOR DELIVERY

Requirements for preparation for delivery and shipment of the POS shall be in accordance with JSCM 5322.

PREDELIVERY ACCEPTANCE TEST PROCEDURES

FOR

PORTABLE OXYGEN SUBSYSTEM

SVSK 90390

PREPARED BY: W Bouchelle 9-23-75
PROJECT ENGINEER

APPROVED BY: F. Goodwin 9-26-75
ENGINEERING PROGRAM MANAGER

APPROVED BY: A B Hooker 9/25/75
QUALITY ASSURANCE

APPROVED BY: J. F. Rayo 9/25/75
RELIABILITY

APPROVED BY: Luigi N Janner 10/15/75
NASA

1.0 INTRODUCTION

This document provides detailed procedures for testing the Portable Oxygen Subsystem in accordance with the predelivery acceptance test plan, prescribed in Section 4 of SVHS 7015, prior to shipment to NASA.

2.0 APPLICABLE DOCUMENTS

The following documents of the exact revision shown form a part of this document to the extent specified herein. In the event of a conflict between the referenced documents and the test procedures specified herein, these test procedures shall take precedence.

Specifications

SVHS 7015	Portable Oxygen Subsystem Acceptance Test Specification
HS 3150B, AM2	Processing, Testing, and Preservation of Parts Subject to High Cleanliness Levels
HS 1550D	Process Specification for Cleanliness Preservation and Handling of Products

Drawings

SVSK 90390	Portable Oxygen Subsystem
SV723020-2	Oxygen Fill Connector

Standards

MIL-O-27210D, AM2	Oxygen, Aviators Breathing, Liquid and Gas
MIL-P-27401C	Propellant, Pressurizing Agent Nitrogen
MIL-STD-794B March 1969	Parts and Equipment, Procedure for Packaging and Packing of

Other Publications

JSCM 5322A	JSC Contamination Control Program Requirements Manual
NHB 5300.4(1D)	Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program

3.0 REQUIREMENTS

3.1 Facility Requirements

Testing shall be performed in a controlled area. The high pressure supply shall be cleaned to HS 3150 CD-3, and the supply gas shall be filtered through a 15μ absolute filter. The breathing circuit instrumentation and connecting lines shall be cleaned with freon or alcohol and shall be free of oil and visible contaminants. The outside of the test unit shall be maintained clean according to HS 1550C1.

3.2 Test Setups

Test setups and mechanical connections shall be as defined in test procedures and as illustrated in the applicable test setup schematics.

3.3 Test Medium

Test shall be conducted with the test stand serviced with oxygen per MIL-O-27210 Type 1 and nitrogen per MIL-P-27401 Type 1. Supply pressures will be specified in the test procedures.

3.4 Test Sequence

The test program shall be conducted in the following sequence:

Sequence	Test	Paragraph
1	Pretest Inspection	7.1
2	Proof Pressure Test	7.2
See Note 1	Make Up O_2 Supply Performance	7.3
See Note 1	Breathing Circuit Performance	7.4
5	External Leakage	7.5
See Note 2	Cartridge/Canister Performance	7.6
7	Post Test Inspection	7.7

Note 1 - These tests may be conducted in any sequence after completion of the proof pressure test.

Note 2 - This test may be conducted in any sequence.

4.0 QUALITY ASSURANCE

4.1 Inspection

Testing shall be conducted under SSD Inspection surveillance. Verification of test results shall be indicated by inspection stamps on each sheet where an asterisk (*) appears in the "inspector" block.

4.2 Component Schematic

The Portable Oxygen Subsystem schematic is shown in Figure 1.

4.3 Calibration and Accuracy Requirements

All test gages, regulators, flow meters, et cetera shall have valid calibration certification with standards traceable to the National Bureau of Standards prior to use. The test equipment has certain gages which are used as indicators only and are not used in performance of these tests. These items do not require current certification.

4.4 List of Equipment

The equipment required for this test program is defined on each test setup schematic.

4.5 Test Data

A. Data shall be recorded in the spaces provided in the applicable data sheets.

B. The dash number, serial number, date of test, and test personnel shall be recorded on each data sheet in the spaces provided.

C. Deviations to the procedures specified in this document shall be recorded on the test sheets.

D. The project engineer shall summarize the test events at the completion of the tests, identifying any test events which are other than ordinary.

E. The completed data sheets and the applicable revision of the test procedure shall be retained and included in the acceptance data package for the unit tested.

4.6 Failure Reporting

A RDR containing a test description, actual test conditions, and results shall be prepared for any test result which does not comply with requirements. All RDR's shall be closed prior to delivery of the unit.

5.0 TESTS/VERIFICATION

The following tests shall be run on the prototype POS to demonstrate the acceptability of the unit following the procedures defined in Section 7.0.

5.1 Pretest Inspection

The Portable Oxygen Subsystem shall be inspected for compliance with the manufacturing drawings. Assembly and subassembly inspection and manufacturing operation records shall be reviewed for adequate completion of the operation and the records thereof. The quality records shall also be reviewed for completeness. All material review action, to this point, must be completed.

5.2 Proof Pressure

The shutoff valve will be in the open position, and pressure will be supplied through the fill fittings. The pressure will be maintained at 15,773 ± 138 KPa (2,288 ± 20 psig) for five minutes using nitrogen. Pressure will then be supplied to the interstage through a pressurization fitting on the pressure reducer. The interstage pressure will be maintained at 689 ± 69 KPa (100 ± 10 psig) for five minutes using nitrogen. Ambient conditions shall be room ambient pressure and 4.4 to 38°C (70 ± 30°F). During the test, the gas will flow to the mask continuously.

The breathing circuit relief valve will be capped, and the breathing circuit will be pressurized with nitrogen to 6.89 ± .69 KPa (1 ± .1 psig) for five minutes. The flow required to maintain a constant pressure shall not exceed 25 cc/min.

5.3 Makeup O_2 Supply Performance

The shutoff valve shall be in the open position, and oxygen shall be supplied through the fill fittings during the following tests:

The supply pressure shall be set at pressures of 689 ± 69 KPa (100 ± 10 psig) and 7,887 ± 138 KPa (1,144 ± 20 psig). The O_2 supply pressure gage shall agree with the rig gage within ±1,102 KPa (160 psi). The interstage pressure gage shall agree with a rig pressure gage (connected to the pressure port on the pressure reducer) within ±27.8 KPa (4.0 psi). The interstage pressure shall be 231 ± 40 KPa (33.5 ± 6 psid). The supply pressure will then be set at 6,205 ± 69 KPa (900 ± 10 psig). The flow to the mask shall be .227 ± .01 Kg/hr (0.5 ± .025 lb/hr). The breathing circuit pressure will be reduced 746 Pa (3 in H_2O) below ambient. The flow to vacuum required to maintain this pressure shall not exceed 25 scc/min. The breathing circuit pressure will then be decreased to 995 Pa (4 in H_2O) below ambient. The flow to the mask shall be 3.6 Kg/hr (8 lb/hr) minimum. The oxygen supply will be shut off, and the system pressure will be decreased to zero. A mask pressure

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

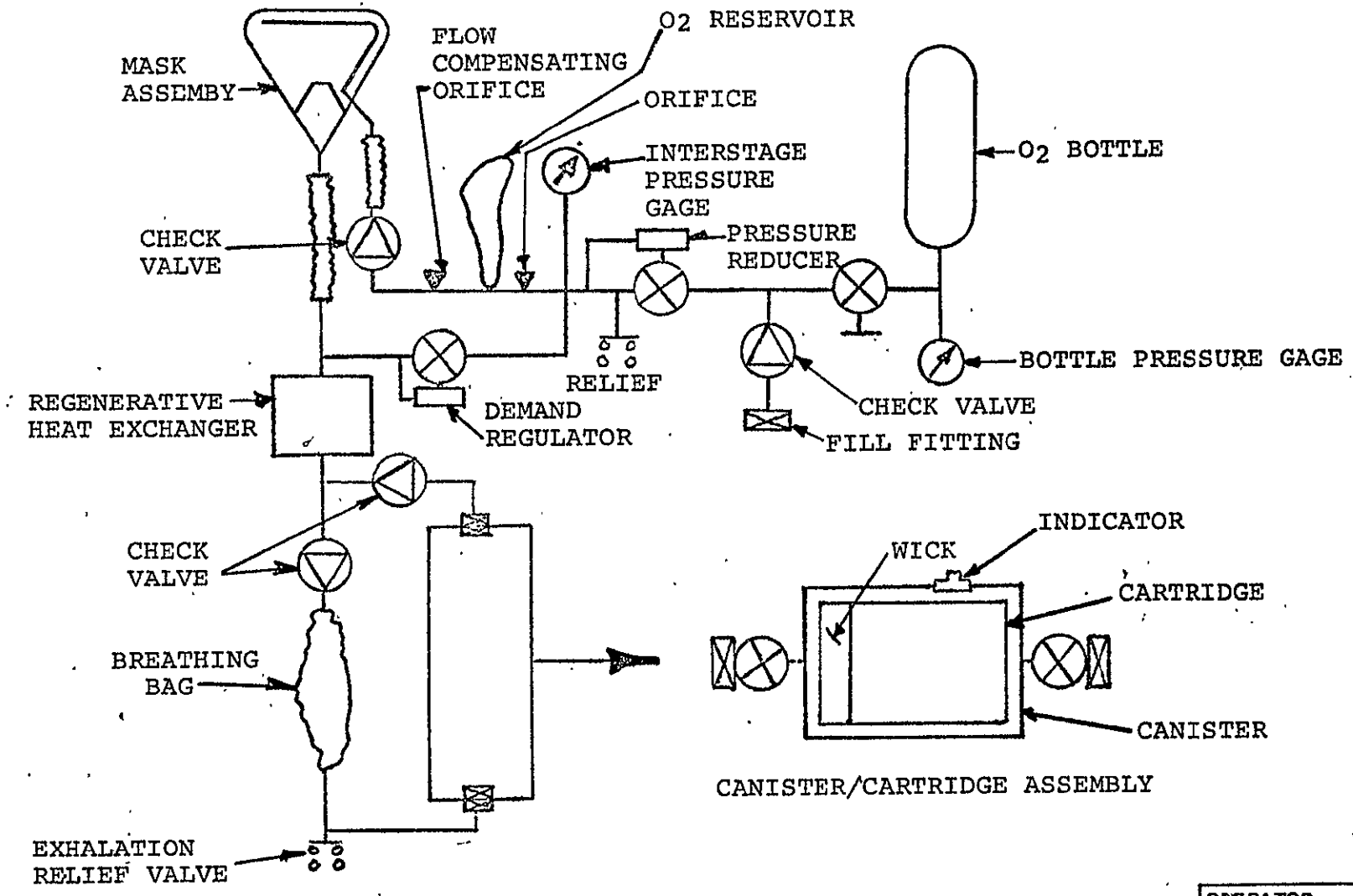

FIGURE 1 - PORTABLE OXYGEN SUBSYSTEM

OPERATOR
INSPECTOR

5.3 (Continued)

of 498 ± 50 Pa (2 ± .2 in H_2O) will be established, and the interstage pressure will be observed. The flow required to maintain the interstage pressure at zero shall not exceed 25 scc/min. The ambient condition shall be room ambient pressure and 4.4 to 38°C (70 ± 30°F).

5.4 Breathing Circuit Performance

With the canister removed from the POS, the pressure in the mask shall be increased until a flow of 4.1 Kg/hr (9.1 lb/hr) is obtained. The pressure drop between the mask and the canister inlet fitting shall not exceed 348 Pa (1.4 in H_2O). The mask pressure shall be decreased below ambient until a flow of 4.1 Kg/hr (9.1 lb/hr) is established. The pressure drop between the canister outlet fitting and the mask shall not exceed 298 Pa (1.2 in H_2O). During this test, the canister inlet fitting shall be capped. With a pressure gage connected to the canister inlet fitting, the pressure in the mask shall be slowly increased until a flow of 65 ± 1 1PM is obtained. The pressure difference between the canister inlet fitting pressure and ambient shall not exceed 498 Pa (2.0 in H_2O). The pressure at which flow is initiated shall be greater than 124 Pa (0.5 in H_2O), and the pressure at which flow stops shall be greater than 50 Pa (0.2 in H_2O).

A pressure of 249 ± 25 Pa (1 ± .1 in H_2O) above ambient shall be established at the canister inlet fitting, and flow to the mask will be collected. The flow shall be less than 25 scc/min. With the canister inlet fitting capped, the mask pressure shall be increased 249 ± 25 Pa (1 ± .1 in H_2O) above ambient, and flow to the canister outlet fitting will be collected. The flow shall be less than 25 scc/min. The test fluid to be used is oxygen, and the ambient conditions shall be room ambient pressure and 4.4 to 38°C (70 ± 30°F).

5.5 External Leakage (Prototype Unit Only)

The system shall be charged to 7,887 ± 138 KPa (1,144 ± 20 psig) with nitrogen, and all joints, couplings, and fittings in the high pressure and interstage circuit shall be coated with an oxygen compatible leak test fluid. There shall be no evidence of leakage. The shutoff valve will be closed, and the gas supply line will be disconnected from the rig and submerged in water. The shutoff valve will be opened, and the end of the supply line will be observed. The flow from the line shall not exceed 2 cc/hr.

5.5 (Continued)

The canister shall be installed in the POS in the open condition. The pressure in the POS will be reduced 746 Pa (3 in H_2O) below ambient. The flow to vacuum required to maintain this pressure shall not exceed 25 scc/min. The ambient conditions shall be room ambient pressure and 4.4 to 38°C (70 ± 30°F).

5.6 Cartridge/Canister Performance

The cartridge weight including preload pads shall be recorded prior to and after charging with LiOH. The weight increase due to LiOH shall be 0.2 Kg (1.1 lb) minimum. The cartridge will be installed in the canister. A flow of 4.1 Kg/hr (9.1 lb/hr) using O_2 shall be established flowing from the canister inlet to the canister outlet. The pressure drop across the cartridge shall not exceed 99 Pa (.4 in H_2O). The canister pressure shall be increased to 3.45 KPa (0.5 psig) and then to 13.8 KPa (2.0 psig). The indicator shall be visible at 3.45 KPa (0.5 psig). At 13.8 KPa (2.0 psig) the canister valve shall be closed. The sealed canister will be submerged in water for 30 minutes. There shall be no evidence of leakage. The ambient condition shall be room ambient pressure and 4.4 to 38°C (70 ± 30°F).

5.7 Post Test Inspection

After the POS has passed the sequence of tests, it shall have a complete, final visual inspection. The purpose of this inspection shall be to establish the final conditions of the unit and to complete all operation records.

6.0 PREPARATION FOR DELIVERY

Requirements for preparation for delivery and shipment of the POS shall be in accordance with JSCM 5322.

PDA 7015

CHG	DATE	P/E	Q/E
ORIG			
A			
B			
C			
D			
E			
F			
G			
H			
I			
J			
K			
L			
M			
N			
O			
P			

Hamilton Standard® DIVISION OF UNITED AIRCRAFT CORPORATION

SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET

MODEL	ITEM NO	SER. NO
ITEM DESCR.		
TEST SPEC.	CHG. LTR.	AMM. NO.
PART NO.	CONT. NO.	PAGE OF

7.0 TEST PROCEDURE

Testing shall be conducted in accordance with the procedures defined herein with results recorded on the applicable log sheet.

Prior to initiation of testing, the cleanliness of the rig/setup shall be verified.

High pressure supply cleaned per HS 3150 CD-3

Breathing circuit rig and instrumentation free of oil and visible contaminants

The sequence of operation shall be recorded on a Hamilton Standard Historical Log (HSF-1843). Any discrepancies shall be recorded on a Hamilton Standard Unit History (HSF-454C).

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION UA®	SER. NO.
5.1	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.1 Pretest Inspection

7.1.1 Examine the item with respect to surface finish, coating, visual defects and compliance with drawing SVSK 90390. Do not disassemble the unit to do a visual examination.

7.1.2 Verify by review of cleaning records that high pressure circuit complies with HS 3150 CD-3 and that the breathing circuit complies with HS 3150 CE-0.

7.1.3 Verify that all assembly operations are complete and that all shop orders have been completed and signed off.

7.1.4 Using the setup shown in Figure 7.1, determine the dry weight of the unit and record in the space provided.

	Unit Complies With Print	High Pressure Circuit Cleaned to HS 3150 CD-3	Breathing Circuit Cleaned to HS 3150 CE-0	All Assembly Operations Completed And All Documentation Completed	Weight
Yes					Actual lbs
No					Required N/A

OPERATOR	
INSPECTOR *	

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5.1	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

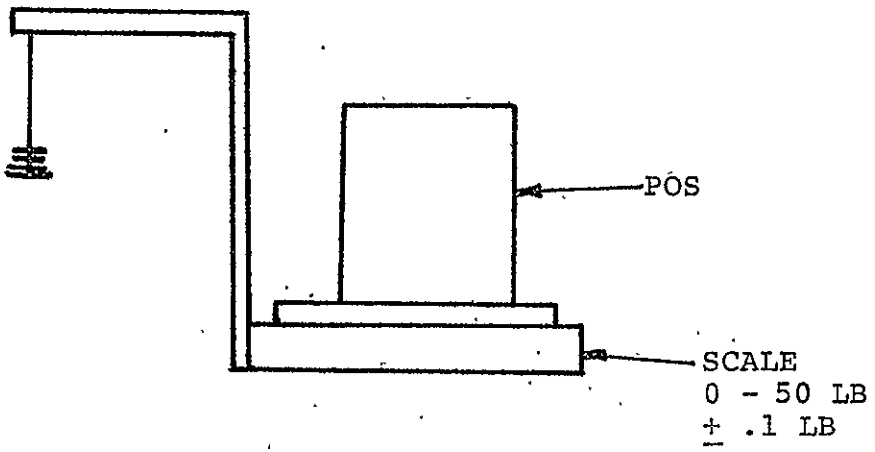

FIGURE 7.1 - WEIGHT SETUP

OPERATOR	
INSPECTOR	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION UA®	SER. NO.
5.2	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.2 Proof Pressure

7.2.1 Supply Circuit

Remove the pressurization fitting from the pressure reducer and install the unit in the test setup shown in Figure 7.2.

With the system shutoff valve open, adjust PR-1 to obtain a pressure of 100 ± 10 psig at the interstage regulator and adjust PR-2 to obtain a pressure of 2,288 ± 20 psig at the fill connector. Hold these pressure levels for 5 minutes.

Decrease PR-1 and PR-2 to return the system to ambient pressure.

There shall be no evidence of permanent deformation.

CAUTION

During this test, gas will flow from the small hose in the mask. Do not block this flow as this could damage the unit.

	Supply Pressure (P2)	Interstage Pressure (P1)	Duration
Required	2,288 ± 20 Psig	100 ± 10 Psig	5 Min. Minimum
Actual			

Freedom from permanent deformation Yes No

CAUTION

The unit shall be installed in a proof pressure chamber for this test.

OPERATOR	
INSPECTOR *	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.2	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

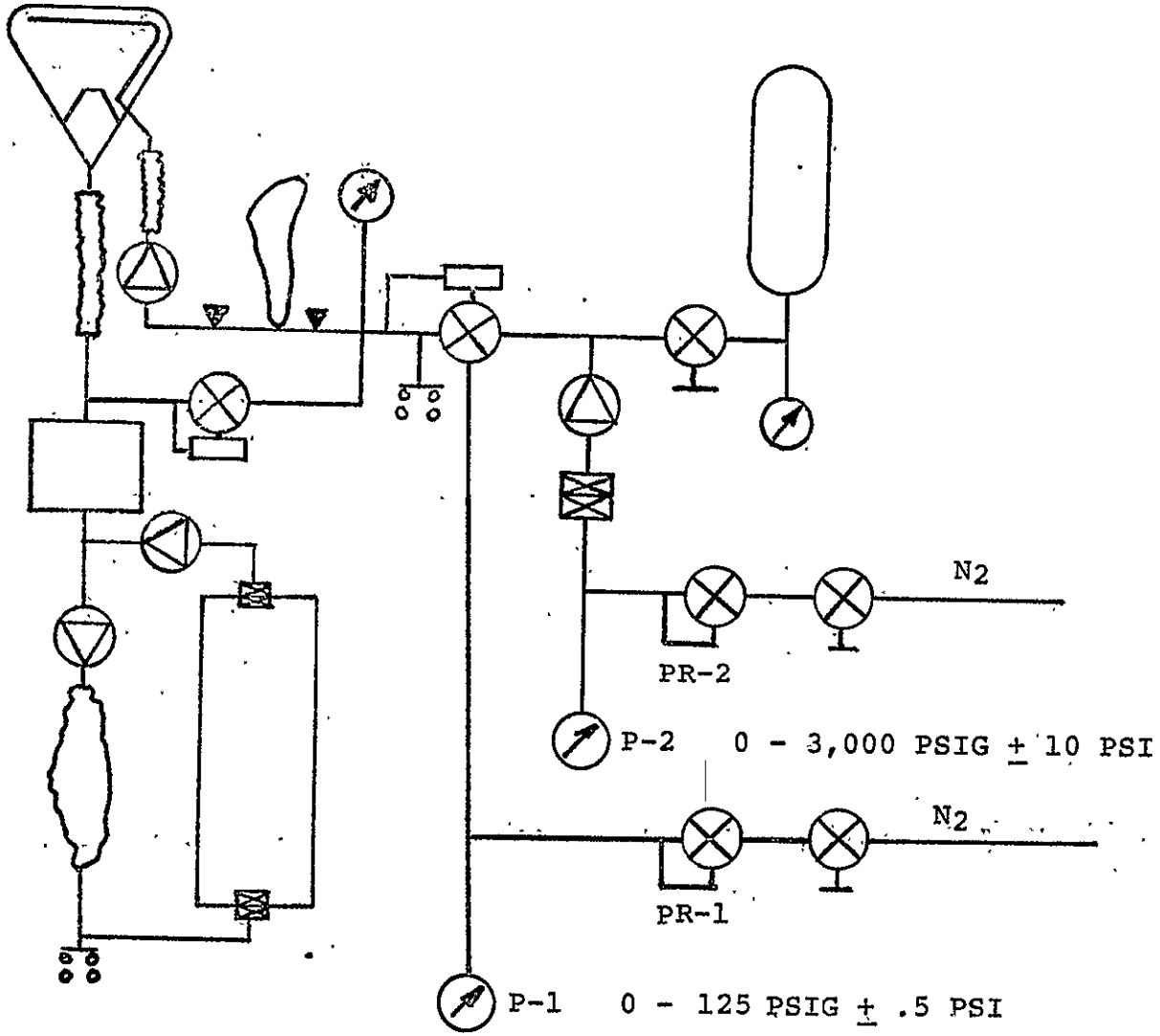

FIGURE 7.2 - PROOF PRESSURE SETUP

OPERATOR	
INSPECTOR	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION UA®	SER. NO.
5.2 Continued	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.2.2 Breathing Circuit

Cap the exhalation relief valve and set up the unit as shown in Figure 7.3 with V-3 closed and V_2 open.

Using PR-1, increase the pressure to 1 ± .1 psig, adjust V_2 to maintain P_1 constant, and hold for five minutes.

Record the flow required to maintain the pressure at a constant level.

Shut off the gas supply (V_1) and open V_3 to vent the unit.

There shall be no permanent deformation, and the flow required to maintain the pressure at a constant level shall not exceed 25 cc/min.

	Pressure P_1	Flow FR-1	Duration
Required	1 ± .1 Psig	25 cc/Min Max.	5 Min. Minimum
Actual			

Freedom from permanent deformation Yes No

OPERATOR	
INSPECTOR *	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION UA	SER. NO.
5.2	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

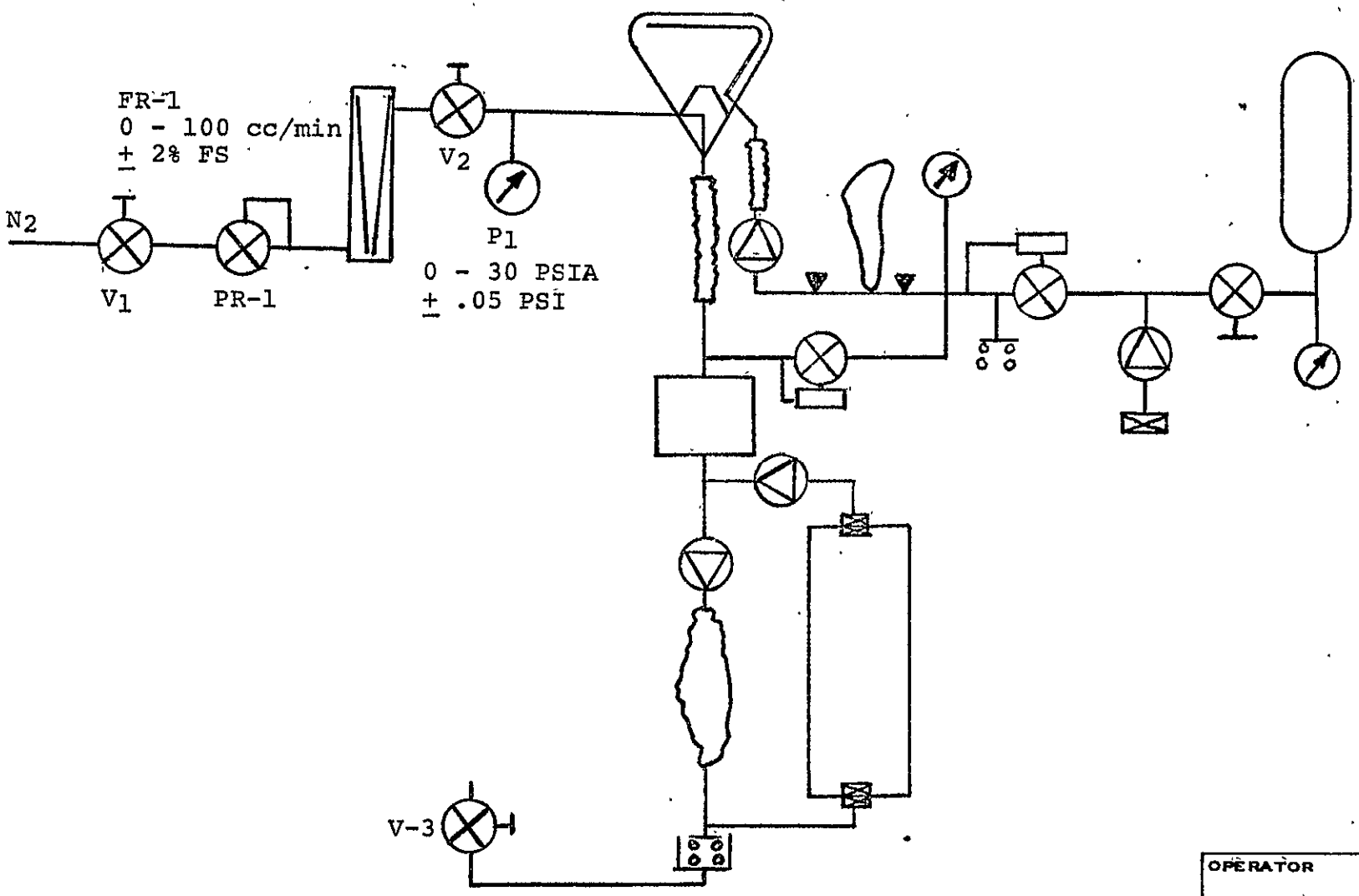

FIGURE 7.3 - BREATHING CIRCUIT PROOF AND LEAKAGE SETUP

OPERATOR
INSPECTOR

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.3	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

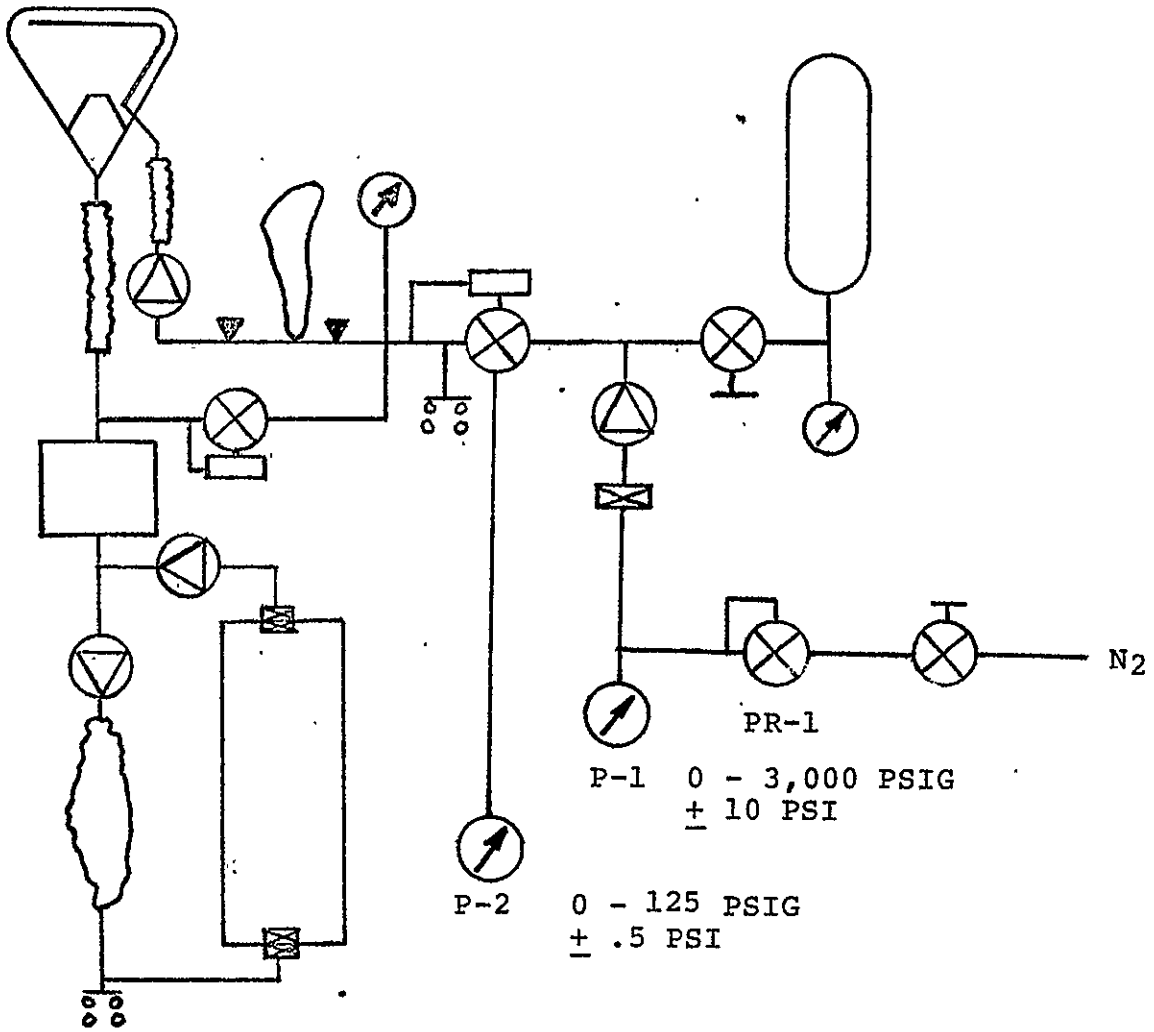

FIGURE 7-4 - PRESSURE GAGE AND PRESSURE REDUCER SETUP

OPERATOR	
INSPECTOR	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.3 Continued	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.3.2 Orifice Performance

With the unit setup as shown in Figure 7.5, adjust PR-1 to obtain a pressure (P-1) of 900 ± 10 psig and collect the flow to the mask.

The flow shall be 2,850 ± 143 scc/min.

After this test, decrease PR-1 and allow the pressure to return to room ambient.

CAUTION

During this test, gas will flow from the small hose in the mask. Do not block this flow as this could damage the unit.

	Supply Pressure (P_1)	Flow
Required	900 ± 10 psig	2,850 ± 143 scc/min
Actual		

OPERATOR
INSPECTOR *

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.3	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

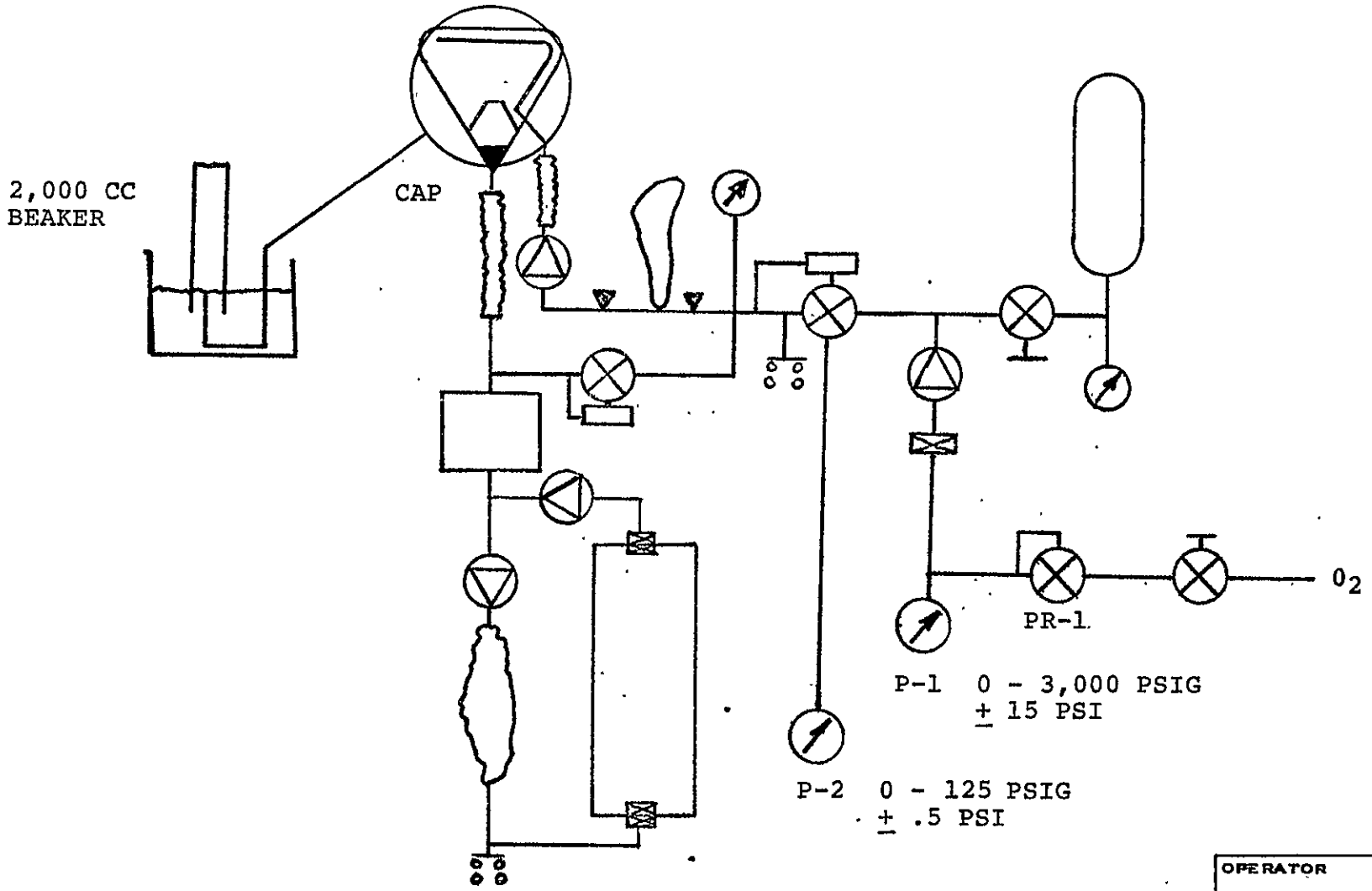

FIGURE 7.5 - ORIFICE PERFORMANCE SETUP

OPERATOR	
INSPECTOR	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.3 Continued	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.3.3 Demand Regulator Performance

Set the unit up as shown in Figure 7.5. Using PR-1, increase the supply pressure (P_1) to 900 ± 10 psig. Adjust valve V-1 to obtain a pressure (P_2) of 2 - 2.5 in H_2O below ambient and record the flow required to maintain this pressure.

NOTE

This test checks leakage of a demand regulator which opens at a pressure slightly below the test pressure (~3" H_2O below ambient). Therefore, reduce the breathing circuit pressure slowly and do not go below the 2.5 in H_2O limit.

CAUTION

During this test, gas will flow from the small hose in the mask. Do not block this flow as this could damage the unit.

The flow (FR-1) required to maintain the system below ambient shall not exceed 25 scc/min. Close V-1.

Adjust V-2 to obtain a pressure (P_2) of 4 to 4.5 in H_2O below ambient and record the flow (FR-2) required to maintain this pressure.

The flow shall be 8 lb/hr minimum.

Reduce the supply pressure (PR-1) to room ambient and close valve V-2 allowing breathing circuit to return to room ambient pressure.

OPERATOR	
INSPECTOR	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION UA	SER. NO.
5.3 Continued	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.3.3 (Continued)

	Supply Pressure (P_1)	Breathing Circuit Pressure (P_2)	Flow FR-1	Supply Pressure (P_1)	Breathing Circuit Pressure (P_2)	Flow FR-2
Required	900 ± 10 psig	-2 to 3" H_2O	25 cc/min Max	900 ± 10 psig	-4 to -4.5" H_2O	8 lb/hr Min
Actual						

OPERATOR	
INSPECTOR *	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.3	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

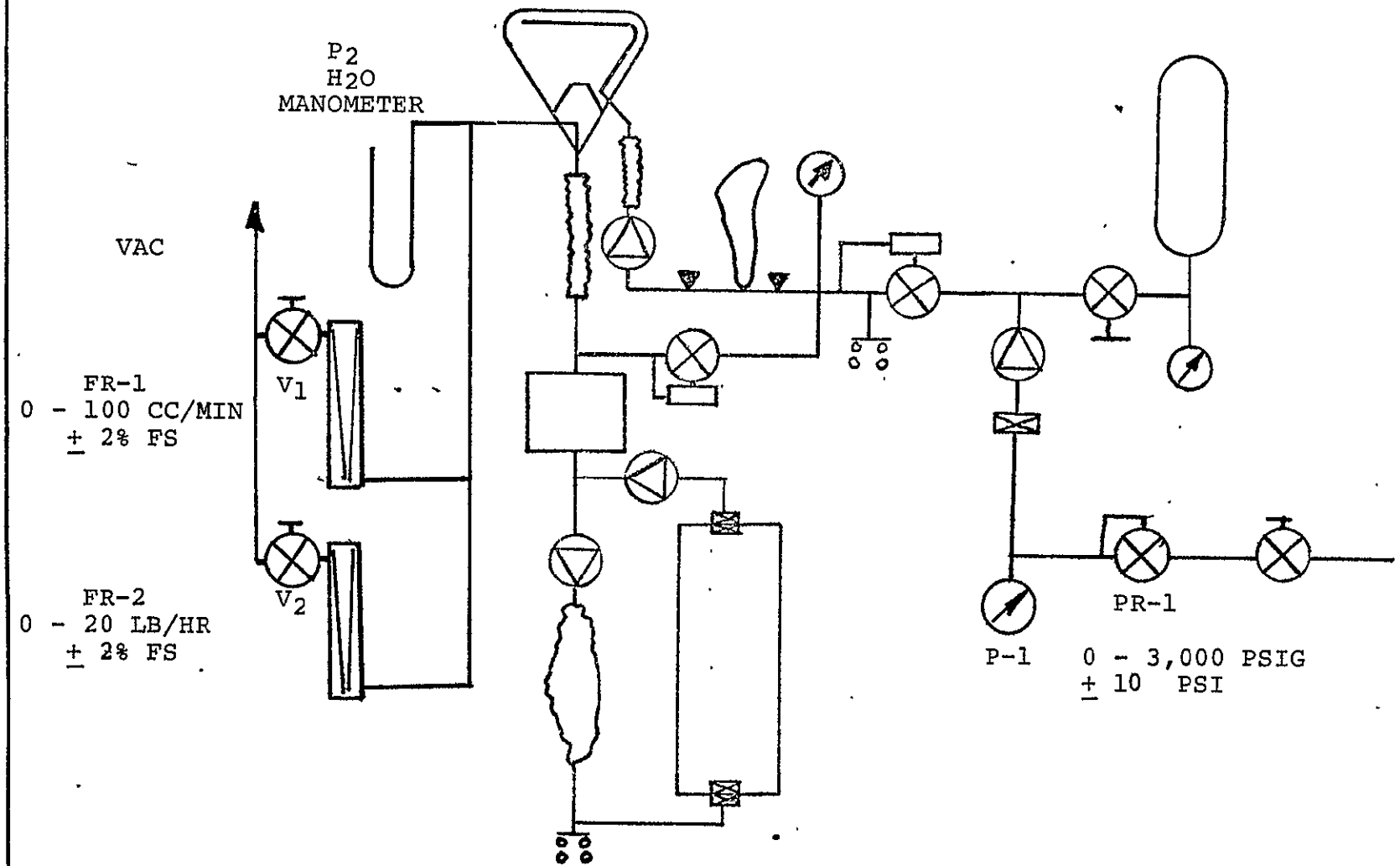

FIGURE 7.6 - DEMAND REGULATOR PERFORMANCE

OPERATOR
INSPECTOR

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION UA®	SER. NO.
5.3 Continued	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.3.4 Check Valve Performance

Set up the unit as shown in Figure 7.7. Using PR-1, increase the mask pressure (P_1) to 2 ± .2 in H_2) and observe the flow compensating bag for 5 minutes minimum. The bag shall not become fully extended in less than 5 minutes.

	Mask Pressure	Test Duration	Time to Bag Extended
Required	2 ± .2 in H_2O	5 min Minimum	>5 Minutes
Actuál			

NOTE: Test may be discontinued after 25 minutes even if bag is not extended.

OPERATOR	
INSPECTOR	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.4	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

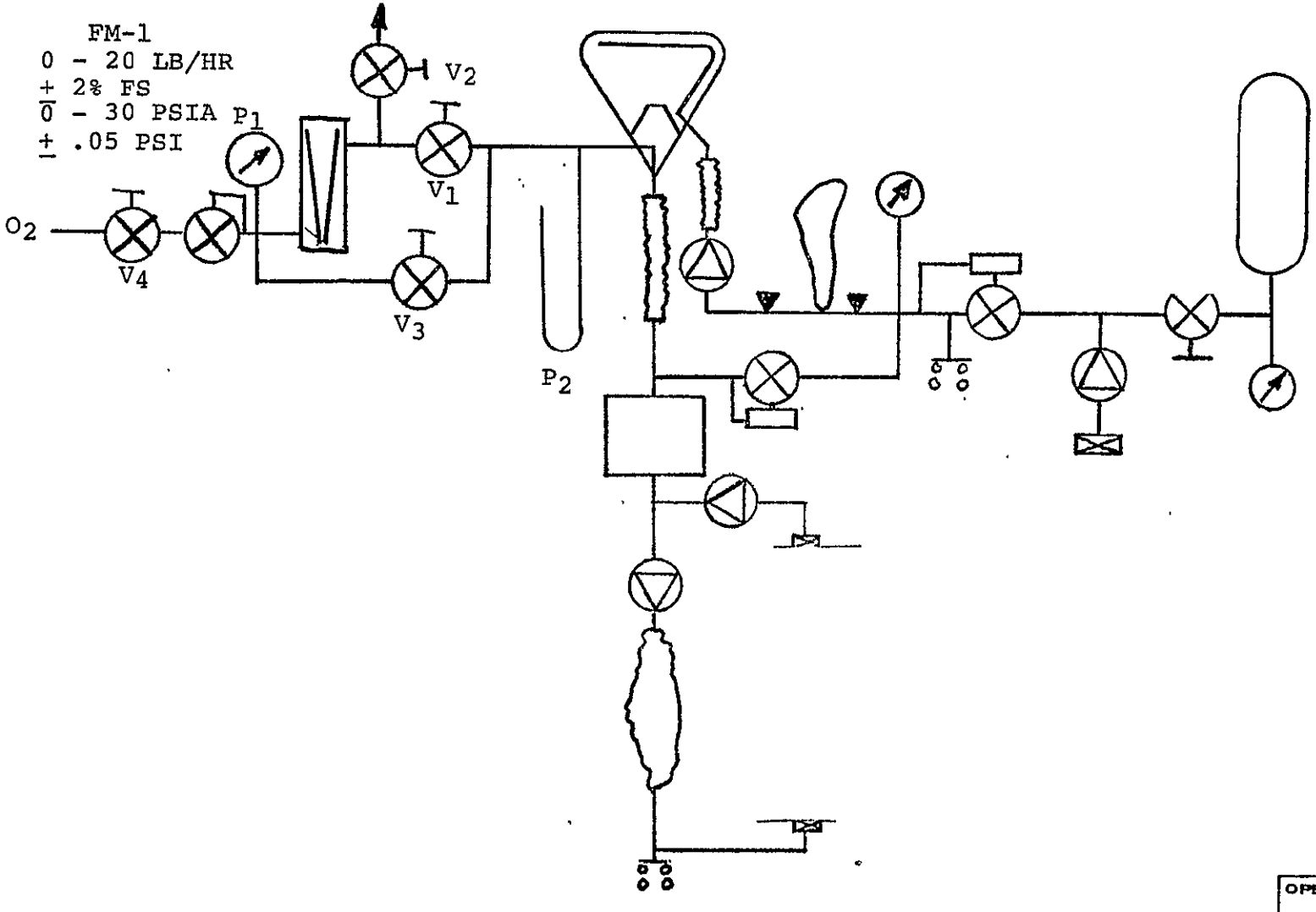

FIGURE 7.8 - EXHALATION/INHALATION RESISTANCE SETUP

OPERATOR	
INSPECTOR	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION UA®	SER. NO.
5.3	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

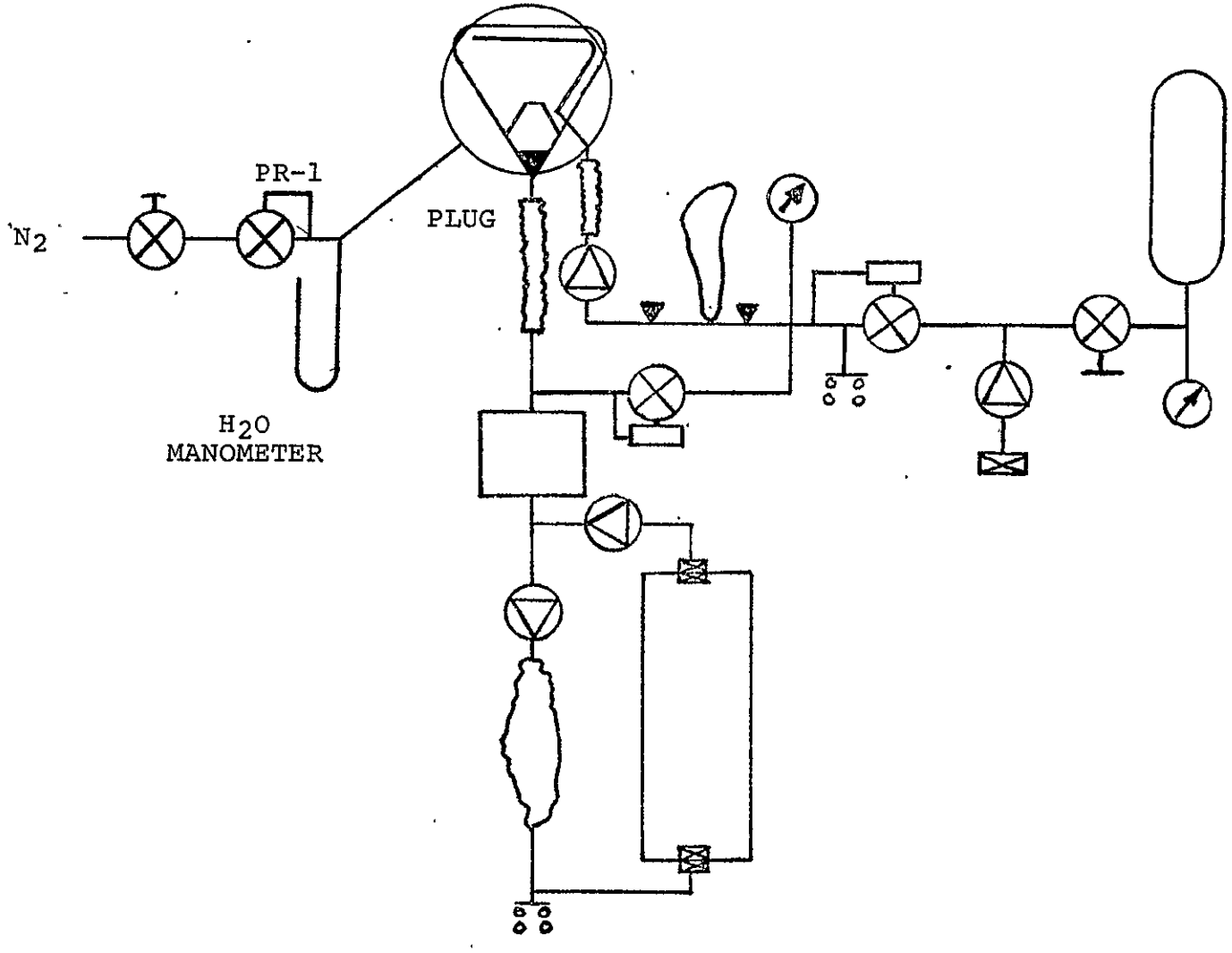

FIGURE 7.7 - CHECK VALVE SETUP

OPERATOR
INSPECTOR

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.4	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.4 Breathing Circuit Performance

7.4.1 Exhalation/Inhalation Resistance

Remove the cartridge/canister assembly from the POS and set up as shown in Figure 7.8 with V_2 and V_3 closed and P_1 set at 1 psig.

Adjust V-1 to obtain a flow of 9.1 $\pm$ .1 lb/hr and observe the pressure at the mask.

The mask pressure shall not exceed 1.4 in H_2O.

Close V-1 and V_4. Cap the cartrdige inlet. Open V_3 and adjust V_2 to obtain a flow of 9.1 $\pm$ .1 lb/hr and observe the pressure of the mask.

The mask pressure shall not be lower than -1.2 in H_2O.

	Exhalation Flow	Mask Pressure	Inhalation Flow	Mask Pressure
Required	9.1 $\pm$ .1 lb/hr	1.4" H_2O Max	9.1 $\pm$ .1 lb/hr	$>$ -1.2" H_2O
Actual				

OPERATOR	
INSPECTOR *	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.4	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

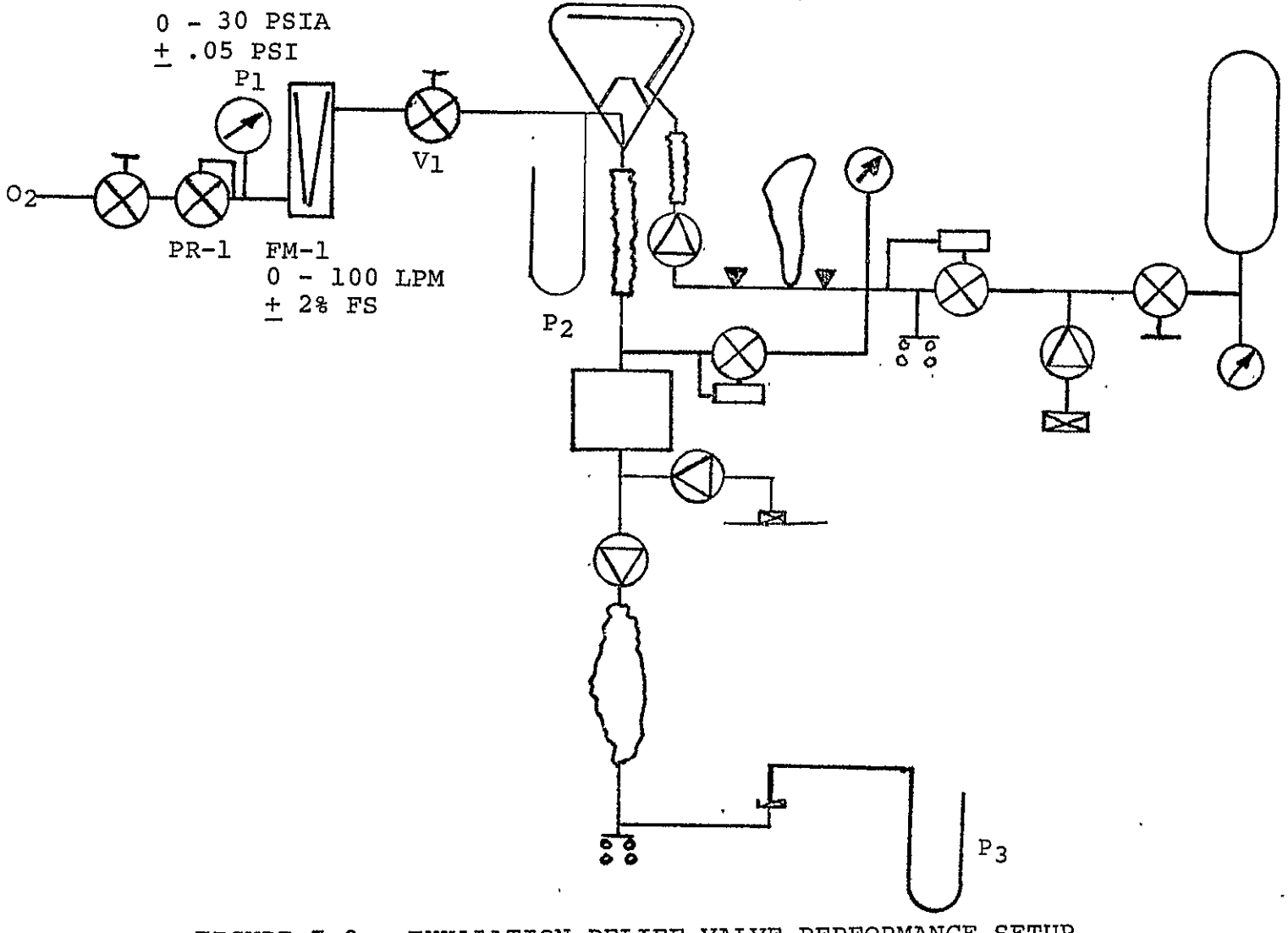

FIGURE 7.9 - EXHALATION RELIEF VALVE PERFORMANCE SETUP

OPERATOR	
INSPECTOR	

PDA 7015-

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION UA	SER. NO.
Continued 5.4	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.4.3 Check Valve Performance

Set up the unit as shown in Figure 7.10.

Adjust PR-1 to obtain a pressure of 1 ± .1 in H_2O and collect the flow at the mask. The flow shall not exceed 25 scc/min.

Decrease PR-1.

Revise the set up as shown in Figure 7.11.

Adjust PR-1 to obtain a pressure of 1 ± .1 in H_2O and collect the flow at the canister outlet. The flow shall not exceed 25 scc/min.

Decrease PR-1.

	Canister Inlet Pressure (P_1)	Flow at Mask	Mask Inlet Pressure (P_1)	Flow at Canister Outlet
Required	1 ± .1 in H_2O	25 cc/min Max	1 ± .1 in H_2O	25 cc/min Max
Actual				

OPERATOR	
INSPECTOR *	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.4	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

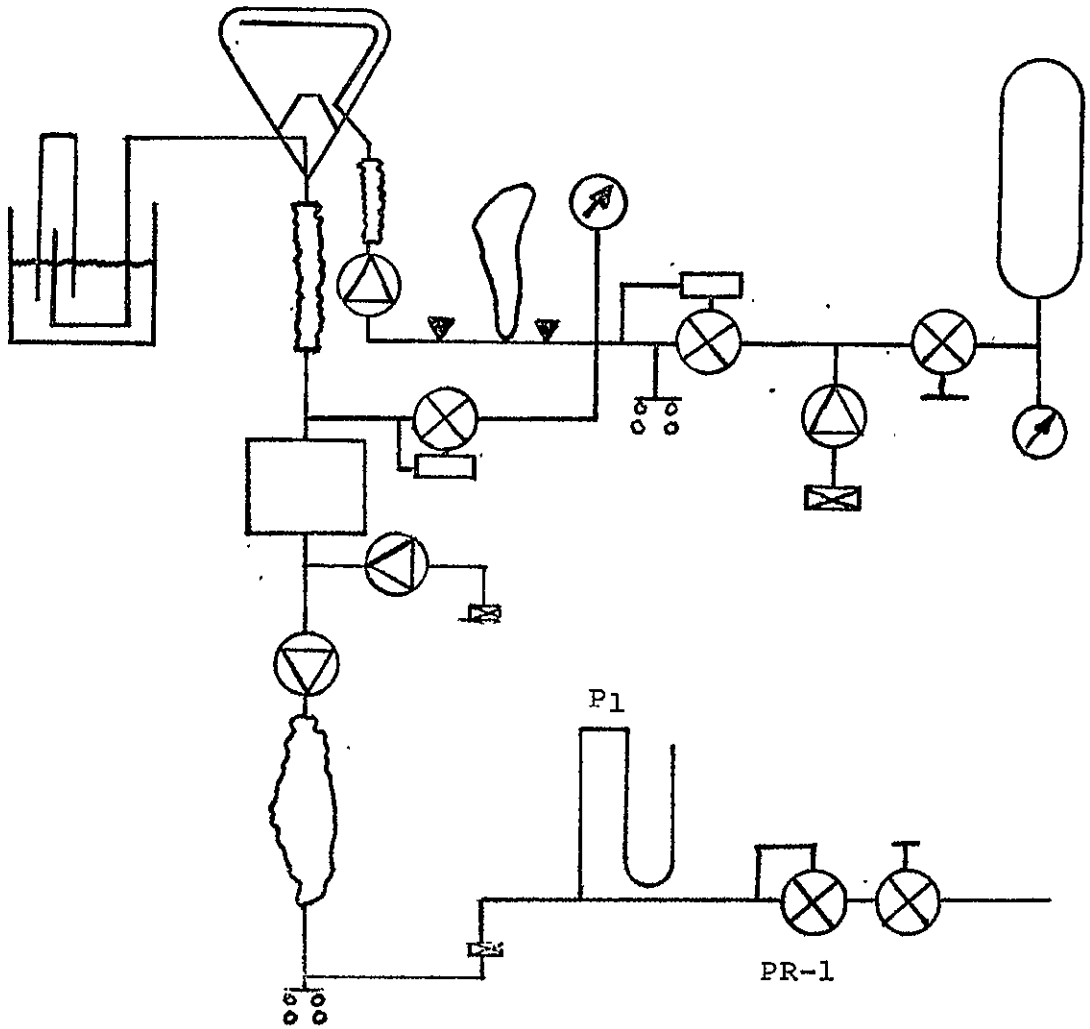

FIGURE 7.1.0 - EXHALATION CHECK VALVE PERFORMANCE SETUP

OPERATOR
INSPECTOR

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.4	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

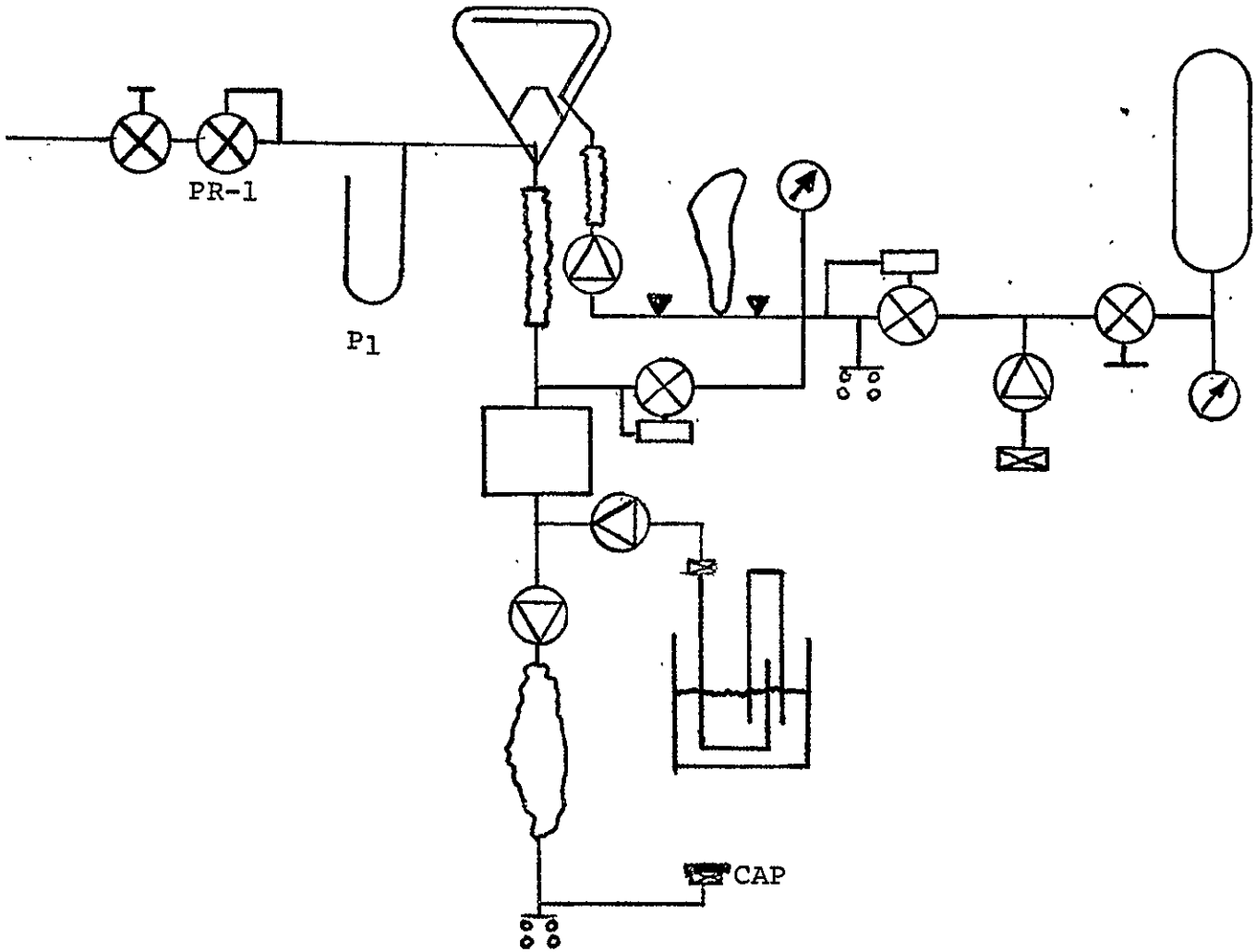

FIGURE 7.11 - INHALATION CHECK VALVE PERFORMANCE SETUP

OPERATOR	
INSPECTOR	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION UA	SER. NO.
5.5	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.5 External Leakage

7.5.1 High Pressure Supply

Set up the unit as shown in Figure 7.12 and adjust PR-1 to obtain a pressure of 1,144 ± 20 psig.

CAUTION

During this test, gas will flow from the small hose in the mask. Do not block this flow as this could damage the unit.

Coat all joints, fittings, and couplings with oxygen compatible leak test fluid and observe.

There shall be no evidence of leakage.

Close the POS shutoff valve and decrease P_1 to room ambient pressure.

Disconnect the fill connector and connect the line to the leakage setup.

Open the POS valve and observe leakage for 1 hour.

The leakage shall not exceed 2 scc/hr.

	Supply Pressure P_1	Visual Leakage	Check Valve Leakage
Required	1,144 ± 20 psig	No Visible Leaks	2 scc/hr Max.
Actual			

OPERATOR

INSPECTOR

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.5	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

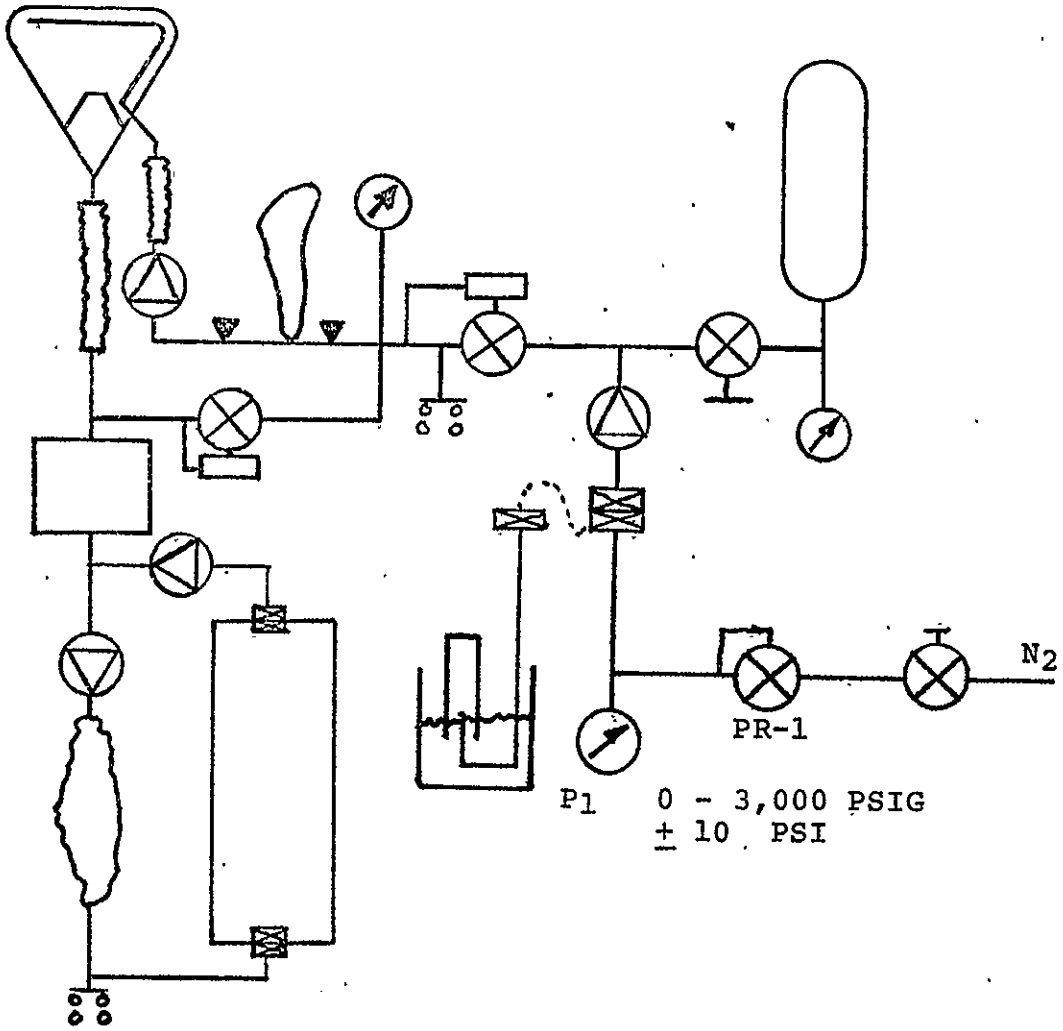

FIGURE 7.12 - HIGH PRESSURE LEAKAGE SETUP

OPERATOR	
INSPECTOR	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION UA®	SER. NO.
5.5 Continued	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.5.2 Breathing Circuit

Set up the unit as shown in Figure 7.13.

Adjust V-1 to obtain a pressure (P-1) of 3 ± .1 in H_2O below ambient. Adjust the valve as required to maintain the pressure at a constant value, and after 20 minutes record the flow (FM-1).

The flow shall be less than 25 scc/min.

	Pressure (P1)	Flow
Required	-3 ± .1 in H_2O	25 scc/min Maximum
Actual		

OPERATOR

INSPECTOR *

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.5	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

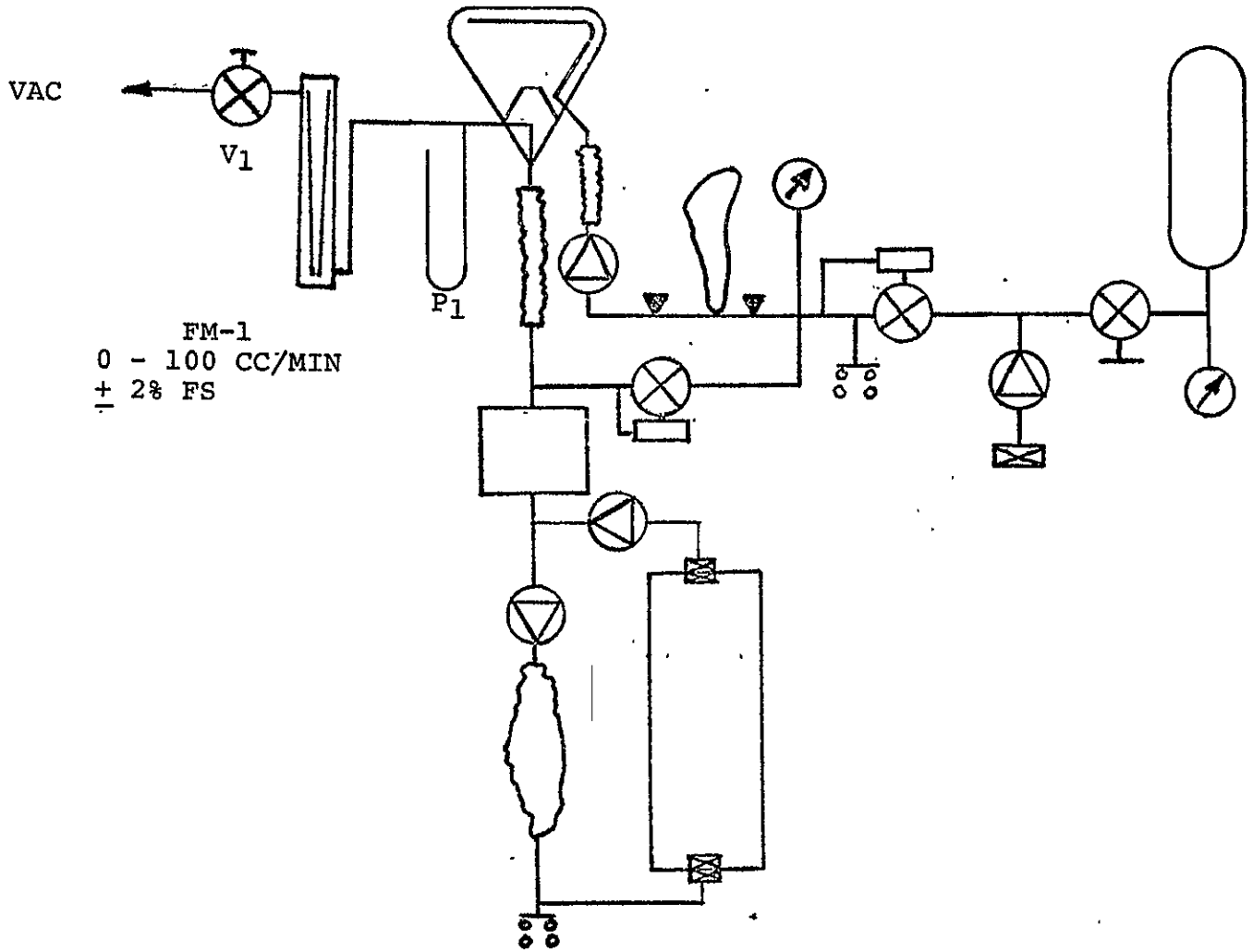

FIGURE 7.13 - BREATHING CIRCUIT LEAKAGE SETUP

OPERATOR	
INSPECTOR	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.6	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.6 Cartridge/Canister Performance

7.6.1 LiOH Charge

Cartridge weight prior to charge _____ lbs (include screws, nuts, washers, and preload pads).

Cartridge weight after charge _____ lbs. Weight increase due to LiOH _____ lbs spec 1.1 lb minimum.

7.6.2 Cartridge/Canister Pressure Drop

Set up the unit as shown in Figure 7.14 with V_1 and V_3 closed and V_2, V_4, and V_5 open.

Using PR-1, set P_3 at 2 ± .1 psig and then set V_1 to obtain a flow of 9.1 ± 1 lb/hr. The pressure drop (P_1) shall not exceed .4 in H_2O.

	Supply Pressure P_3	Flow FM-1	Pressure Drop P_1
Required	2 ± .1 psig	9.1 ± .1 lb/hr	<.4 in H_2O
Actual			

OPERATOR	
INSPECTOR *	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.6	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

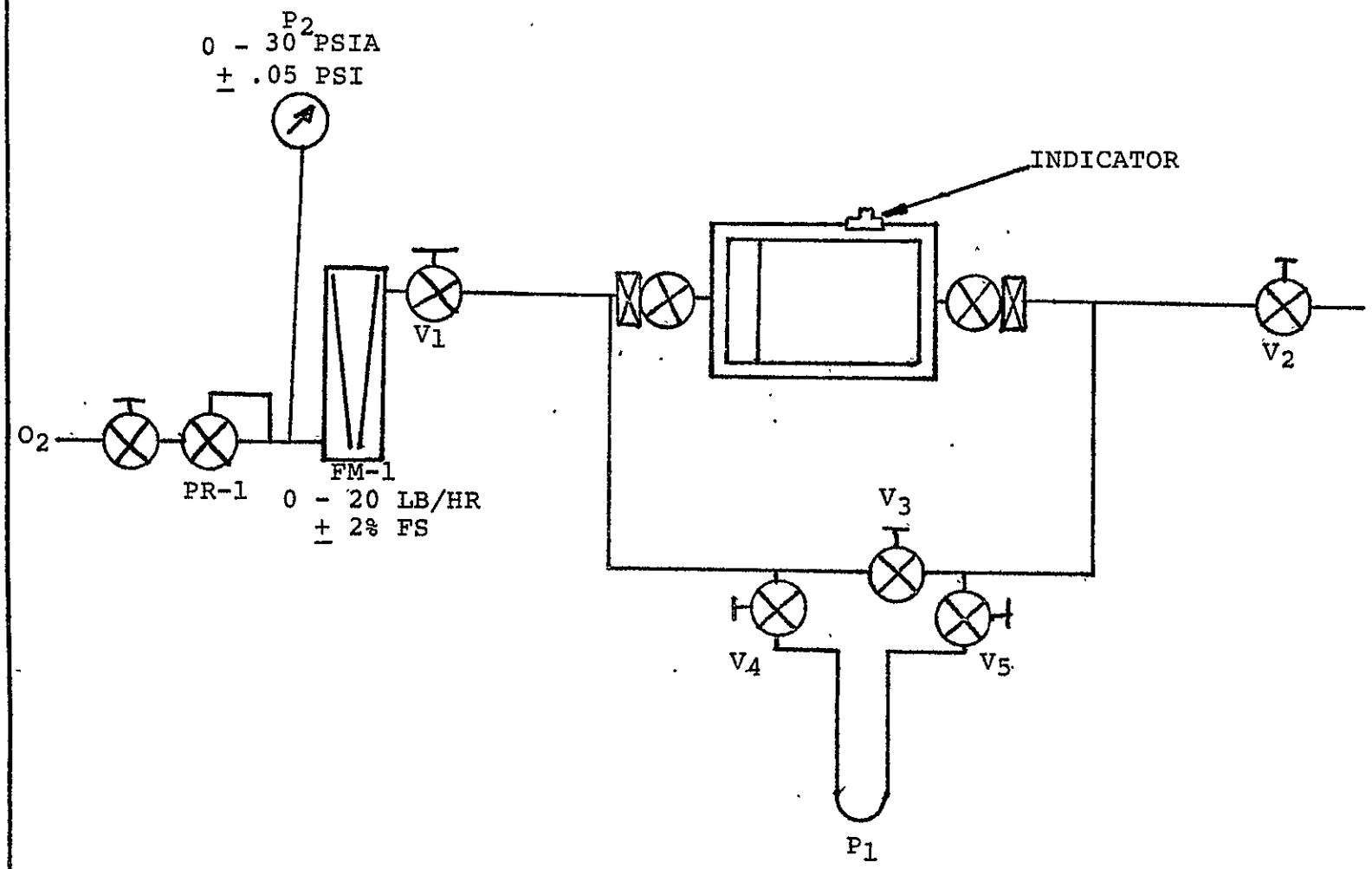

FIGURE 7.14 - CARTRIDGE/CANISTER PERFORMANCE SETUP

OPERATOR	
INSPECTOR	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION UA®	SER. NO.
5.6 Continued	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.6.3 Indicator Performance and Leakage

Continuing from the previous test, reduce P_3 to 0 psig, close V_2, V_4, and V_5 and open V_3 and V_1.

Observe the indicator on the side of the canister. The green should not be visible.

Increase P_3 to .5 $\pm$ .05 psig using PR-1 and observe the indicator. The green should be visible.

Increase P_3 to 2.0 $\pm$ .1 psig using PR-1 and close the canister sealing piston.

Reduce PR-1, open V_2 and remove the canister away from the setup. Verify that the green indicator is still visible and submerge the assembly in water and observe for 30 minutes. There shall be no evidence of leakage. Remove the canister assembly from the water and blow dry using N_2.

	Indicator Status at 0 Psig	P_3	Indicator Status	P_3	Piston Status	P_3	Indicator Status	Leakage
Required	Not Visible	.5±.05 psig	Visible	2.0±.1 psig	Sealed	0 psia	Visible	No Bubbles in 30 Min.
Actual								

OPERATOR	
INSPECTOR *	

PDA 7015

REF. SPEC. PARA.	ROOM TEMP (°F)	Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION	SER. NO.
5.7	CORR BAR. PRES. (IN.HG)	SLS ACCEPTANCE TEST OPERATIONS/LOG SHEET	TEST DATE
	TEST RIG		

7.7 Post Test Inspection

Yes	No

Unit free of visual defects not previously accepted.

POS dry and in accordance with HS1550 P_1.

Canister assembly dry and in accordance with HS1550 P_1.

All test completed and all records complete.

OPERATOR	
INSPECTOR *	

APPENDIX F

POS-P-1

TEST PROCEDURE

PORTABLE OXYGEN SUBSYSTEM

UNMANNED DEVELOPMENT TEST

AND

POS-P-2

TEST PROCEDURE

PORTABLE OXYGEN SUBSYSTEM

MANNED DEVELOPMENT TEST

TEST PROCEDURE

PORTABLE OXYGEN SUBSYSTEM

UNMANNED

DEVELOPMENT TEST

PREPARED BY: J Bouchelle DATE: 9-29-75

APPROVED BY: F. Goodwin DATE: 10-1-75
ENGINEERING PROGRAM MANAGER

APPROVED BY: A B Hooker DATE: 10/2/75
QUALITY ASSURANCE

APPROVED BY: J. Rose DATE: 10/3/75
RELIABILITY

APPROVED BY: Roger N Danner DATE: 10/15/75
NASA

1.0 INTRODUCTION

1.1 Purpose

This document defines the procedure to be utilized in conducting the Portable Oxygen Subsystem (POS) unmanned development test program.

1.2 Scope

This document outlines and describes the items to be tested, test conditions and objectives, test setups, performance requirements and reporting requirements.

1.3 Test Objective

The objective of the test program is to verify that the POS complies with the performance requirements of the POS specification CSD-SH-025 and to verify that the unit is safe for manned usage.

1.4 Description of Test Item

The test item is the Portable Oxygen Subsystem which is defined schematically in Figure 1. The test unit is defined by drawing SVSK 90390.

2.0 APPLICABLE DOCUMENTS

Drawings

SVSK 90390	Portable Oxygen Subsystem
SVSK 90329	Breather Assembly

Standards

MIL-O-27210	Oxygen Aviators Breathing, Liquid and Gas

Specifications

CSD-SH-025	Specification for Design and Performance Requirements for Shuttle Portable Oxygen Subsystem (Prototype Only)
HS 3150	Cleanliness Levels, High.....Processing, Testing and Preservation of Parts Subjected to.....

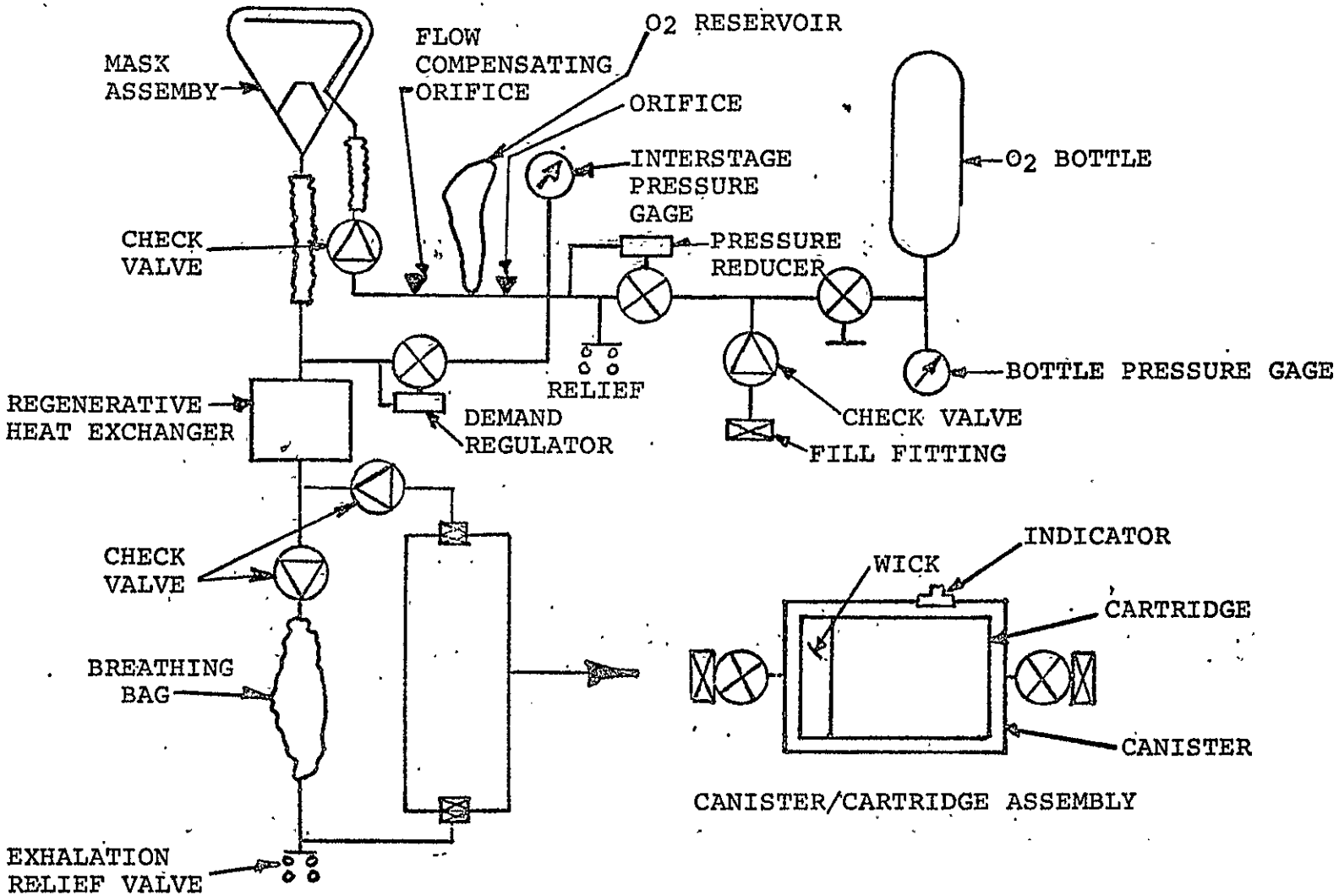

FIGURE 1 - PORTABLE OXYGEN SUBSYSTEM

3.0 TEST SEQUENCE

Sequence	Test	Test Number
1	Examination of Product	5.1
2	Mission Test Denitrogenization Simulation	5.2
3	Examination of Product	5.1
4	Mission Test Rescue Simulation	5.3

4.0 SPECIAL INSTRUCTIONS

4.1 Rigor

The test program shall be conducted under the direction of the cognizant project engineer. Hamilton Standard inspection shall be on a surveillance basis only. Any changes to the approved test plan will be coordinated with NASA.

4.2 Reporting

The results of the test program will be included in the monthly progress reports.

4.3 Control of the Test Item

It shall be the responsibility of the project engineer to insure that the historical log sheets reflect all operations performed on the test article during the test program.

4.4 Equipment Logs (Test Logs)

The test operator shall obtain sufficient data to verify that the test conditions and environmental conditions have been controlled as specified herein. This log will be maintained by the test operator(s). In general, the log shall include, but not be limited to, the following data:

a. Test Title and Procedure Section Number
b. Date
c. Environmental Conditions
d. Test Operator
e. Test Equipment
f. Notes and Comments
g. Test Results

4.5 Environmental Requirements

Unless otherwise specified, testing shall be conducted at local ambient temperatures and barometric pressure. Correction shall be made to provide agreement with the temperature and pressure calibration of the instruments.

4.6 Cleanliness Requirements

The supply gas shall be filtered through a 15 micron absolute filter. The high pressure supply shall be cleaned to HS 3150 CD-3. The breathing circuit instrumentation and connecting lines shall be cleaned with freon and shall be free of oil and visible contaminants.

4.7 Gas Sampling

A gas sample will be taken from the mask area during each run. These samples will be analyzed to verify that the gas inspired from the POS is free of toxicants in harmful concentrations (permissible concentrations are listed in Table I). The gas sample cylinders will be GFE.

4.8 Instrumentation

The instrumentation required for this test is shown in Figures 2 and 3 and listed in Table II. The surface temperature thermocouples will be located as specified by engineering and will be attached with a thermally conductive epoxy. A Bristol Recorder or equivalent shall be used to record all temperature readouts.

4.9 Test Gas

The test gas will be a mixture of oxygen per MIL-O-27210 and carbon dioxide as follows:

Metabolic Load	Mixture	Bottle Number
633KJ/Hr (600 Btu/Hr)	18 ± .5% by Vol. CO_2 in O_2	1
844KJ/Hr (800 Btu/Hr)	24 ± .5% by Vol. CO_2 in O_2	2
1160KJ/Hr (1,100 Btu/Hr)	34 ± .5% by Vol. CO_2 in O_2	3
1582KJ/Hr (1,500 Btu/Hr)	48 ± .5% by Vol. CO_2 in O_2	4
844KJ/Hr (800 Btu/Hr) (Rescue)	29 ± .5% by Vol. CO_2 in O_2	5

4.10 Breathing Simulation

The pulse flow device (SVSK 90329) will be set as follows:

Metabolic Load	Total Stroke, Rate	Test Cond.
633KJ/Hr (600 Btu/Hr)	0.77±0.05 in, 12±0.2 cpm	1
844KJ/Hr (800 Btu/Hr)	1.02±0.05 in, 12±0.2 cpm	2
1160KJ/Hr (1,100 Btu/Hr)	1.4 ±0.05 in, 12±0.2 cpm	3
1582KJ/Hr (1,500 Btu/Hr)	1.4 ±0.05 in, 16.36±0.2 cpm	4
844KJ/Hr (800 Btu/Hr) (Rescue)	0.77±0.05 in, 4.8±0.2 cpm	5

4.11 Failure Reporting

A RDR containing a test description, actual test conditions, and test results shall be prepared for any test result which does not meet requirements. All RDR's must be cleared before delivery of the unit.

5.0 TEST PROCEDURE

5.1 Examination of Product

Examine the unit to verify the presence of a fresh cartridge and that all instrumentation hookups are proper. Set up the system as shown in Figure 2 and evacuated to 3 in. H_2O below ambient to verify pressure integrity. The flow to vacuum required to maintain a constant pressure shall not exceed 25 scc/min. Record data on log sheet 6.1.

5.2 Mission Test - Denitrogenization Simulation

After setting the breather stroke and rate per test condition 2 (reference paragraph 4.10), set up the unit as shown in Figure 3. Turn on all instrumentation line heaters. During this test, maintain the lines in the mask area at approximately 120°F and the lines in the canister area at approximately 180°F. Record the weight of the test gas bottles No. 2 (800 Btu/hr), No. 3 (1,100 Btu/hr), and No. 4 (1,500 Btu/hr) as installed in the test setup. Turn on the bellows heat lamp and adjust the variac to establish a temperature of 98-99°F within the ambient box. Activate all CO_2 sensors and verify consistent readings. Verify that the O_2 and N_2 monitors are reading values consistent with room air. Turn on the temperature recorder and verify all pickups are operational. With V_1 closed, establish a pressure on P_1 of 900 + 20 psig using test bottle No. 2 (800 Btu/hr). Open V_2 and allow steam to enter the breather plenum until the dew point in the plenum is 96-97°F, then close valve V-2.

Caution: Do not permit the dew point in the plenum to exceed 98°F.

Open V_1 and turn on the breather. After five minutes record all data required by the log sheet (6.2). After 30 minutes of operation, record all data then shut off flow to the two lira CO_2 readouts. Maintain these conditions for a total of two hours and 42 minutes recording all data every 30 minutes. (Turn on flow to the liras two minutes before reading and shut off flow after completing the readings.) After the two hour and 30 minute reading, draw a gas sample from the plenum and seal it in the GFE gas sample bottle. After the two hours and 42 minutes, close V_1 and shut off the breather. Switch to gas bottle No. 3 and reset the breather per test condition 3. Open V_1 and restart the breather.

5.2 (Continued)

Caution: Allow no more than one minute for change in test conditions.

Note: During this test, TC_{G6} should be within 5°F of TC_{G5}. If needed, the breathing bag may be heated using a heat lamp. If heat is added, all areas except the bag must be shielded from the heat lamp.

Record all data after restarting and then record all data again before completing 15 minutes at this test condition. Close V_1 and stop the breather. Switch to sample bottle No. 4 and reset the breather per test condition 4. Open V_1 and restart the breather. Wait one minute then quickly record all data. After a total of three minutes, record the cartridge outlet and the mask inlet CO_2 level and close V_1 and stop the breather. Reset to the initial test gas and breather conditions and restart the test. Maintain these conditions until the mask inlet CO_2 level exceeds 15 mm Hg. Close V_1 and stop the breather. Initiate flow of dry nitrogen at the plenum and allow it to flow until all dew pointers indicate a low ($< 40°F$), consistent dew point. Complete shutdown of system.

During the first three hours of operation, TC_{G2} shall not exceed 110°F, DP_2 shall not exceed 100°F, and outside surface temperatures shall not exceed 113°F. At 800 Btu/hr the cartridge outlet CO_2 shall not exceed 7.6 mm Hg, and at 1,100 Btu/hr and above the cartridge outlet CO_2 shall not exceed 15 mm Hg. The N_2 level in the plenum shall be less than 5% within 10 minutes.

5.3 Mission Test - Rescue Simulation

After installation of a fresh cartridge and completion of examination of product, install the unit in the setup defined by Figure 3 and repeat the previous test except set the breather per condition 1 and use bottle No. 1. Maintain these conditions for two hours then close V_1 and stop the breather. Adjust P_3 to 43 ± 1 psia and set breather to condition 5. Open V_3 and restart the breather. Maintain this condition until the CO_2 partial pressure exceeds 7.6 mm Hg. During the first three hours of operation, TC_{G2} shall not exceed 110°F, DP_2 shall not exceed 100°F, outside surface temperature shall not exceed 113°F, and the CO_2 level shall not exceed 7.6 mm Hg. The N2 level in the plenum shall be less than 5% within 10 minutes.

TABLE I
HUMAN TOLERANCES TO VARIOUS GASES AND VAPORS

Concentrations in Parts of Substance per Million Parts of Ambient Atmospheric Air by Volume

Substance	Maximum Allowable Concentration
Ammonia	100
Amyl Acetate	200
Benzone	100
Butyl Acetate	200
Carbon Disulfide	20
Carbon Monoxide	100
Carbon Tetrachloride	50
Chlorine	1
Dichloroethyl Ether	15
Dichlorodifluoromethane	100,000
Ether	400
Ethyl Acetate	400
Ethyl Alcohol	1,000
Ethylene Dichloride	100
Formaldehyde	10
Gasoline	500
Hydrogen Chloride	10
Hydrogen Cyanide	20
Hydrogen Fluoride	3
Hydrogen Sulfide	20
Methane	10,000
Methyl Bromide	20
Methyl Chloride	100
Nitric Oxide	25
Nitrogen Dioxide	25
Ozone	0.05
Phenol	5
Phosgene	1
Styrene	400
Sulfur Dioxide	10
Toluene	200
Trichlorethylene	200

TABLE II
INSTRUMENTATION

Location	Parameter	Range	Accuracy
Plenum	Gas Temp(1)	32-300°F	± 2°F
	O_2	0-100%	± 2%
	N_2	0-100% & 0-20%	± 2%
	Dew Point(1)	32-120°F	± 2°F
Mask	Gas Temp(2)	32-300°F	± 2°F
	Dew Point(2)	32-120°F	± 2°F
Hose/Regin' Hx Interface	Gas Temp(4)	32-300°F	± 2°F
	CO_2(3)	0-20 mmHg	± .1%
Cartridge Inlet	CO_2(2)	0-40 mmHg	± 1 mmHg
	Dew Point(3)	32-180°F	± 2°F
Cartridge Outlet	CO_2(1)	0-40 mmHg	± 1 mmHg
	Dew Point(4)	32-180°F	± 2°F
Gas Temperatures	Supply Gas(3)	32-300°F	± 2°F
	Bag Inlet(5)	32-300°F	± 2°F
	Bag Outlet(6)	32-300°F	± 2°F
	Cartridge Outlet(7)	32-300°F	± 2°F
Skin Temperatures	Mask Visor(1)	32-300°F	± 2°F
	Regen Hx Mask Side(2)	32-300°F	± 2°F
	Regen Hx Bag Side(3)	32-300°F	± 2°F
	Bag Inlet Duct(4)	32-300°F	± 2°F
	Relief Valve Duct(5)	32-300°F	± 2°F
	Cartridge Inlet(6)	32-300°F	± 2°F
	Canister(3)(7,8,9)	32-300°F	± 2°F
	Cartridge Outlet(10)	32-300°F	± 2°F
	Back Panel Outside(11)	32-300°F	± 2°F
	Radiation Grid(12)	32-300°F	± 2°F
	Cover(13)	32-300°F	± 2°F

POS INSTRUMENTATION

Instrument	Manufacturer	Model	Range	Accuracy	Response Time
DP(1) + DP(2)	EG&G	992	0-120°F	± 1°F	3°F/Sec
DP(3) + DP(4)	Cambridge Systems (Now EG&G)	108	0-180	± 1°F	1°F/Sec
O_2	Westinghouse	209P	0-100%	± 1.5%	1 Sec
N_2	Med Science Elect.	300AR	0-100% 80-100% 60-80% 40-60% 20-40% 0-20%	± 1% FS ± 1% FS ± 1% FS ± 1% FS ± 1% FS ± 1% FS	Not Specified
CO_2(1) + CO_2(2)	M.S.A.	Lira 300			90% of Reading in 5 Sec
CO_2(3)	Beckman	LB-1	0-1% CO_2 1-10% CO_2	.3 mmHg .1%	90% FS in 0.1 Sec

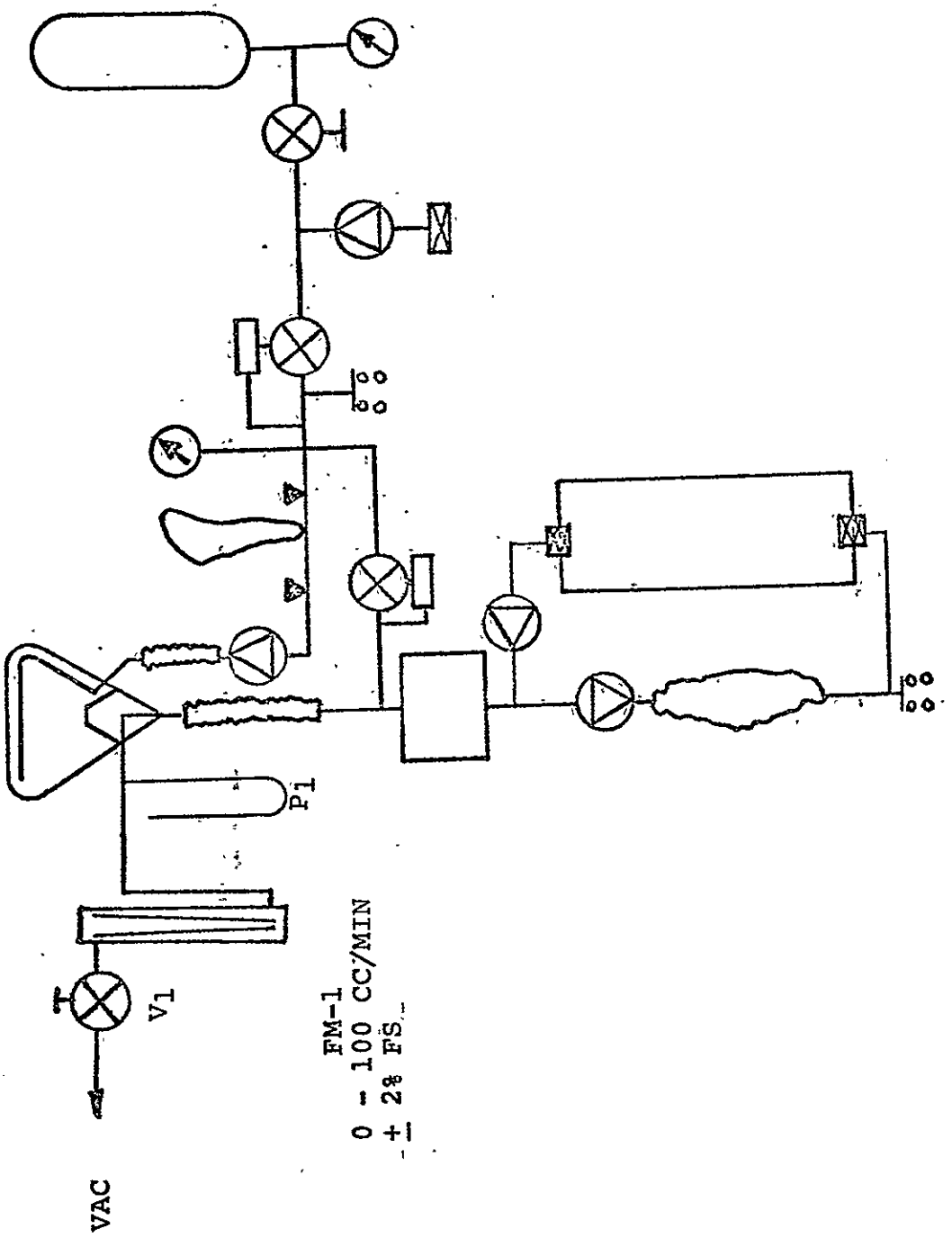

FIGURE 2 - BREATHING CIRCUIT LEAKAGE SETUP

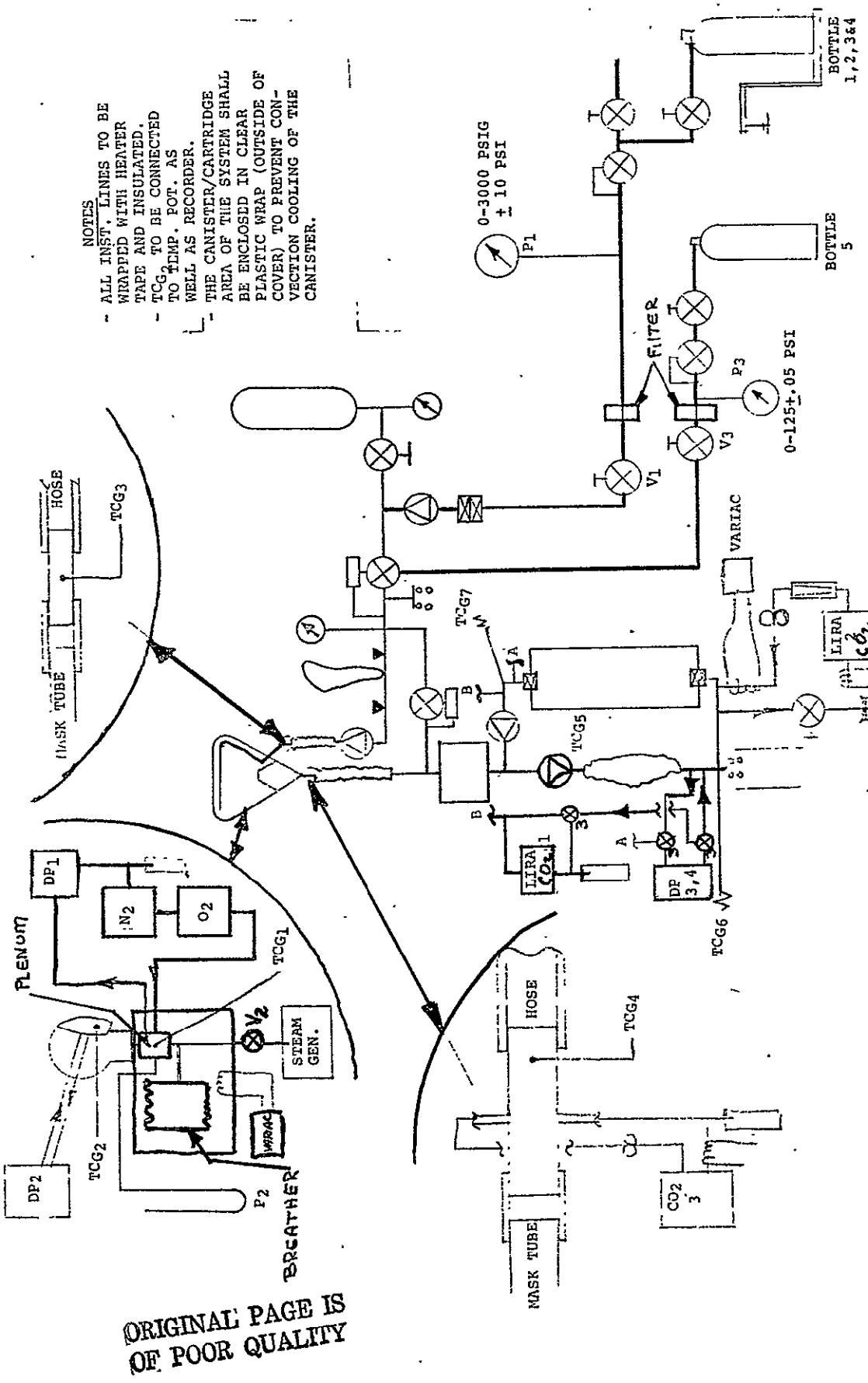

FIGURE 3 - PERFORMANCE TEST SETUP

HSF-175.1A 1/66

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST Sheet 6.1

TYPE OF TEST	
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG. ORDER NO.	

SHEET OF	DATE
TEST PLAN NO.	
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

New Cartridge Installed

Yes No

	Pressure	Flow
Requirement	-3 in H_2O	25 scc/min max
Actual		

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REMARKS:

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST Sheet 6.2

TYPE OF TEST		SHEET OF	DATE
TEST ENGINEER		TEST PLAN-NO	
NAME OF RIG		MODEL NO.	
PROJECT & ENG ORDER NO.		PART NO.	
		SERIAL NO.	
		OPERATORS	

.me	Time	Bottle Weight (lb)			Pressure			O_2	N_2		CO_2				Dew Point				Breather	
.ock	Test				Supply	Plenum		%	%		1	2		3	1	2	3	4	Stroke	Rate
					Psi	in H_2O				%	mmHg	%	mmHg	%	mmHg	°F	°F	°F	°F	in	CPM

REMARKS:

HSF-175 1A 1/66

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST 6.2 (Continued)

TYPE OF TEST	
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG. ORDER NO.	

SHEET OF	DATE
TEST PLAN NO.	
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

Test Time	Temperature °F																			
			Gas											Skin						
	1	2	3	4	5	6	7		1	2	3	4	5	6	7	8	9	10	11	12	13	

14

REMARKS:

TEST PROCEDURE

PORTABLE OXYGEN SUBSYSTEM

MANNED

DEVELOPMENT TEST

PREPARED BY: W Bouchille DATE: 10-6-75

APPROVED BY: F. Goodwin DATE: 10-10-75
ENGINEERING PROGRAM MANAGER

APPROVED BY: A B Hooker DATE: 10/9/75
QUALITY ASSURANCE

APPROVED BY: J. Rayo DATE: 10-8-75
RELIABILITY

APPROVED BY: N.L. Bailis DATE: 10/14/75
SAFETY

APPROVED BY: M. W. Radomski M.D DATE: 11/5/75
MEDICAL

APPROVED BY: Roger N Jenner DATE: 10/15/75
NASA

1.0 INTRODUCTION

1.1 Purpose

This document defines the procedure to be utilized in conducting the Portable Oxygen Subsystem (POS) manned development test program.

1.2 Scope

This document outlines and describes the item to be tested, test conditions and objectives, test setups, performance requirements and reporting requirements.

1.3 Test Objective

The objective of this test program is to verify that the POS complies with the performance requirements of the POS specification CSD-SH-025.

1.4 Description of Test Item

The test item is the Portable Oxygen Subsystem which is defined schematically in Figure 1. The test unit is defined by drawing SVSK 90390 and shall have been man rated per Test Plan POS-1.

2.0 APPLICABLE DOCUMENTS

Drawings

SVSK 90390	Portable Oxygen Subsystem

Standards

MIL-O-27210	Oxygen Aviators Breathing, Liquid and Gas

Specifications

CSD-SH-025	Specification for Design and Performance Requirements for Shuttle Portable Oxygen Subsystem (Prototype Only)
HS 3150	Cleanliness Levels, High.....Processing, Testing and Preservation of Parts Subjected to

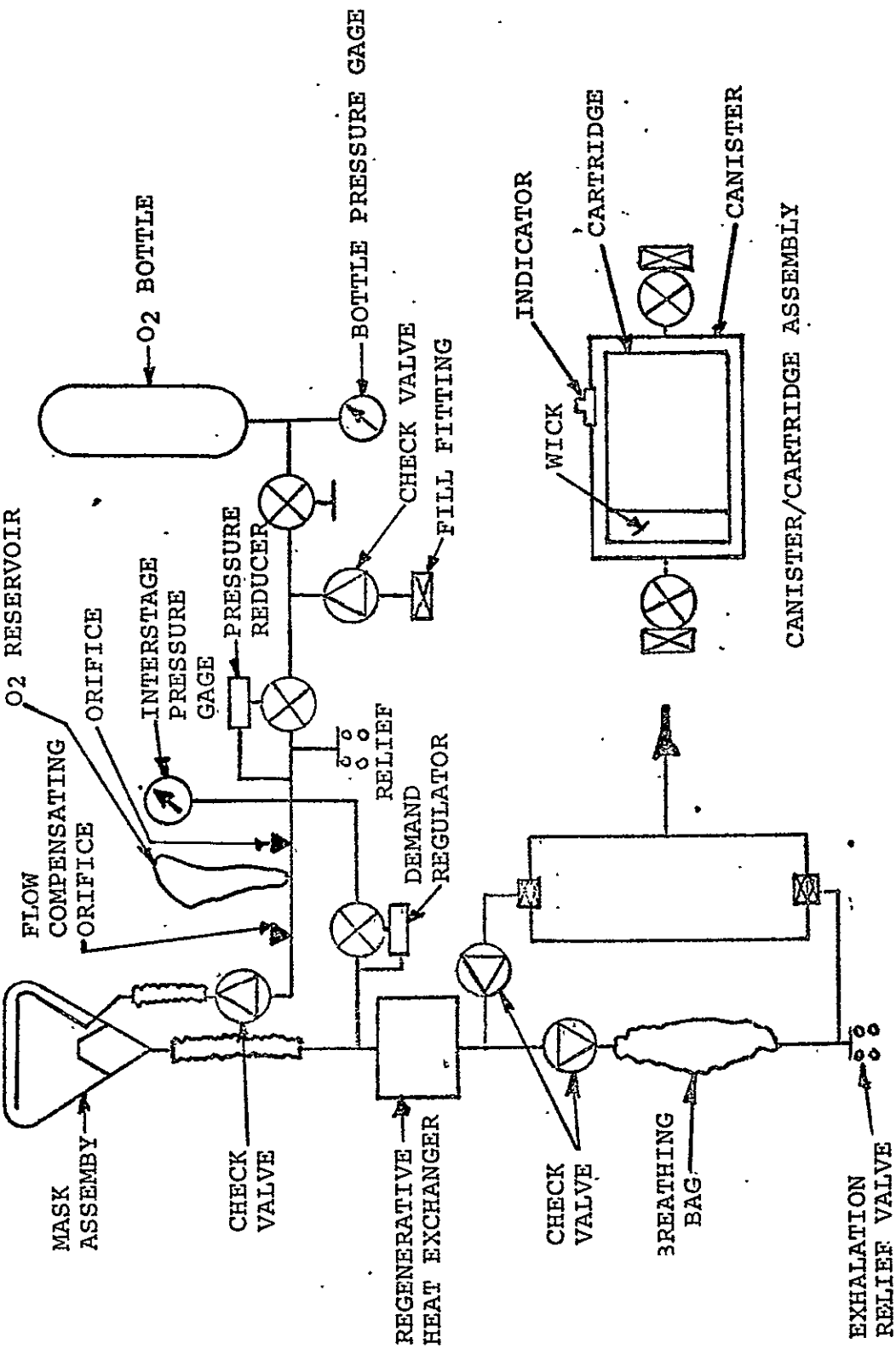


FIGURE 1 - PORTABLE OXYGEN SUBSYSTEM

3.0 TEST SEQUENCE

Sequence	Test	Test Number
1	Examination of Product	5.1
2	Prestart Up and Check Out	5.2
3	Mission Test - Steady State	5.3
4	Examination of Product	5.1
5	Prestart Up and Check Out	5.2
6	Mission Test - Prebreath	5.4

4.0 SPECIAL INSTRUCTIONS

4.1 Rigor

The test program shall be conducted under the direction of the cognizant project engineer. Hamilton Standard inspection shall be on a surveillance basis only. Any changes to the approved test plan will be coordinated with NASA.

4.2 Reporting

The results of the test program will be included in the monthly progress reports.

4.3 Control of the Test Item

It shall be the responsibility of the project engineer to insure that the historical log sheets reflect all operations performed on the test article during the test program.

4.4 Equipment Logs (Test Logs)

The test operator shall obtain sufficient data to verify that the test conditions and environmental conditions have been controlled as specified herein. This log will be maintained by the test operator(s). In general, the log shall include, but not be limited to, the following data:

a. Test Title and Procedure Section Number
b. Date
c. Environmental Conditions
d. Test Operator
e. Test Equipment
f. Notes and Comments
g. Test Results

4.5 Failure Reporting

A Reliability Data Report (RDR) containing a test description, actual test conditions, and test results shall be prepared for any test result which does not meet requirements. All RDR's must be cleared before delivery of the unit.

4.6 Environmental Requirements

Unless otherwise specified, testing shall be conducted at local ambient temperatures and barometric pressure. Correction shall be made to provide agreement with the temperature and pressure calibration of the instruments.

4.7 Cleanliness Requirements

The supply gas shall be filtered through a 15 micron absolute filter. The high pressure supply shall be cleaned to HS 3150 CD-3. The breathing circuit instrumentation and connecting lines shall be cleaned with freon and shall be free of oil and visible contaminants.

4.8 Instrumentation

The instrumentation required for this test is shown in Figures 2 and 4 and listed in Table I. The surface temperature thermocouples will be located as specified by engineering and will be attached with a thermally conductive epoxy. A Bristol recorder or equivalent shall be used to record all temperature readouts.

4.9 Test Gas

The test gas will be oxygen per MIL-O-27210.

4.10 Test Subject

Prior to initiation of the test program, the test subject shall have been approved by Medical and shall have completed a metabollic calibration per SS/SSP2135, paragraphs 5.1 through 5.1.3.4.

4.11 Medical Coverage

Prior to starting each test, the Medical and Safety supervisors shall be notified. An adequately trained medical monitor shall be available, as required, for each test. The proximity of the medical monitor during each test shall be agreed to by the Medical and Safety supervisors and the test conductor prior to starting any of the tests defined herein.

4.12 Safety Precautions

If the inlet CO_2 partial pressure exceeds 1.99 KPa (15 mm of Hg) or if the inspired temperature exceeds 49°C (120°F) at any point during the test, the test shall be terminated by removing the mask from the subject and shutting the O_2 supply off.

5.0 TEST PROCEDURE

5.1 Examination of Product

Examine the unit to verify the presence of a fresh cartridge and that all instrumentation hookups are proper. Set up the unit as shown in Figure 2 and evacuate to 3 in H_2O below ambient to verify pressure integrity. The flow to vacuum required to maintain a constant pressure shall not exceed 25 scc/min. Record data on log sheet 6.1.

5.2 Prestart Up Check Out

Prior to donning the POS, the test subject shall conduct a prestart up check out consisting of:

	Check Point	Procedure
a.	Bottle Pressure Verification	Turn on rig supply to 900 ± 20 psig. Verify bottle gage is reading same as rig gage ± 160 psi.
b.	LiOH Cartridge Indicator Check Out	Verify green indicator pin is visible.
c.	Exhalation Check Valve Performance	Shut off O_2 supply. Exhale and inflate breathing bag. Attempt to inhale from mask. Breathing bag should not collapse and crewman should not be able to inhale.
d.	Check Relief Valve Leakage	Open canister, inhale from mask and exhale to ambient. Once breathing bag is collapsed, crewman should not be able to inhale from system.
e.	O_2 Supply Subsystem Check Out	Turn on O_2 supply, place mask to face and inhale deeply. Crewman should feel flow in oral nasal area (demand regulator). Hold breath for about 5 seconds, crewman should feel flow entering at spray bar. Check interstage; pressure should read 33.5 ± 6 psi.

5.3 Mission Test Steady State

5.3.1 Preparation of Test Subject

The test subject will adhere to the following conditions:

a. Will not deviate from his normal diet.

b. Obtain a minimum of eight (8) hours sleep on the night pri to the test.

c. Abstain from drinking alcoholic beverages for twenty-four (24) hours before the test.

d. Refrain from food consumption for three (3) hours prior to the test.

Approximately one-half hour before the start of test preparation, the test subject will be given a pretest physical examination which includes blood pressure, pulse rate, and temperature.

Bioinstrumentation will be positioned on the test subject as shown in Figure 3.

The test subject will don test clothing which consists of light weight gym clothes. Footwear will be sneakers or equivalent.

5.3.2 Test Preparation

Set up the unit as shown in Figure 4.

Allow all instrumentation to warm up over night before this test.

Turn on instrumentation line heaters and maintain the lines near the mask at approximately 120°F and the lines near the cartridge at approximately 180°F.

Verify that all dew pointers provide consistent readings.

Verify that all CO_2 detectors provide consistent readings.

Verify that the N_2 and O_2 detectors provide readings consistent with room air.

5.3.3 Test Performance

With V_1 closed, adjust P_1 to 900 $\pm$ 20 psig and record the O_2 bottle weight.

The test subject shall don the mask and attempt to inhale. The ability to inhale or evidence of any flow indicates an external leak which must be eliminated prior to starting the test.

5.3.3 (Continued)

Once the system is leak tight, open V_1 and the canister actuator and start the test clock.

The subject shall mount the treadmill and start walking. He shall adjust his speed to maintain a heart rate equivalent to 800 Btu/hr as established by the metabolic calibration.

The subject shall maintain this condition until the inlet CO_2 partial pressure exceeds 7.6 mm Hg.

When the inlet CO_2 partial pressure exceeds 7.6 mm Hg, the subject shall remove the mask and V_1 shall be closed. The final O_2 bottle weight shall be recorded.

All test data (log sheet 6.3) shall be recorded five minutes after start up and at 30 minute intervals thereafter.

After the first 30 minutes of operation, the flow to the two lira CO_2 analyzers shall be shut off. The flow shall be reestablished for each reading about two minutes before the reading is to be made.

Note: During this test, TC_{G6} should be within 5°F of TC_{G5}. If needed, the breathing bag may be heated using a heat lamp. If heat is added, all areas except the bag must be shielded from the heat lamp.

The mask inlet conditions shall be monitored continuously during the run with particular attention to the safety precautions defined in Section 4.12.

The nitrogen level shall be less than 5% after 10 minutes of operation. The inspired CO_2 (cartridge outlet) shall not exceed 7.6 mm Hg for at least three hours. Vision shall not be obscured by fogging on the inside of the visor. Inspired temperature and dew point shall not exceed 110°F and 100°F respectively.

5.4 Mission Test - Denitrogenization

This test will be identical to the previous run except that after two hours and 42 minutes of operation the work rate will be increased to 1,100 Btu/hr for 15 minutes and then 1,500 Btu/hr for three minutes. The work rate will then be reduced to 800 Btu/hr for the remainder of the run. The requirements are the same as for the steady state test except that at the higher metabolic work rates the inspired CO_2 can be a maximum of 15 mm Hg.

5.5 Post Test Service

Subsequent to the manned testing, the breathing circuit (less cartridge) shall be washed by flushing with soapy distilled water followed by a thorough rinse with distilled water. The unit shall be dried by flowing dry nitrogen through the breathing circuit until the outlet dew point is less than $0^{o}F$.

TABLE I
INSTRUMENTATION

Location	Parameter	Symbol	Range	Accuracy
Mask	Gas Temperature	TC_{G2}	32-300°F	± 2°F
	O_2		0-100%	± 2%
	N_2		0-100% & 0-20%	± 2%
	Dew Point	DP_1	32-120°F	± 2°F
Hose/Regin' Hx Interface	Gas Temperature	TC_{G4}	32-300°F	± 2°F
	CO_2	CO_23	0-20 mmHg	± .1%
Cartridge Inlet	CO_2	CO_22	0-40 mmHg	± 1 mmHg
	Dew Point	DP_2	32-180°F	± 2°F
Cartridge Outlet	CO_2	CO_21	0-40 mmHg	± 1 mmHg
	Dew Point	DP_3	32-180°F	± 2°F
Gas Temperatures	Supply Gas	TC_{G3}	32-300°F	± 2°F
	Bag Inlet	TC_{G5}	32-300°F	± 2°F
	Bag Outlet	TC_{G6}	32-300°F	± 2°F
	Cartridge Outlet	TC_{G1}	32-300°F	± 2°F
Skin Temperatures	Mask Visor	TC_{S1}	32-300°F	± 2°F
	Regen Hx Mask Side	TC_{S2}	32-300°F	± 2°F
	Regen Hx Bag Side	TC_{S3}	32-300°F	± 2°F
	Bag Inlet Duct	TC_{S4}	32-300°F	± 2°F
	Relief Valve Duct	TC_{S5}	32-300°F	± 2°F
	Cartridge Inlet	TC_{S6}	32-300°F	± 2°F
	Canister(3)	$TC_{S7,8,9}$	32-300°F	± 2°F
	Cartridge Outlet	TC_{S10}	32-300°F	± 2°F
	Back Panel Outside	TC_{S11}	32-300°F	± 2°F
	Radiation Grid	TC_{S12}	32-300°F	± 2°F
	Cover	TC_{S13}	32-300°F	± 2°F

POS INSTRUMENTATION

Instrument	Manufacturer	Model	Range	Accuracy	Response Time
DP(1)	EG&G	992	0-120°F	± 1°F	3°F/Sec
DP(2)+DP(3)	Cambridge Systems (now EG&G)	108	0-180	± 1°F	1°F/Sec
O_2	Westinghouse	209P	0-100%	± 1.5%	1 Sec
N_2	Med Science Elect.	300AR	0-100% 80-100% 60-80% 40-60% 20-40% 0-20%	± 1% FS ± 1% FS ± 1% FS ± 1% FS ± 1% FS ± 1% FS	Not Specified
CO_2(1)+CO_2(2)	M.S.A.	Lira 300			90% of Reading in 5 Sec
CO_2(3)	Beckman	LB-1	0-1% CO_2 1-10% CO_2	.3 mmHg .1%	90% FS in 0.1 Sec

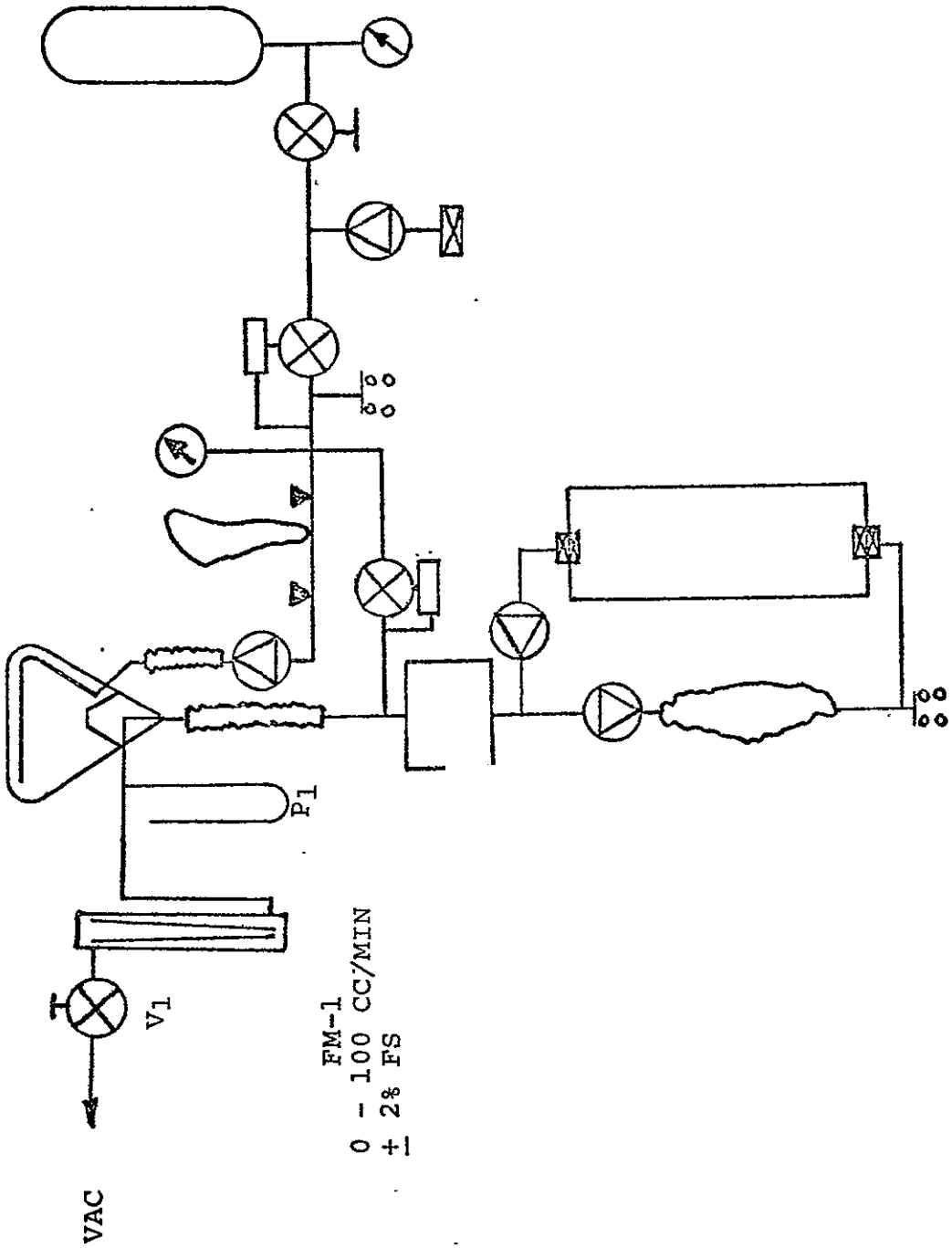
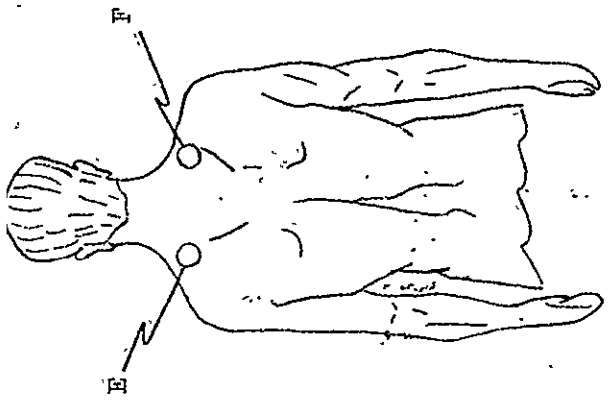
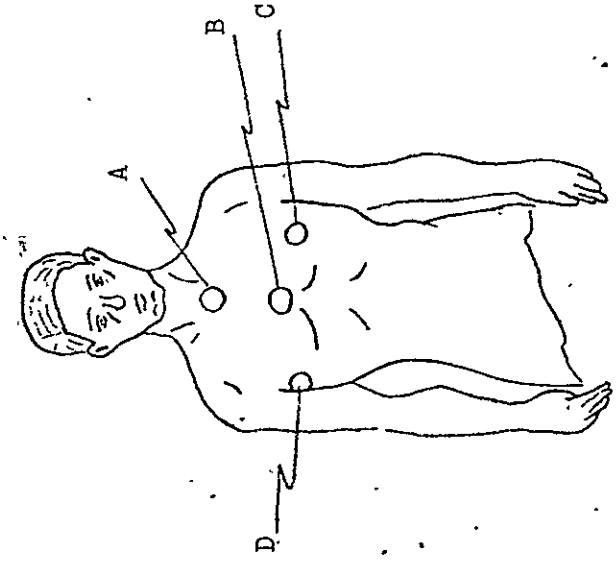


FIGURE 2 - BREATHING CIRCUIT LEAKAGE SETUP

BIO-INSTRUMENTATION LOCATIONS

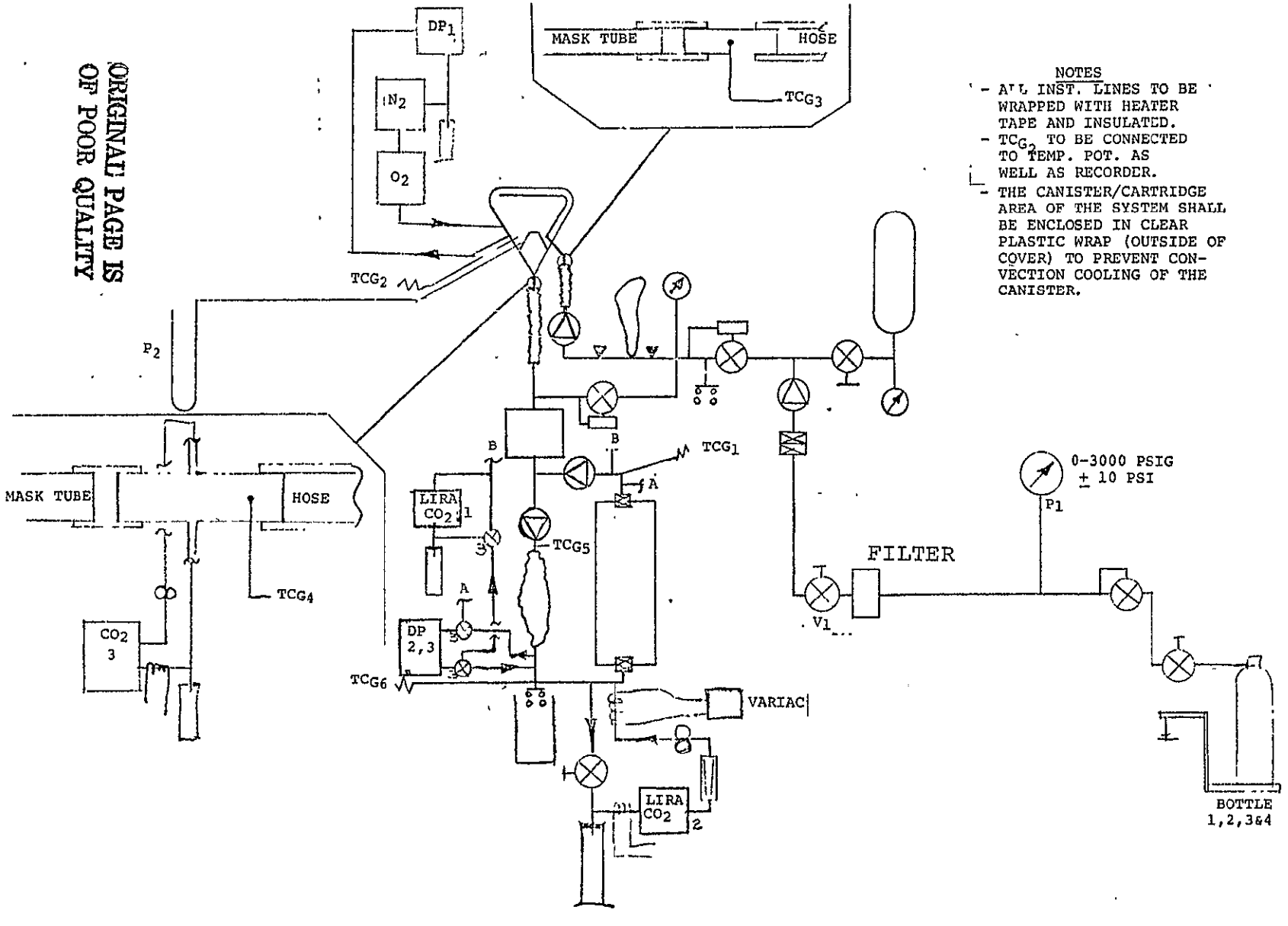




EKG

A - Sternum
B - Sternum
C - Axillary
D - Axillary
E - Ground
F - Ground

FIGURE 3



NOTES

- ALL INST. LINES TO BE WRAPPED WITH HEATER TAPE AND INSULATED.
- TC_{G_2} TO BE CONNECTED TO TEMP. POT. AS WELL AS RECORDER.
- THE CANISTER/CARTRIDGE AREA OF THE SYSTEM SHALL BE ENCLOSED IN CLEAR PLASTIC WRAP (OUTSIDE OF COVER) TO PREVENT CONVECTION COOLING OF THE CANISTER.

FIGURE 4 - PERFORMANCE TEST SETUP

75 1A 1/66

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST Sheet 6.1

TYPE OF TEST	
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG. ORDER NO.	

SHEET OF	DATE
TEST PLAN NO.	
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

New Cartridge Installed

Yes No

	Pressure	Flow
Requirement	-3 in H_2O	25 scc/min max
Actual		

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REMARKS:

83538

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WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST Sheet 6.2

TYPE OF TEST	
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG. ORDER NO.	

SHEET OF	DATE
TEST PLAN NO.	
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

		Yes	No
A.	Bottle Pressure Verification - Does POS gage agree with rig within + 160 psi?	*	
B.	LiOH Cartridge Indicator Check Out - Is indicator pin visible?	*	
C.	Exhalation Check Valve Performance - Does bag collapse on inhalation?		*
D.	Relief Valve Leakage - Can crewman inhale?		*
E.	O_2 Supply Subsystem Check Out - Does crewman feel demand flow?	*	
	Does crewman feel make up of flow?	*	
	Does interstage gage read 33.5 + .6 psi?	*	

REMARKS:

*Indicates required answer.

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST Sheet 6.3

TYPE OF TEST	
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG. ORDER NO.	

SHEET OF	DATE
TEST PLAN NO.	
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

Time Clock	Time Test	Bottle Weight Lb	Supply Psi	Mask in H_2O	O_2 %	N_2 %	CO_2 %	1 mmHg	CO_2 %	2 mmHg	CO_2 %	3 mmHg	Dew Point 1 °F	Dew Point 2 °F	Dew Point 3 °F	Heart Rate BPM	Resp Rate BPM	Met Load Btu/Hr

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REMARKS:

Absence of Condensate

Absence of Free Water

Yes	No

83539

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SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST Sheet 6.2 (Continued)

TYPE OF TEST	
TEST ENGINEER	
NAME OF RIG	
PROJECT & ENG. ORDER NO.	

SHEET OF	DATE
TEST PLAN NO.	
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

Test Time	Temperature °F																			
	Gas								Skin											
	1	2	3	4	5	6			1	2	3	4	5	6	7	8	9	10	11	12	13	

17

REMARKS:

83709

APPENDIX G

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