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FINAL REPORT

COMPRESSED AIR DEMAND-TYPE FIREFIGHTER'S BREATHING SYSTEM

Dated: October 15, 1975

Scott Engineering Report No. 1075
Volume II

Appendices

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APPENDIX A

SYSTEM SAFETY ANALYSIS FIREFIGHTER'S BREATHING SYSTEM

ER 1018

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ER-1018

System Safety Analysis

Firefighter's Breathing System

Dated: 14 December 1972

Revision A - 10 July 1973

Prepared by: [signature]
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Manager of Engineering -
Commercial Products

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REVISIONS

1. Added Section III, "Specific Corrective Action/Minimizing Provisions" - Pages 8 through 28.

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System safety is primarily concerned with prevention of events that may result in injury or death to personnel or damage to equipment. Safety analysis is a progressive activity. As the program life cycle progresses, the system safety analysis are updated, revised and expanded to assure that all hazards are identified and subsequently minimized and controlled.

A three-stage program is utilized on this program that includes the following stages:

1. Preliminary Hazard Analysis
2. General Corrective Action/minimizing provisions, which are safety criteria that are imposed on the designers.
3. Specific Corrective Action/minimizing provisions which define how the designers have responded to the safety criteria previously established.

I. <u>PRELIMINARY HAZARD ANALYSIS</u>

1. <u>Explosion</u> - Explosive failure of pressure vessel, valves or fittings. Possible causes: overheating in a fire; electrical arc burn-through; gunfire damage, severe impact, environmental exposure and/or corrosion damage.
2. <u>Inadvertent Release of Potential Energy</u> - Failure of high pressure, valves, fittings, hoses, gage, or pressure relief devices. Separation of high pressure components while pressurized.

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3. Failure of Respirable Air Supply - Includes loss of supply and/or failure of air supply system, or failure of the user to leave the toxic or oxygen deficient area before the air supply is depleted.

4. Failure of Support Section - Loss of support for air supply.

II. GENERAL CORRECTIVE ACTION/MINIMIZING PROVISIONS

1.0 EXPLOSION

1.1 Explosive Failure of Pressure Vessels

1.1.1 Overheating (by fire) - Protect with burst-type safety device, preferably with fusable alloy support. Heat transfer through the walls of the G.R.P. vessel, with the resultant increase in pressure of the contained gas, may not be as rapid as degradation of the outer surface of the vessel. Consequently, the rupture would not result from the increase of pressure inside the vessel, but from the weakening of the vessel wall.

1.1.2 Electric arc burn-through - No danger since the G.R.P. outer shell is electrically non-conductive.

1.1.3 Gunfire - G.R.P. vessel non-shatterable when exposed to gunfire.

1.1.4 Environmental Exposure and/or Corrosion Damage - Select materials of construction or apply protective coatings to prevent degradation due to environmental exposure, or internal corrosion. An elastomic or

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metal outer coat may be required to protect against normal handling damage.

1.2 Explosive Failure of Valves or Fittings - Design cylinder valve such that section that fits into the cylinder provides sufficient restriction to preclude explosive failure of the downstream components.

2.0 INADVERTENT RELEASE OF POTENTIAL ENERGY

2.1 Failure of High Pressure Valves - Design with conservative stress levels and arrange controls and protuberances to prevent damage by dropping. If possible, incorporate shock absorbing device(s) in the design.

2.2 Failure of High Pressure Fittings - Design at conservative stress levels; include flexibility to prevent unnecessary connection stresses. Select materials considering environmental exposure.

2.3 Failure of High Pressure Hoses - Select a hose with a safe margin, use as great a length as practical to minimize connection stresses.

2.4 Failure of Gage(s) - Incorporate an orifice in gage connection to prevent massive loss of breathing air. Use low mass lens and arrange for "pop-out" at a relatively low differential pressure. Locate gage so that it is protected against damage from dropping or other abuse.

2.5 Failure of Pressure Relief Devices - Select to be compatible with environmental exposure; arrange so that there is no high velocity gas impingement on the user if it should fail during use.

2.6 Separation of High Pressure Components While Pressurized Provide locking devices where practical, or include warning vent holes to vent the gas while the connection is secure, such as on the CGA (1340) fitting, or the Scott (P/N 800011) cylinder valve. Apply caution labels to apparatus.

3.0 FAILURE OF RESPIRABLE AIR SUPPLY

3.1 Leakage of Air from the System through Valves, Fittings, Hoses, Gage, Pressure Relief Devices and their Associated Joints and Seals: Minimize the number of joints and seals. Design utilizing proven components and sealing techniques. Arrange the valve seat on the cylinder valve so that it shuts off the maximum number of seals. Design the system to allow a substantial margin between relief valve operation and service pressure.

3.2 Leakage of Air from the System Through a Fail-Open Regulator(s): Design regulators to minimize the probability of a high flow fail-open mode of failure. Use conservative design stress levels for bellows and diaphragms. Position the cylinder valve so it can be manipulated by the user to manually control the flow for egress purposes.

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3.3 <u>Blockage of Air Supply from the Compressed Air Cylinder</u>: Select materials and/or surface treatment for the inside of the compressed air cylinder to prevent internal generation of contaminants that might block hoses and/or valves. Include a filter to prevent ingress of contaminants during recharging with compressed air. Utilize a pressure opening type valve so that a dislodged valve seat, or particles from the seat will not "check" the air flow.

3.4 <u>Blockage of the Air Flow by a Fail-Closed Regulator</u> Design the regulators so that a total fail-closed situation has a low level of probability. (e.g. Use a compression type coil spring such that failure of the spring would cause it to drop one coil, thereby reducing the outlet pressure somewhat but not to zero.) Include a backup circuit for bypass of a fail-closed regulator. This circuit may be manually controlled, or may be a completely redundant regulator system. If transfer to the backup system is automatic, then some warning must be provided to indicate this condition.

3.5 <u>Failure of User to Leave the Toxic or Oxygen Deficient Area Before the Air Supply is Depleted</u>: Provide an effective low pressure warning to warn the user at an appropriate time that his supply of air is low and that he should leave the area. The warning system should be such that the most probable failures

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result in a premature warning. The user should be able to readily determine if the alarm is his own, or that if a partner who may be in the same area. An automatic or separate method of pre-checking the alarm system, such as a "press-to-test", should be incorporated if there is a possibility of a "no-warning" failure.

4.0 EXPOSURE TO TOXIC MATERIALS

4.1 Poisoning Through the Skin

Self-contained breathing apparatus, unless supplemented by an appropriate protective suit, does not protect against poisoning through the skin. The system should be designed such that it can be worn inside a protective garment, and warnings should be included in the instruction manual to warn the user of this hazard.

4.2 Inward Leakage into the Breathing System through Faulty or Inadequate Valves or Seals:

Design the facemask for optimum fit on the maximum number of various facial shapes when worn with the fireman's helmet. Devise a simple method for determining fit of the facemask on any fireman, that can be performed simply in any firehall. Establish a quick-check for inward leakage to be performed by the user immediately before entry into a hazardous area, and define this procedure in the instruction manual. Design the exhalation check valve to provide

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very small back leakage for all anticipated environmental conditions. Minimize sections of breathing system that are exposed to negative pressures.

4.3 Inward Leakage into the Breathing System through Damaged Components: Design the faceseal section of the mask to be self-energizing, if possible, or to provide an indication of leakage if it is an inflatable seal design. Design the facemask so that it securely positions itself on the face, i.e. it is difficult to dislodge, the visor should be strong to preclude impact damage, or a supplemental device should be provided for impact protection. Provide a guard to protect the exhalation valve against damage that may cause distortion of the sealing surfaces.

5.0 FAILURE OF SUPPORT SECTION

Design the harness and frame assembly to minimize the possibility of loss of support for the air supply. The greatest risk is from heat and/or chemicals causing rapid deterioration of the harness assembly or the cylinder clamp.

III. *SPECIFIC CORRECTIVE ACTION/MINIMIZING PROVISIONS

*To be included at the conclusion of the Design Phase.

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III. SPECIFIC CORRECTIVE ACTION/MINIMIZING PROVISIONS

1.0 EXPLOSION

1.1 Explosive Failure of the Pressure Vessel

1.1.1 Overheating (by fire)

The vessel is protected by combination frangible disc-fusible plug safety device. At heat inputs to the valve assembly, that result in temperatures in excess of 220°F, the fusible alloy melts leaving a disc with a rupture value of 4500 to 5000 psig. An increase of pressure in the vessel to this value results in immediate and safe venting of the cylinder. Safety devices of this type have been in use for many years, and although they do not provide protection against overpressurization of the vessel in the absence of heat, the design appears to be ideally suited to this particular application.

1.1.2 Electric Arc Burn-Through

No danger since the Glassfiber Reinforced Plastic (G. R. P.) outer shell is electrically non-conductive.

1.1.3 Gunfire

The G. R. P. vessel is non-shatterable when exposed to gunfire.

1.1.4 Environmental Exposure and/or Corrosion Damage

Corrosion-resistant aluminum alloy is utilized as the liner material to preclude corrosion damage from the inside. An extra resin coat is applied over the outer windings on the cylinder to protect against abrasion of the outer walls. Regular examination and retesting of cylinders is a Department of Transportation (DOT) requirement and is specified in the maintenance section of the user's manual.

1.2 Explosive Failure of Valves or Fittings

The cylinder valve is designed with a small bore in the section that fits into the cylinder. The bore is only large enough to pass the required flow of air. The volume of gas contained in the high-pressure lines and fittings is held to a minimum by the use of the shortest and smallest diameter hose that will accept fittings that have bore

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diameters that will pass the required air flow. The total volume of gas contained in the high pressure hoses and fittings is 2.2 standard liters at 4500 psig. Conservative stresses are utilized in the design of the valve, hose and fittings. The cylinder valve is constructed of an aluminum alloy with an ultimate strength of 52,000 psi and a yield strength of 42,000 psi at .2% offset. A maximum design stress of 31,000 psi at a burst pressure of 11,250 psi has been used in the preparation of this design.

A commercial quality high pressure hose assembly is utilized with a service pressure of 5000 psi. The proof pressure of the hose is 7500 psi minimum, with a minimum burst pressure of 20,000 psi. The fittings and their assembly to the hose are such that the normal failure mode, during burst tests, is one of leakage at the hose/fitting interface. The hose assembly will be 100% proof tested at 7500 psi to assure its integrity.

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The high pressure hose connects to the pressure reducer assembly with a flange-type mounting held by four 8-32 stainless steel machine screws. The stress level in these screws is 21,892 psi at a burst pressure of 11,250 psi which is well below their tensile strength of 80,000 psi.

The maximum mechanical load caused by a man falling, being struck by falling or moving objects, or even being dragged or lifted by the hose, might conceivably create a 400-inch/lb. moment at this joint. This moment would be resisted by two 8-32 screws on 3/4" arm.

$$\frac{400}{.75 \times 2 \times .014 \text{ sq. in.}} = \begin{array}{l}19{,}000 \text{ psi} \\ \text{unit stress}\end{array}$$

6 to 10 inch/lbs. installation torque would be satisfactory for 8-32 screws loaded at this level.

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2.0 INADVERTENT RELEASE OF POTENTIAL ENERGY

2.1 Failure of High Pressure Valves

The only high pressure valve, the cylinder valve, is designed with conservative stress levels as defined in 1.2. The valve knob is side-mounted and a rubber bumper is mounted on the extreme end to protect the knob and to serve as a shock absorber, should the cylinder valve assembly be dropped. An aluminum gage guard, connected below the rubber bumper, provides protection to the pressure gage that is mounted on the cylinder valve.

2.2 Failure of High Pressure Fittings

The high pressure fittings are conservatively designed for integration with the high pressure hose as described in 1.2. A four-bolt flange mount is swaged to one end of the high pressure hose. Since the opposite end contains a right-angled fitting, a ¼" pipe thread connection is utilized between the hose and the cylinder valve coupling in order to allow proper orientation of the fittings to minimize the connection stresses.

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The cylinder valve nipple is constructed of 2024-T4 aluminum alloy with a design stress of 25,200 psi at burst pressure. This fitting connects into a 2024-T4 aluminum alloy elbow with a design stress of 20,500 psi at burst pressure. The 2024-T4 aluminum alloy has a tensile strength of 64,000 psi and a yield strength of 40,000 psi.

The hose fittings are constructed of low carbon steel. They are designed to hold tight onto the hose at a burst pressure four times the service pressure. In this case, a 5,000 psi service pressure hose has been selected. Consequently, they must hold tight to the hose at a pressure of 20,000 psi.

2.3 Failure of High Pressure Hose

Hose with a service pressure of 5,000 psi and a burst pressure of 20,000 psi was selected. To minimize both weight and connection stresses, a short hose was utilized, but the manifold to which it is connected is not rigidly connected to the backplate. The manifold can slide up and down to allow easy alignment of the fittings.

2.4 Failure of Gage

The gage is connected into a port on the cylinder valve that has an orifice to restrict the loss of air through a broken gage. The orifice limits the flow to a maximum of 60 lpm at 1000 psig. A low mass lens is incorporated in the gage such that it will pop out at a differential pressure less than 100 psi. The gage is protected from damage by an aluminum gage guard that is fastened to the valve below the rubber bumper.

2.5 Failure of the Pressure Relief Device

A fusible alloy supported burst disc has been utilized. The fusible alloy protects the burst disc from premature failure due to corrosive attack. The fusible alloy also provides an indication of slight leakage that sometimes occurs. Leakage causes the fusible alloy to extrude slightly outward and indicate the problem.

The outlet from the disc is ported to provide balanced thrust and to prevent direct impingement

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on the user, or onto others who may be in the area, if it should fail during use.

2.6 Separation of High Pressure Components while Pressurized

A bent tab lock washer locks the cylinder valve into the high pressure cylinder to prevent unintentional separation. The modified CGA 1340 fitting includes warning vent holes that vent gas and provide a warning when the connection has been loosened while pressurized. This venting occurs while the connection is still secure. A warning decal attached to the cylinder is used to warn the user of the hazards of high pressure air.

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3.0 FAILURE OF RESPIRABLE AIR SUPPLY

3.1 Leakage of Air from the System through Valves, Fittings, Hoses, Gage, Pressure Relief Device and their Associated Joints and Seals

The number of joints and seals were minimized by the use of manifold type assemblies such as the pressure reducer assembly, and the breathing regulator assembly. Proven "O" ring type seals and swage connected joints are predominantly utilized to support the interconnection of the components that are not manifolded.

The cylinder valve is designed such that when it is closed, the valve stem seal is not pressurized, thereby minimizing the number of sealing surfaces for a stored system.

The fusible alloy type safety device for the high pressure cylinder provides self-indication of leakage as previously described. It should be checked for this indication of leakage at each recharge.

The low pressure relief valve is integrated into the flange mounted low pressure hose fitting. It is set to relieve at 160 psig minimum, a pressure sufficiently above the maximum service pressure of 125 psig to minimize the risk of slight leakage at the valve. It has a flow capacity of 1900 slpm at the proof pressure of 225 psi.

3.2 <u>Leakage of Air from the System through "Fail-Open" Regulators</u>

Fail-open regulators can result from either of two failures: (1) Failure of the valve seat; (2) Failure of the control element (diaphragm, bellows or piston). The design selected for both the primary regulator and the backup regulator in the Fire-fighter's Breathing System utilizes a downstream type valve where the closing force increases with the tendency to leak. As a result of this characteristic, the regulator tends to correct its own valve leakage by reforming the valve seat utilizing pressures up to the relief valve setting. However, the reforming of the seat sometimes results in a reduction in the flow capacity of the regulator.

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Failure of the control sensing element always results in a fail open regulator unless there is a redundant control element. The outlet pressure of a regulator is established by the balance of the force resulting from the outlet pressure acting on a control sensing element, such as a bellows or diaphragm, and the force from a suitably adjusted spring. In this system all regulators are gage pressure regulators; therefore, the opposite side of the control element is exposed to the ambient pressure. If the control element fails, there is no differential pressure and hence, no force to push back the spring to cause the valve to close. The relief valve and the ambient reference hole for the control element must then be capable of passing all of the flow that results from the full open regulator valve. Two large diameter ambient reference holes are provided for each regulator. Each hole is partially plugged with a "pop-out" plug that is drilled with a small hole. If the control element fails, the plugs will pop out at 60 psi and provide full venting.

Most commercial regulators will fail open if the control element fails, yet very few fail in this way. The control elements are designed at conservative stress levels, and they usually far outlast the valve seats.

A design with a nylon fabric reinforced silicone elastomer diaphragm control element has been utilized. Previous experience in aircraft oxygen systems has proven this arrangement, particularly for temperatures to -60°F. The selected design has a maximum stress level of 3,900 psi which is well below the 67,000 psi tensile strength of the diaphragm material..

In the event of failure of the diaphragm, the air supply would be rapidly lost unless the cylinder valve is quickly manipulated by the user. That valve has been conveniently located so it can be operated by the right hand.

In order to provide the air for egress, with a failed open pressure reducer (regulator), the

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user would immediately close off the cylinder valve, open the purge valve, then re-open the cylinder valve to provide the constant flow of air to the facemask.

3.3 Blockage of Air Supply from the Compressed Air Cylinder

If the components are clean when assembled, and all the air that is put into the system is filtered, then the only contaminants what might block the air supply would be generated within the system. Rust from steel high pressure cylinders is such a contaminant. In this system, aluminum has been selected as the liner material for the glass fiber reinforced plastic high pressure cylinder. Its oxidation product, aluminum oxide, is tightly adherent and does not break loose from the interior of the cylinder. Consequently, the filter screen normally included in the inlet port of the cylinder valve has been intentionally omitted.

It has been assumed that contaminants that get into the system will be admitted through the

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cylinder valve either during recharge, or by accidentally leaving the valve open after use. A screen in the cylinder valve would trap those contaminants and assure that they would get into the high pressure hose and manifold inlet on the next system use. Without a screen in the cylinder valve, the contaminants would drop down into the cylinder and there would be much less chance that they would get back into the high pressure hose. A tube that protrudes down into the cylinder assures that contaminants will not "funnel" down into the valve when the assembly is worn in the valve down position.

Since some contaminants may get back into the high pressure hose, a replaceable screen type filter has been incorporated into the inlet fitting of the pressure reducer assembly. The filter effectively blocks particles of 70 microns nominal size. It is the same as that used successfully for many years in the Scott Air-Pak line of self-contained breathing apparatus.

A pressure opening type valve is used in the cylinder valve. With this type of valve, a dislodged valve seat, or particles from the seat, will not act like a check valve to block the flow from the cylinder.

3.4 Blockage of the Air Flow by a Fail Closed Regulator

The pressure reducing regulators are designed with compression type coil spring loading. The springs are designed such that failure causes them to drop one coil and to establish a new lower outlet pressure rather than a zero outlet pressure. A backup regulator system is included in the pressure reducer assembly, such that failure of the primary regulator to provide adequate flow results in automatic transfer to the backup regulator. The warning whistle in the facemask is actuated to warn that the backup regulator is in use.

Proper functioning of the backup regulator is essential for the system to be truly safe. Consequently, a "press-to-test" button is provided

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on the manifold to establish that the secondary regulator, the automatic transfer valve and the alarm whistle are all functioning properly.

3.5 Failure of the User to Leave the Toxic or Oxygen-Deficient Area before the Air Supply is Depleted.

A low pressure warning is provided to warn the user when his air supply has dropped to 850 psig. The warning system is initiated by a valve that senses the cylinder pressure. At a preselected pressure it transfers the output of the pressure reducer assembly from the primary regulator to the secondary regulator. The resultant increase in pressure actuates a slide valve, in the mask-mounted demand regulator, that transfers some of the outlet flow from the demand regulator through a whistle mounted inside the facemask. The whistle sounds with each breath, unless the purge valve is turned on, in which case it would sound continuously.

Because the warning is matched to his breathing, the user can readily determine that the warning is his own, rather than that of a nearby "buddy". However, since the alarm is tied to the air flow through the demand regulator, pre-check of the low pressure warning is more difficult than for existing systems.

A recommended procedure is: Don and begin using the system, verifying that it is functioning properly, then momentarily close off the cylinder valve and listen for the alarm to sound, then reopen the valve.

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4.0 EXPOSURE TO TOXIC MATERIALS

4.1 Poisoning through Skin

The FBS is designed so it can be worn beneath a protective garment. A section in the instruction manual warns the user against materials that poison through the skin.

4.2 Inward Leakage into the Breathing System through Faulty or Inadequate Valves or Seals

The facemask is designed for optimum fit on the maximum number of various facial shapes when worn with the fireman's helmet.

The facemask contains a minimum number of system components. Consequently, it is ideally suited for issue as personal equipment. As personal equipment, it can be pre-fit and adjusted to the individual fireman under controlled conditions. By repeated donning and fit checking, the fireman can be reasonably sure that he will have a good fit when he dons it under emergency conditions.

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A quick check for inward leakage to be performed immediately before entry into a hazardous area is an extension of the check or the low pressure warning. The system is donned, proper operation verified, then the cylinder valve is closed, the low pressure warning is checked for operation, then the system is breathed down until a negative pressure can be slowly created in the facemask, then the cylinder valve is turned back on and entry can be made into the hazardous area.

The exhalation check valve is designed for minimum leakage; at a maximum leakage rate of 1.5 scc/min. it is at least 10 times better than existing exhalation valves. By shrouding the valve with the cover of the demand regulator, danger, from back leakage of a contaminated atmosphere, is reduced even further.

The system utilizes a mask-mounted demand regulator. Consequently, only the facemask and demand regulator are exposed to negative pressure during the breathing cycle. Possible damage from leakage in a flexible breathing tube is eliminated.

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4.3 <u>Inward Leakage into the Breathing System through Damaged Compounds</u>

The faceseal section of the mask is self-energizing. It is designed such that it securely positions itself on the face and is difficult to dislodge. The visor is strong enough to withstand nominal impact damage (Steel Ball Test per Federal Spec. GGG-M-125d). However, for greater impact protection, an auxiliary faceshield should be used over the facemask.

The exhalation valve is protected against damage by its location beneath the cover of the demand regulator.

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5.0 FAILURE OF SUPPORT SECTION

The harness and frame assembly is designed to minimize the possibility of loss of support for the air supply. Polypropylene webbing has been utilized in the harness, since failure from chemical attack (on nylon) has been found more common than failure from heat.

The frame is designed so metal parts hold the cylinder to the frame. Both high and low temperature exposures increase the risk of failure of plastic parts. However, plastic is desirable for its light weight, ruggedness and flexibility under normal conditions. By combining it with metal in a composite assembly, a safe, light, functional assembly results.

APPENDIX B

CALCULATIONS

Appendix B

CALCULATIONS

Firefighter's Breathing System

STRESS CALCULATIONS:

INTRODUCTION:

Three types of loading should be considered in designing the subject system. First, and of most importance, is the result of internal pneumatic pressure in the high-pressure portion of the breathing system. Second are the loads created by attaching the various components to each other and to the man's back. Third are the miscellaneous loads due to handling, shipping, dropping and manufacturing. Some of the components are subjected to all three loadings.

Stresses created by pneumatic loads will be computed at burst pressure of 2½ times the max. operating pressure of 4500 psig (11,250 psig). Unit stresses will also be computed at max. operating pressure of 4500 psig. The margin between these stresses and the allowable for the material involved will be available for resisting shipping and handling loads as mentioned above.

GENERAL:

Cylindrical sections with substantial internal pressure will be treated as thick-walled cylinders wherein the maximum hoop tension stress will occur at the inside surface of the cylinder wall. The stresses will be calculated by the following formula:

$$\text{MAX } P_t = P_1 \ (r_1^2 + r_2^2) \ / \ (r_1^2 - r_2^2)$$

(Page 477, Fuller & Johnson, Applied Mechanics, Wiley)

where: P_t = Max. hoop tension stress at inside wall in psi.

P_1 = Internal pressure in psig.

r_1 = Inside radius

r_2 = Outside radius

Stress allowables are taken from MIL-HDBK-5A and QQ-A-367d. Materials and stress allowables will be noted with each component discussed.

CYLINDER VALVE, P/N 27238

Body material 2014-T6, alt. 2024-T4 or T351.

Mechanical properties 2014-T6 die forgings not parallel to forging flow lines per QQ-A-356C.

F_{tu}	ultimate tensile	52000 psi
F_{ty}	yield tensile (.2% offset)	42000 psi

Alt. matl. 2024-T4 and T351 per MIL-HDBK-5A

F_{tu}	ultimate tensile (transverse)	54000
F_{ty}	yield tensile (transverse)	37000
F_{su}	ultimate shear	37000
e	percent longitudinal	10%
e	percent transverse	2%

Area "A" See Fig. B-1

I. D. = .580, O. D. - 1.0

For burst pressure of 2.5 x 4,500 = 11,250 psi

Max. hoop tension stress at "A"

$P_t = 11,250 \text{ (psig)} \times (.29^2 + .5^2)/(.29^2 - .5^2) = 22,600$ psi
Max. hoop tension unit stress at inside wall.
There are no mechanical loads to be considered in this area.

<u>Area "B"</u>

I. D. - .53 (basic pitch) O. D. = 1.0

P_t = 11,250 psig $(.265^2 + .5^2)/(.265^2 - .5^2)$ = 20000 psi

Max. hoop tension unit stress at inside of wall due to pneumatic loads.

In addition to the above, there is the radial component caused by the 60° threads resisting the axial load of the 11,250 psig against the #27260 stem guide.

Seal area for .64 diameter - .321 sq. inches.

.321 x 11250 = 3610 lbs. axial load. The stem guide will be torqued to exceed the 3610# axial load.

Use 5000 lbs. axial load for calculations (about 30 ft. lbs. torque per E.S.N.A. torque tables).

5000 lb. x tan 30° = 2885 lbs. radial load which will be distributed equally over the .29 inch length of threads.

thread area - .53 (pitch dia.) π x .29 = .481 sq. in.

2885 / .481 = 6000 psig equivalent pneumatic load.

This equivalent pneumatic load creates a hoop tension unit stress of P_t = 6000 psig $(.265^2 + .5^2)/(.265^2 - .5^2)$ = 10,650 psi. 20,000 + 10,650 = 30,650 psi unit stress combined total. This is 17% below the yield allowable of 2024 and at this burst pressure no handling

At the max. working pressure of 4500 psig, the above max. unit stress will be reduced by the ratio of 4500/11250 or to 12250 psi unit stress. This leaves about 67% of the yield allowable for external applied loads.

No other areas of the valve body are critical structurally from an internal pressure standpoint.

<u>Area "C"</u>

From loads created by rough handling, shipping, dropping, etc. this area is critical in bending as it is the weakest section and subject to the largest moment arm. To the tensile loads caused by the bending moment at this section must be added the longitudinal pneumatic loads created by the differential pressure across the "O" ring at area "A".

The seal area at A is (.64 diameter) .321 sq. in. Longitudinal load is .321 x 4500 psi = 1440 lbs. The cross section area at "C" = $\pi .437^2 - \pi .250^2 = .405$ sq. in.

1440 / .405 = 3560 psi unit longitudinal stress. Reducing the 37000 psi allowable yield tensil by this 3560 we have 33440 psi to resist bending moments at this area "C". Section modulus at "C" = $I/c = \pi/4 \times R^4 - r^4 /R =$ .0585. Maximum allowable bending moment = F_{ty} = SI/c = 33440 x .0585 = 1955 inch pounds. The maximum moment will result from a force applied at the on-off knob. The maximum arm would be 1.6 inches. 1955/1.6 = 1222 pounds max. load which can be applied to on-off knob. Actual wt of charged cylinder & valve 19.4#. 1222/19.4 = 63 g loading allowable. If the charged 60cu. ft. cylinder were dropped and stopped by the knob, it could be decelerated at (1220/19.4) 63 g without yielding the valve body. Based on an ultimate of 52000 psi, the max. allowable moment would be 2830 inch pounds, or 2830/1.6 = 1790 pounds load at knob. 1790/19.4 = 92 g max. deceleration.

Loads in the same area as above could cause bending of the 27258 stem where it is supported by the stem guide. The stem is .304 inch diameter and made of 303 CRES Condition A.

Mechanical properties are: (MIL-HDBK-5A)

F_{tu}	75000
F_{ty}	30000
F_{su}	35000

Section modulus of stem $Z = I/c = \pi r^3/4 - .0027$.

Maximum arm possible on stem extension is .56 in.

Maximum moment at yield = $M = F_{ty}\ I/c = 30000 \times .0027$

$M = 810$ inch pounds

810 inch pounds / .56 arm = 1445# maximum load at yield.

Based on ultimate max. load would be 75000 x .0027/.56 =

3620# at failure.

Gage guard (27261) loading.

.090 thick, 1.25 wide, 1.12 arm, 2024T4

F_{tu}	ultimate tensil transverse	63000 psi
F_{ty}	yield tensil transverse	42000 psi
F_{cy}	yield compression longitudinal	39000 psi
F_{su}	shear	37000 psi

Based on compressive yield at 39000 psi:

$$\text{section modulus } Z = \frac{bh^2}{6} = 1.25 \times .09^2/6 = .0167$$

$$\text{max. allowable moment } M = F_{cy} \times Z$$

$$M = 39000 \times .0167 = 660 \text{ inch pounds}$$

Max. arm for loading this section is 1.6 inches.

660/1.12 = 590# max. load at end of guard to cause yielding.

Load required to ultimate failure is meaningless as the guard would deflect and strike the gauge long before it would break.

590/19.4 lbs. = 30.4 g at which cylinder valve assembly can be decelerated if dropped.

With a minimum effort, expense and a weight increase of only .02 pounds, the bending stiffness of this guard can be doubled if field observations indicate such a requirement.

No other area of the valve body or parts is critical from a structural standpoint.

HOSE COUPLING ASSEMBLY, P/N 27239 (see Figure B-2)

Elbow - Material 2014-T6 alternate 2024-T4. Same mechanical properties as listed previously for valve body.

From a pneumatic loading condition, the worst case condition is hoop tension at pitch diameter of pipe threads near tip end of nipple and hose fitting.

Pitch diameter is .48 inches

O. D. is .938 inches

Max. $P_t = P\ (r_1^2 + r_2^2)/(r_1^2 - R_2^2)$

P_t = 11250 psig $(.24^2 + .47^2)/(.24^2 - .47^2)$ = 18,000 psi

Tap drill is .437 I. D. so stress will be less in the area beyond threads.

Worst case from mechanical loading will occur in bending at minor diameter of pipe threads of nipple at junction with elbow. Minor diameter is .456 inches and bore is .156 inches. Material 2024-T4. Net area at this section is .14 sq. in. Section modulus $Z = I/c = \pi(R^4 - r^4)/4R = .0091$

Max. moment $M = F_{cy} \times I/c$

Failure (yield) would be on compression side F_{cy} = 32000

Max M = 32000 x .0091 = 291 inches lbs. (at zero internal air pressure)

Ultimate failure would come as a result of longitudinal stresses due to pneumatic loading at 4500 psig which amount to less than 1000 psi unit tensile stress and the tensile loads caused by bending.

Max. moment in this case would be:

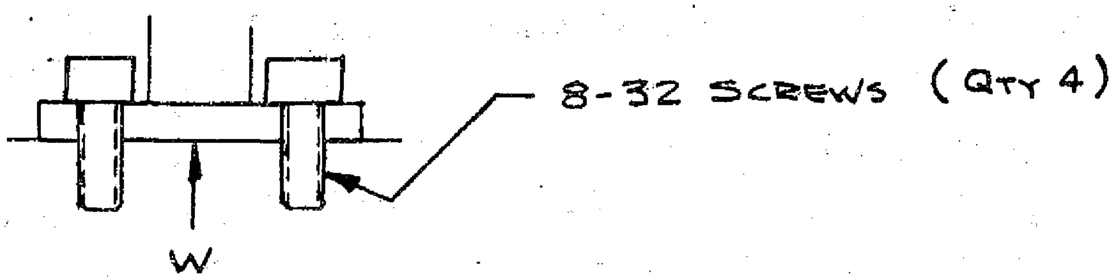
Max M = (62000 -1000) x .0091 = 555"#

The 1/8 in. pipe nipple end of the hose sees the same loading conditions as the above nipple; however, it is made from one of the free machining cold finished low carbon bars. The allowable for this material is substantially higher than the allowable of the 2024-T4.

PLATE FITTING - HIGH PRESSURE TUBE TO PRESSURE REDUCER.

1. Formula from Machinery's Handbook, 17th Edition, 1966; Erik Oberg & F. Jones; Page 1050, 1051

2. Handbook H-28, Part I; U. S. Dept. Commerce National Bureau of Standards (1969)



a) Le - length of thread engagement (inches)

$$L_e = \frac{2A_t}{\pi K_n \text{ MAX}\left[\frac{1}{2} + .57735n\left(E_s \text{ MIN} - K_n \text{ MAX}\right)\right]} \quad (1)$$

WHERE: A_t = TENSILE AREA 8-32 = .0140 IN^2 (2) TABLE 2.8
E_s MIN = MIN PITCH DIA EXT THD = .1399 IN (2) TABLE 2.21
K_n MAX = MAX MINOR DIA INT. THD = .139 IN (2) TABLE 2.21

L_e = .124 IN. MIN REQ'D

.188 IN. MIN PROVIDED

b) As = Shear area ext. thd.

$$A_s = \pi n L_e K_n \text{ MAX}\left[\frac{1}{2n} + .57735\left(E_s \text{ MIN} - K_n \text{ MAX}\right)\right] \quad (1)$$

A_s = .028 IN^2 (STAINLESS SCREW)

c) An = Shear area of int. thd.

$$A_n = \pi n L_e D_s \text{ MIN}\left[\frac{1}{2}n + .57735\left(D_s \text{ MIN} - E_n \text{ MAX}\right)\right] \quad (1)$$

WHERE: D_s MIN = MAJOR DIA EXT THD = .1571 (2) TABLE 2.21
E_n MAX = MAX PITCH DIA INT THD = .1475 (2) TABLE 2.21

A_n = .04146 IN^2 (ALUMINUM BODY)

d) J - ratio strength ext to int thd

$$J = \frac{(A_s)(\text{TENSILE STRENGTH OF EXT THD})}{(A_n)(\text{TENSILE STRENGTH OF INT. THD})}$$ 1

$$J = \frac{(.028)(80000)}{(.04146)(70000)} = \underline{.772}$$

$.772 < 1.0$ THEREFORE L_e (.124) IS O.K.

e) Ws - max load @ burst press.

$W = PA = (4500)(2.5)(.109)$ 1

$W = 1226$ lb / 4 SCREWS

$W_s = \underline{306.5}$ lb / SCREW

f) Screw stress

$$S = \frac{W_s}{A} = \frac{306.5}{.014} = \underline{21892} \text{ PSI}$$ 1

(80000 PSI MAX ALLOW.)

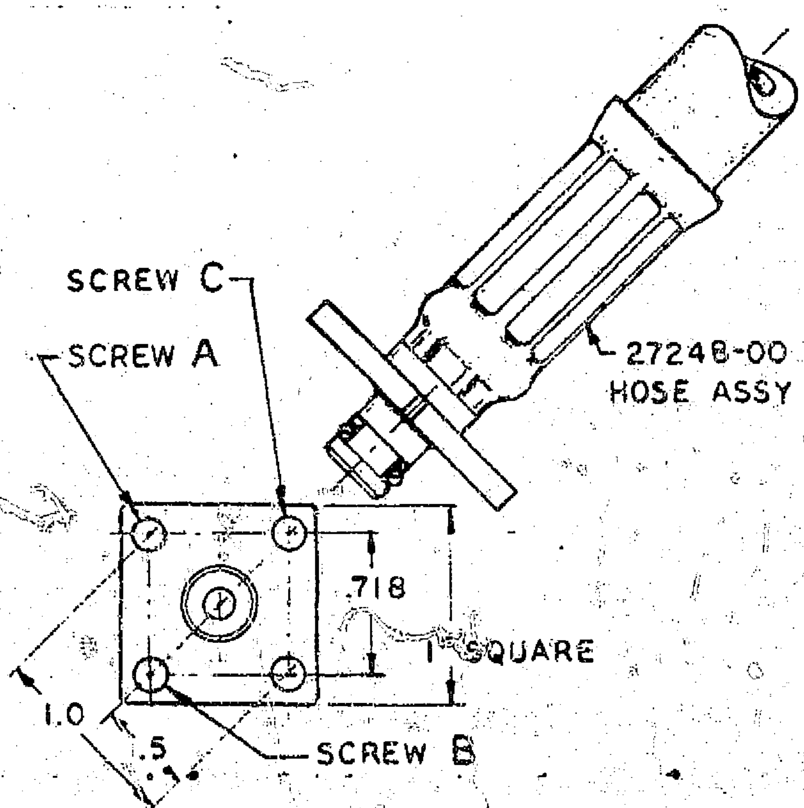
At the max. operating pressure at 4500 psig, the per screw load would be (306.5#/2.5 (burst factor)) 123 pounds or 123/.014 sq. in. = 8770 psi unit stress in each screw. Allowable total tensil for each screw is 80000 x .014 sq. in. = 1120 lbs. 1120 lbs - 123 lbs = 1000 pounds per screw remaining to resist mechanical handling loads.

Max. load on screw will occur when moment is applied to hose fitting at 45° angle with hole pattern.

Screw A will be fully loaded. Moment 1.0 x 1000 = 1000"#. Screws B & C will be half loaded.

Moment 2 screws x .5 arm x 500# = 500"#

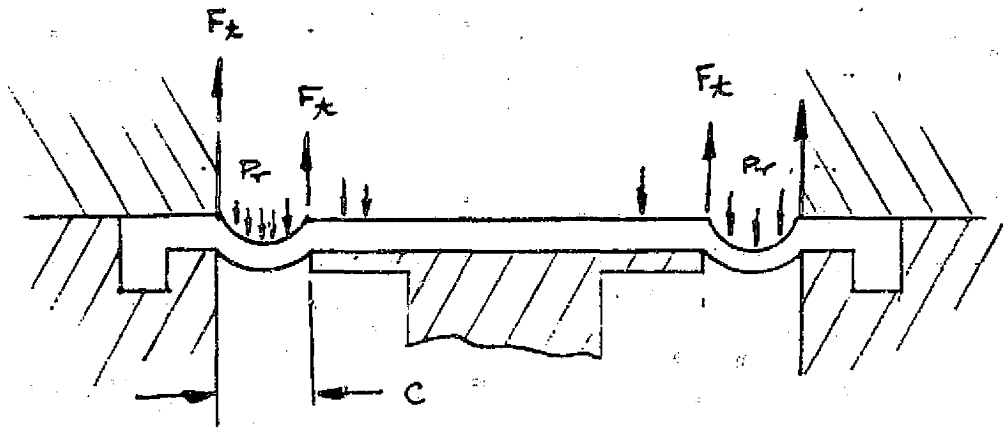
Total resisting moment = 1000 + 500 = 1500 in. lbs.



The fixity at the ends of this high pressure line and the flexibility of the short connecting hose make a quantitative analysis impractical; however, it is apparent that a 250-pound man could be lifted or dragged by grasping the high pressure hose and pulling in any direction.

The guaranteed breaking strength of the polypropylene webbing in the harness exceeds 2000 lbs. for the 2" and 1000 lbs. for the 1". All buckles and attachments structurally exceed their intended loading.

DIAPHRAGM STRESS - PRESSURE REDUCER DIAPHRAGM @ BURST PRESSURE



F_t = TENSION FORCE (LBS)
P_r = APPLIED PRESS. (PSI) = 315
C = CONVOLUTION WIDTH (IN.) = .125
ℓ = INCH CIRCUMFERENCE (INCH)
S_f = FIBER STRESS (PSI)

$\Sigma F_y = 0$

$\therefore \; 2F_t = (P_r)(\ell)(c)$

$2F_t = (315)(1.0)(.125)$

$2F_t = 39.4$ lb / INCH CIRC.

$F_t = \underline{19.7}$ lb / INCH CIRC.

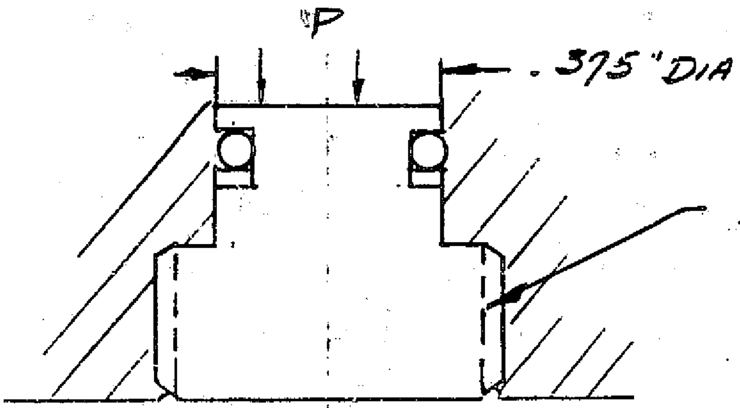
LET Q = NO OF FIBERS PER INCH OF CIRCUM. = (48 BY MEAS.)
LET A_F = CROSS SECTIONAL AREA OF EACH FIBER = (5×10^{-5} IN² BY MEAS.)
THEN - $A_t = Q A_F$, WHERE A_t = TOTAL AREA OF FIBER (IN²)

THEN $S_f = \dfrac{F_t}{A_t}$

$S_f = \dfrac{19.7}{(48)(5\times10^{-5})} = \underline{8208 \text{ PSI}}$

(67000 PSI MIN FIBER TENSILE STR)

SHEAR AREA & STRESS OF PRESSURE REDUCER SEAT INSERT



A_{sn} = SHEAR AREA INT. THREAD

$$A_{sn} = \pi E \frac{S}{4} L_e \quad (2)$$

WHERE: E = BASIC PITCH DIA - .5354 (2) TABLE 2.10

L_e = PERFECT THD. ENGAGE. - .250 IN.

A_{sn} = .105 in²

S = STRESS OF INT. THREAD

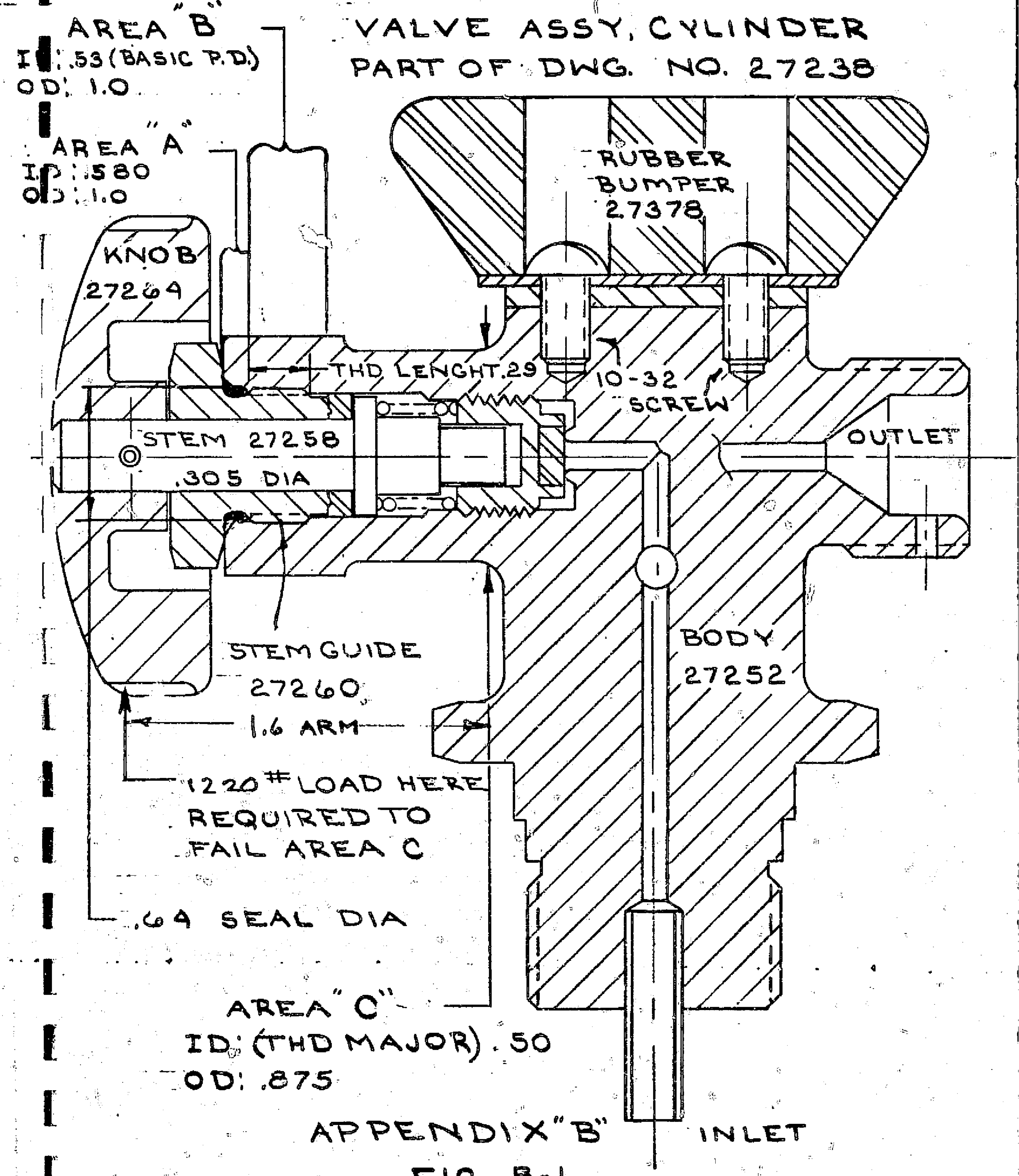
$$S = \frac{PA}{A_{sn}}$$

S = 11,786 psi

WHERE: P = 11,250 psi

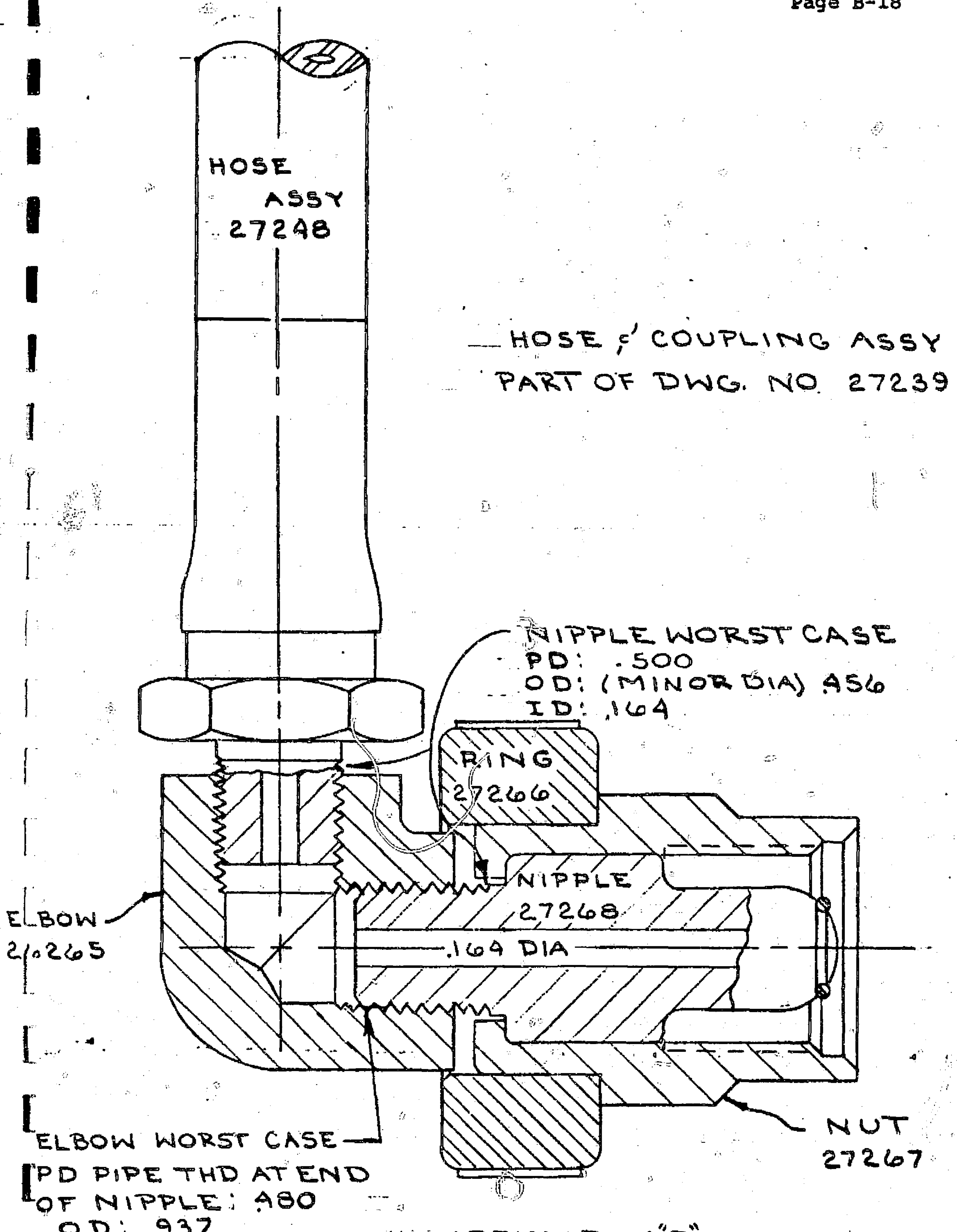
$A = \frac{\pi D^2}{4} = .11 \text{ in}^2$

(70,000 psi MAX ALLOW)



APPENDIX "B"

FIG B-1



APPENDIX "B"
FIG B-2

FLOW CALCULATIONS

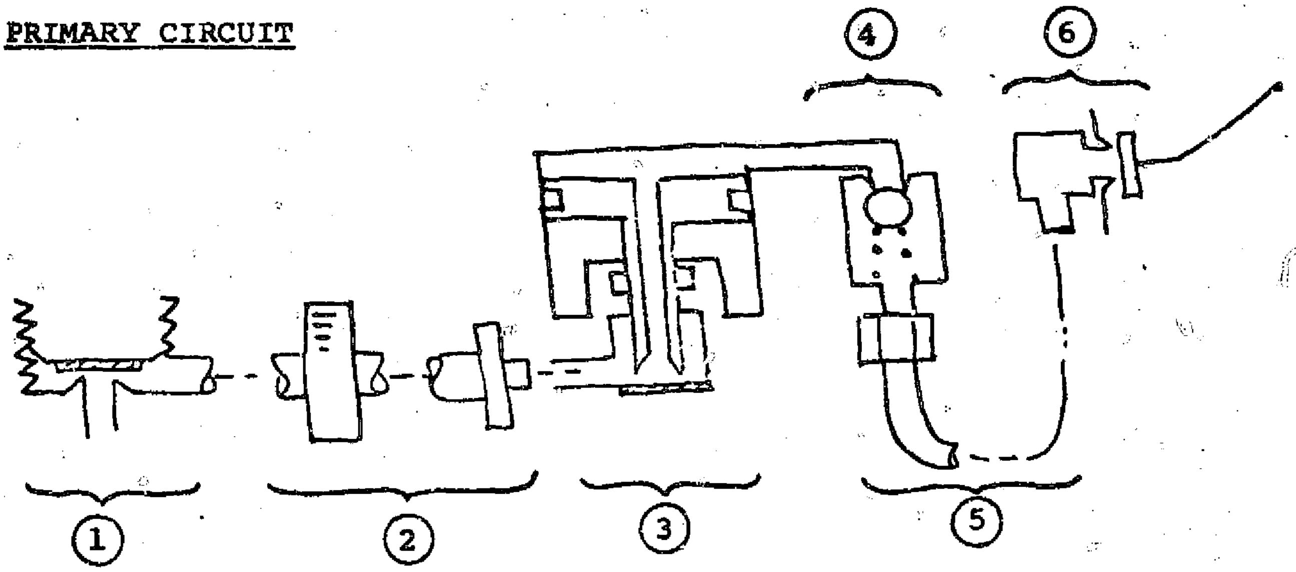
FBS VALVE SIZING

Diameters determined using "ECKEL" air flow calculator:

$$W = \frac{6.30\ Cd \times d^2 \times P_1}{\sqrt{53.34 \times T_{ABS}}} \times \sqrt{3.5\left[\left(\frac{P_2}{P_1}\right)^{1.429} - \left(\frac{P_2}{P_1}\right)^{1.714}\right]}$$

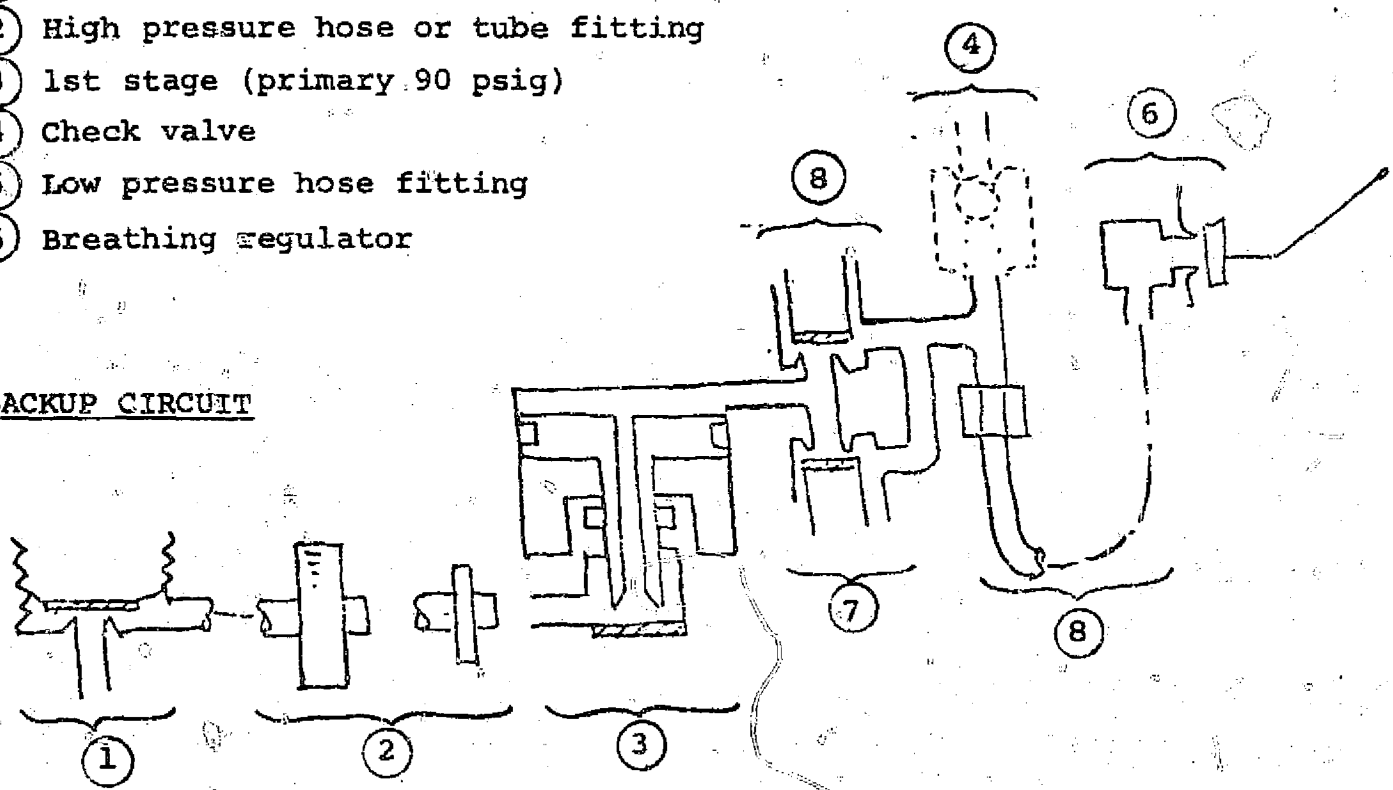
WHERE:	W	=	Flow (lbs/sec)
	Cd	=	Flow coefficient (0.65 to 0.8)
	d	=	Inside diameter of valve seat (inches)
	P_1	=	Upstream absolute pressure (psia)
	P_2	=	Downstream absolute pressure (psla)
	T_{abs}	=	Absolute temperature (^oR)

PRIMARY CIRCUIT



1. Cylinder valve
2. High pressure hose or tube fitting
3. 1st stage (primary 90 psig)
4. Check valve
5. Low pressure hose fitting
6. Breathing regulator

BACKUP CIRCUIT



1. Cylinder valve
2. High pressure hose
3. 1st stage (backup - 125 psig)
4. Check valve ref.
5. L. P. hose
6. Breathing reg.
7. Automatic actuator
8. Cylinder actuator

PRIMARY CIRCUIT

COMPONENT	P_1 PSIA	P_2 PSIA	FLOW #/SEC	FLOW LPM BTPS	VALVE DIA. CALC.	VALVE DIA. SELECT	REMARKS
Cyl. Valve (1)	585 115	580 110	.022 .008	535 200	.118 .115	.125 .125	
H. P. Hose 1st Ftg. (2)	580 110	575 107.5	.022 .008	535 200	.132 .149	.156 .156	Hose pressure drop verified by test
2nd ftg.	575 107.5	570 105	.022 .008	535 200	.133 .150	.156 .156	110 psig
1st Stage Lo (3)	105	89	.008	200	.099	.178/.125	.178 = regulated dia.
	570	86	.022	535	.060	" "	.125 = flow port
Check Valve (4)	89 92*	86 86	.008 .022	200 535	.156 .191	- .193	* Based on projected 1st stage regulator performance.
L. P. Hose (5)	86 86	84.5 79.5	.008 .022	200 535	.159 .189	.203 .203	Hose pressure drop verified by test.
Breathing Regulator (6)	80	15	.022	535	.162	.200	Valve sized larger than required to reduce stroke.

BACKUP CIRCUIT

COMPONENT	P_1 PSIA	P_2 PSIA	FLOW		VALVE DIA.		REMARKS
			# / SEC	LPM ETPS	CALC.	SELECT	
Cyl. Valve 1	585	580	.022	535		.125	
H. P. Hose 2	580	575	.022	535		.156	
1st Stage H. 3	575	121*	.022	535		~~.178~~ .125	* Based on projected 1st stage (backup) regulator performance. .178 regulated dia. .125 flow port.
Automatic or Cylinder Actuator 7 or 8	121	111	.022	535	.175	.175	
L. P. Hose 5	111					.203	As sized previously
B. Regulator 6						.200	As sized previously

APPENDIX C

DEVELOPMENT TEST REPORT

FIREFIGHTER'S BREATHING SYSTEM

ER 1041

SCOTT ATO
225 ERIE STREET
LANCASTER, N.Y. 14086
TEL. 716 683-5100
TELEX 91-394

ER-1041

Development Test Report for the Firefighter's Breathing System

NASA Contract NAS9-13177

Dated: 21 February 1974

Prepared by: P. R. Bement
P. R. Bement
Supervisor of Technical Services

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Concurred by: F. J. Ellis
F. Ellis
DCASO Representative
Buffalo, New York Office

TABLE OF CONTENTS

1.0 ABSTRACT

This report presents the results of a series of development tests performed on the Firefighter's Breathing System (FBS), Scott Part Number 27275, Revision A. The tests performed were a full series of both functional and environmental tests that would show that the FBS met the design and performance requirements of NASA Specification Number FBS-SP-001, Revision 2.

The unit successfully passed most of the tests although high and low temperature operation and impact shock caused some problems. It can be concluded that the final configuration of FBS meets the intent of the NASA specification and is both safe and suitable for its intended use.

2.0 GENERAL

2.1 Item Tested

Firefighter's Breathing System - Scott P/N 27275, Revision A, Serial Number 002.

2.2 Applicable Documents

The following documents are applicable to the extent specified herein:

NASA

Specification FBS-SP-001, Revision 2, dated November 3, 1971.

MILITARY

MIL-STD-810B "Environmental Test Methods"

COMPRESSED GAS ASSOCIATION

"Commodity Specification for Air", Number G-7.1

SCOTT AVIATION

Engineering Report No. ER-1027, "Development Test Procedure for the Firefighter's Breathing System", Revision B dated 8 February 1974.

3.0 TEST PROGRAM

3.1 Procedure

All tests were performed in accordance with the Scott Aviation Test Procedure Number ER-1027, Revision B. This procedure is incorporated as a part of this report as Exhibit I.

3.2 Data

All data sheets appear in Exhibit II.

3.3 Test Performance

All tests were performed by Scott Aviation except for Sand and Dust and Impact Shock which were performed by Dayton T. Brown, Inc., Long Island, New York. The reports of these tests appear in Exhibit IV.

4.0 TEST RESULTS

4.1 SEQUENCE 1 - (TABLE II, ER-1027) COMPONENT TESTS

4.1.1 Overpressurization Protection

The fusible plug which is assembled to the cylinder valve was removed and subjected to the overpressurization test as defined in Paragraph 4.12 of ER-1027. The fusible alloy melted as required at 220°F. The frangible disc burst at 4100 psig. Since this pressure was below the 4500 psig minimum, some supplemental tests were performed. At room temperature (70°F) the frangible disc, without the fusible alloy backing, burst at 4500 psig.

4.1.2 Proof Pressure

The FBS assembly was subjected to the Proof Pressure Test described in Paragraph 4.4 of ER-1027. Following this exposure, the unit was subjected to the Static Flow Test of Paragraph 4.15.1 of ER-1027. No damage was noted as a result of proof pressure.

4.1.3 Mask Weight

The facemask/breathing regulator/low pressure hose assembly was weighed and was found to be 1 lb. 1 oz.

4.1.4 Mask Leakage - IN

Mask Leakage - OUT

Since this series of tests is rather complex in both procedure and result, they have been addressed separately in Exhibit III of this report.

4.1.5 Pressure Gage Accuracy

The accuracy of the cylinder valve mounted pressure gage was checked both before and after exposure to proof pressure. Its function and accuracy were unaffected.

4.2 SEQUENCE 2 - PERFORMANCE TESTS

4.2.1 Flow Requirements

The FBS was subjected to the flow requirements series of tests defined in Paragraph 4.1 of ER-1027. The unit delivered the required amounts of breathing gas at the proper mask pressures during both static and dynamic flow conditions. A maximum inhalation resistance of -1.2 in. H_2O and a maximum exhalation resistance of +2.5 in H_2O were experienced at the dynamic flow condition of 476 lpm NTPD peak flow. Specific results along with recordings of the unit response during dynamic flow conditions appear with the data sheets in Exhibit II of this report.

4.2.2 Response Time

It can be observed from the data obtained in Paragraph 4.2.1 (Dynamic Flow Requirements) that (a) flow into the facemask ceases prior to cracking of the exhalation valve, and (b) facemask pressure does not drop below the minimum of -1.5 inches of water at 257 lpm NTPD peak flow.

4.2.3 Purge Flow

The FBS was subjected to the purge flow requirements series of tests defined in Paragraph 4.3 of ER-1027. The unit delivered the required amounts of breathing gas at the proper mask pressures during both static and dynamic flow conditions. A maximum inhalation resistance of -1.0 in. H_2O and a maximum exhalation resistance of +4.5 in. H_2O were experienced at the dynamic flow condition of 476 lpm NTPD peak flow. Specific results along with recordings of the unit response during dynamic flow conditions appear in Exhibit II of this report.

4.2.4 System Weight

The system was weighed and the results were as follows:

Valve Assy. including lock ring and seal	.85 lb.
High pressure hose	.80 lb.
Pressure reducer	1.80 lb.
Breathing regulator & hose	.62 lb.
Facemask	.61 lb.
Harness & Frame Assembly	3.50 lb.
Total FBS Weight (less cylinder)	8.18 lb.

4.2.5 Operating Leakage

The system was checked for operating leakage as defined in Paragraph 4.13 of ER-1027. No leakage was found.

4.2.6 Stored Leakage

The cylinder valve/cylinder assembly was tested for stored leakage characteristics as defined in Paragraph 4.21 of ER-1027. No leakage was found.

4.2.7 Warning Actuation

The FBS was subjected to the warning actuation test as defined by Paragraph 4.22 of ER-1027. The low pressure alarm actuated at a cylinder pressure of 850 psig.

4.2.8 Warning Signal Frequency and Intensity

The FBS was subjected to the warning signal frequency and intensity test as defined in Paragraph 4.23 of ER-1027. The alarm provided a peak signal intensity of 103 dbA and frequency of 3570 Hz at a flow of 55 lpm NTPD.

4.3 SEQUENCE 3 - ENVIRONMENTAL TESTS

4.3.1 High Temperature Operation

The FBS was subjected to the high temperature operation test as defined by Paragraph 4.15.3 of ER-1027. The static flow check to check unit operation at high temperature showed that at specific negative mask pressures the flow had dropped and also the alarm whistle never operated properly. Only a slight chirp was detected with an actuation pressure of 640 psig. No leakage or physical damage was noted. Subsequent failure analysis showed that the pressure reducer regulator springs had relaxed as a result of exposure to high temperature. Corrective action for this problem is to hot soak all springs before assembly into pressure reducers. The pressure reducer of the development test unit was brought back to the proper output pressures by shimming. The high temperature operation test was again performed with no problems in operation noted. However, a cylinder and cylinder valve assembly fully charged was also placed in the chamber for exposure to high temperature and was found to have leaked all stored gas to atmosphere. Investigation showed that the fusible alloy which backs up the burst disc in the overpressurization protection device had experienced a "creep" deformation while at 200°F. Since pressure in the cylinder had increased to approximately 4500 psig, the burst disc then cracked allowing the stored gas to slowly escape. It is concluded that the cylinder charged to 4000 psig cannot be stored at 200°F. However, during use of the apparatus at 200°F, the rate of reduction in pressure from use would be greater than the increase due to the heat input. A maximum storage temperature of 165°F is indicated. A cylinder and valve assembly charged to 4000 psig was exposed to 165°F for 13 hours and exhibited no leakage or extrusion of the fusible alloy.

4.3.2 Low Temperature Operation

The FBS was subjected to the low temperature operation test as defined by Paragraph 4.15.2 of ER-1027. The static flow check at low temperature (-60°F) revealed normal flow characteristics but a low alarm actuation pressure (740 psig). When the unit was first pressurized to 2000 psig, leakage was found in the low pressure hose disconnect and gas flowed from the vent holes in the side of the pressure reducer. The low pressure hose was found to be very stiff. No other visual defects were noted.

The low temperature operation test was rerun at a temperature of -48°F. The low pressure hose disconnect leaked and the low pressure hose was stiff.

A third low temperature operation test was performed at -40°F. The only defects noted were a stiff low pressure hose and the dust plugs in the side of the pressure reducer loosened and fell out. The test at -40°F was considered successful.

4.3.3 Relative Humidity

The FBS was subjected to the relative humidity test as defined by Paragraph 4.15.4 of ER-1027. The unit operated with no degradation in performance after 120 hours exposure to the prescribed humidity cycle. However, the following physical defects were noted:

a) There was corrosion on the waist buckle, but its operation was unaffected.

b) The ferrules and the fitting (1/4" pipe end) of the high pressure hose were corroded.

c) There was corrosion around the swivel fitting of the breathing regulator.

d) The heads of the cadmium plated screws on the back frame were corroded.

e) There was moisture under the gage lens.

After the unit was conditioned at 77°F and 60% relative humidity for 13 hours, the moisture disappeared from under the gage lens. The corrosion did not affect the operation of the system.

4.3.4 Salt Fog

The FBS was subjected to the salt fog exposure test as defined by Paragraph 4.16.1 of ER-1027. The unit operated with no degradation in performance after 48 hours exposure to the prescribed salt fog environment. However, the following physical defects were noted:

a) Moisture appeared under the gage lens.

b) The corrosion that had started during relative humidity continued, but to a lesser degree.

c) There was a small leak from the low pressure hose disconnect.

After a 48 hour drying period, the FBS was checked for performance with no problems noted. The moisture had disappeared from under the gage lens.

4.3.5 Sand and Dust

The FBS was subjected to the sand and dust exposure test as defined by Paragraph 4.16.2 of ER-1027.

The unit operated with no degradation in performance after exposure to the prescribed sand and dust environment. No physical defects were noted following this test. See Exhibit IV for Dayton T. Brown, Inc. Laboratory Report of this test.

4.3.6 Impact Shock

The FBS was subjected to the impact shock test as defined by Paragraph 4.16.3 of ER-1027. The results of each drop follow. Orientations are shown in Figure 11 of ER-1027.

Drop #1
a) The gage lens popped out;
b) The bar above the gage was bent down contacting the gage;
c) The cylinder surface was scratched but not severely.

Drop #2
a) The cylinder valve handle was broken;
b) The surface of the cylinder was scuffed again.

Drop #3
a) The retainer tab on the cylinder valve was straightened;
b) Cylinder scuffed again.

<u>Drop #4</u> The threaded nipple of the cylinder valve broke at the root of a thread which would render the unit out of service.

<u>Drop #5</u> The cylinder strap of the back pack opened and the cylinder partially separated from the unit.

<u>Drop #6</u>
a) Five screws were sheared from the cover of the pressure reducer;
b) The cylinder was gouged;
c) The pressure reducer was dented in two places by the cylinder strap.
d) The cover of the breathing regulator was slightly crushed.
e) The left shoulder strap and the waist belt were partially cut.

The only conditions which would be considered hazardous were the breaking of the cylinder valve nipple and the shearing of screws from the cover of the pressure reducer. A subsequent redesign was undertaken to eliminate the aforementioned conditions.

a) The direction of grain structure in the aluminum of the cylinder valve was arranged to run parallel to the axis of the outlet.

b) The valve nipple was shortened to allow the hand disconnect to locate closer to the valve body.

c) A plate was installed between the backframe and pressure reducer to prevent the cylinder strap from contacting the cover of the pressure reducer.

d) The material of the probe in the high pressure hand disconnect was changed from aluminum to stainless steel.

<u>NOTE</u>: After completion of development tests up through and including Sequence 7 "Burst Tests", a second series of impact shock tests were performed to verify the effectiveness of corrective action taken. The following results were observed:

<u>Drop #1</u> a) The gage lens popped off;

b) The gage case was deformed by bending of plate overhanging gage;

c) Gage inoperative.

<u>Drop #2</u> Cylinder valve handle cracked.

<u>Drop #3</u> The breathing regulator was stored in the pocket of the waist belt and was

subsequently destroyed when the back pack apparently fell onto it. Gas flowed from the low pressure hose but since it did not whip around, it was not considered hazardous. The cylinder valve was then closed and the test continued.

Drop #4 The resin coating on the outside of the cylinder at the dome end appeared to have cracked but did not appear hazardous.

Drop #5
a) The low pressure disconnect on the pressure reducer was badly deformed and would not operate.
b) The cylinder strap popped open and would not reclose tightly.

Drop #6
a) Cylinder valve handle broke into many pieces;
b) Gage face separated from gage.
c) Cylinder strap popped open.

The above defects, although rendering the unit inoperative, were not considered hazardous to others who may be in the area.

4.4 SEQUENCE 4 - USEFUL LIFE TESTS

4.4.1 High Pressure Hose to Cylinder Valve Connector

The high pressure hand disconnect was connected and disconnected from the nipple of the cylinder valve as defined by Paragraph 4.19.1 of ER-1027. After 4500 total cycles, a leakage of less than 1.0 cc/min. was detected in the vent hole. This was corrected by tightening the set screw holding the O-ring on the probe. No leakage was detected following 5000 total cycles. Visual inspection showed that some of the teflon coating had worn from the mating threads. No other damage was noted.

4.4.2 Low Pressure Hose to Pressure Reducer Disconnect

The low pressure hose/pressure reducer disconnect was mated and separated 1000 times as defined by Paragraph 4.19.2 of ER-1027. Following 1000 cycles, a leakage of approximately 2 cc/min. was detected. Investigation showed that the O-ring inside the disconnect was badly worn. This was replaced and the leakage was eliminated.

exhalation valve showed no degradation in performance; (c) that although total flow at specific demand pressures had reduced somewhat, it was still well above minimum requirements.

The unit was then disassembled and the following observations made:

(a) The body of the breathing regulator was cracked in two places. These cracks are suspected to be a result of the impact shock test performed earlier.

(b) The demand valve shroud was cracked at the bend nearest the left screw hole. When removed, it separated into two pieces.

(c) The diaphragm appears in good shape along with the exhalation valve.

(d) The pivot of the demand valve was worn causing a reduction in valve stroke.

(e) The slide valve for whistle actuation required some lubrication.

(f) Generally, the unit showed little wear and was somewhat dirty inside.

4.4.3 Breathing Regulator to Facemask Connection

The breathing regulator/facemask connection was mated and separated 5000 times as defined by Paragraph 4.19.3 of ER-1027. No leakage was detected following 4500 total cycles. After 5000 total cycles, a leak of less than 2 cc/min. was detected at the right side center of the seal. The seal was cleaned and a small amount of Krytox lubricant applied. The parts were mated with no apparent leakage. Visual inspection did not reveal any apparent wear in the seal. The brass latch in the mask was grooved considerably by the head of the locking screw. This did not affect latch performance.

4.4.4 Cylinder Mounting in Backpack

The cylinder/cylinder valve assembly was subjected to 5000 placement/lock-in-place/unlock/remove cycles. Visual inspection following cycling determined that the only wear point was at the very top of the rubber strips which are cemented to the backplate and are used to cradle the cylinder. Their function was unaffected by this wear.

4.4.5 <u>Operational Cycling</u>

The gas controls of the FBS; i. e., the cylinder valve, high pressure hose, pressure reducer, low pressure hose and breathing regulator were subjected to 5000 simulated use cycles as defined by Paragraph 4.19.5 of ER-1027. After 2000 total use cycles, the whistle was audible at the start of each breath at all inlet pressures above the normal actuation point. This was traced to the fact that the output pressure of the primary pressure regulator had "crept" as high as 110 psig. The regulator seat was replaced and the test continued. At the 4215 cycle point in the test, the roll pin which attaches the cylinder valve handle to the valve stem was sheared. This was determined to be faulty test equipment. The roll pin was replaced and the test restarted.

Following 5010 total use cycles and 58075 breathing cycles, it was determined that: (a) the cylinder valve did not leak externally or internally; (b) the

The unit was reassembled and then subjected to a static flow check and performed with no problem evident.

4.4.6 Purge Valve

The purge valve was fully opened and closed a total of 5000 times as defined by Paragraph 4.19.6 of ER-1027. At the 1000 cycle point of the test, no leakage was present but increasing friction was noted in the operation of the valve. At the 1150 cycle point, only 38 lpm of flow was emitted with the valve fully open. The assembly was disassembled and inspected. Wear was found on the mating threads which resulted in the formation of plastic dust and an increase in friction. There also was some wear evident on the contact point of the valve piston and pin of the stem assembly. The assembly was cleaned and reassembled and the flow set at 150 lpm.

4.5 SEQUENCE 5 - PERFORMANCE TESTS

4.5.1 Flow Requirements

The FBS was subjected to the flow requirements series of tests defined in paragraph 4.1 of ER-1027. The unit delivered the required amounts of breathing gas at the proper mask pressures during both static and dynamic flow conditions. A maximum inhalation resistance of -2.0 inches of water and a maximum exhalation resistance +2.0 inches of water was experienced at the dynamic flow condition of 476 LPM NTPD peak flow. Specific results along with recordings of unit response during dynamic flow conditions appear with the data sheets in Exhibit II.

4.5.2 Response Time

It can be observed from the data obtained in paragraph 4.5.1 (Dynamic Flow Requirements) that a). flow into the mask ceases prior to cracking of the exhalation value and b). face mask pressure does not drop below the minimum of -1.5 inches of water at 257 LPM NTPD peak flow.

4.5.3 Purge Flow

The FBS was subjected to the purge flow requirements series of tests defined in paragraph 4.3 of ER-1027.

The unit delivered the required amounts of breathing gas at the proper mask pressures during both static and dynamic flow conditions. A minimum inhalation resistance of -2.0 inches of water and maximum exhalation resistance +4.0 inches of water was experienced at the dynamic flow condition of 476 LPM NTPD peak flow. Specific results along with recording of the unit response during dynamic flow conditions appear in Exhibit II.

4.5.4 System Weight

This test was not repeated.

4.5.5. Operating Leakage

The system was checked for operating leakage as defined in paragraph 4.13 of ER-1027. No leakage was detected.

4.5.6 Stored Leakage

The cylinder valve/cylinder valve assembly was tested for stored leakage characteristics as defined in Paragraph 4.21 of ER-1027. No leakage was detected.

4.5.7 Warning Actuation

The FBS was subjected to the warning actuation test as defined by Paragraph 4.22 of ER-1027. The low pressure alarm actuated at a cylinder pressure of 850 psig.

4.5.8 Warning Signal Frequency and Intensity

The FBS was subjected to the warning signal frequency and intensity test as defined by Paragraph 4.23 of ER-1027. The alarm provided a peak signal intensity of 98 dbA and frequency of 3570 Hz at a flow of 55 lpm NTPD.

4.6 SEQUENCE 6 - COMPONENT TESTS (PARTIAL)

4.6.1 Overpressurization Protection

The fusible plug which is assembled to the cylinder valve was removed and subjected to the overpressurization test as defined in Paragraph 4.12 of ER-1027. The fusible alloy melted as required at 220°F. The frangible disc burst at 4100 psig.

4.6.2 Pressure Gage Accuracy

The accuracy of the cylinder valve mounted pressure gage was checked following the lift cycling test series. Its function and accuracy were unaffected.

4.7 SEQUENCE 7 - BURST TESTS

All gas control components of the FBS were subjected to the burst test as defined by paragraph 4.5 of ER-1027. Visual inspection showed that no deformation of any kind resulted. In addition no leakage was present when an outward leakage test was performed.

4.8 SEQUENCE 8 - DEMONSTRATION TESTS

4.8.1 Donning/Doffing

A trained test subject performed the donning doffing test series as defined in paragraph 4.7 of ER-1027. The subject averaged 14.5 seconds for a series of five donning exercises. The same subject averaged

1.5 seconds for a series of five doffing exercises.

4.8.2 Startup

A properly trained subject donned and performed the FBS startup procedure as defined in paragraph 4.8 of ER-1027. No problems were noted during this operation.

4.8.3 Orientation

A trained subject wearing the FBS performed the orientation procedure as defined in paragraph 4.9 of ER-1027. The FBS operated with no degradation in performance in all orientations.

4.8.4 Controls

It was verified that all controls are accessible to the wearer and are arranged to minimize the possibility of inadvertent actuation as defined by paragraph 4.10 of ER-1027.

4.8.5 Pressure Vessel Replacement

A trained subject performed the pressure vessel replacement test as defined by paragraph 4.11 of ER-1027. The maximum elapsed time to remove and replace a cylinder was 58 seconds.

4.8.6 System Envelope

A subject wearing the FBS over a turnout coat performed the system envelope test as defined by paragraph 4.17 of ER-1027. It was verified by inspection that a). the unit was as closely conformal to the wearer as possible b) corners and edges are rounded c). protrusions are minimized.

4.8.7 Comfort

Three subjects wearing the FBS over a turnout coat performed the comfort test as defined by paragraph 4.18 of ER-1027. No abnormal reactions were experienced by any of the subjects.

4.8.8 Visor Fogging

A subject wearing the FBS performed the visor fogging test as defined by paragraph 4.26 of ER-1027. It should be noted that due to a low temperature chamber malfunction the temperature during this test ranged from -6 to -8^{o}F instead of the required -20 $\pm$5^{o}F.

Before entering the chamber the mask lens was cleaned and treated with a commercial anti-fogging agent named "Magic Lens Cleaning Anti-Fogging Fluid" manufactures by the Silicone Paper Company of America. The FBS with a nosecup installed in the mask was donned and the subject entered the cold chamber. The mask immediately formed an approximately ½" wide band of fog around the periphery near the face seal. After the first exercise period this became more pronounced. Approximately six minutes after entering the chamber, moisture droplets began to form just above and to the subject's left of the breathing regulator connection. The pattern indicated that the droplets were being sprayed up from the spray bar.

Fogging increased until the 14-minute mark at which point the lens was 90% covered. At the 15-minute mark, the nose cup was removed and the lens became completely covered. The test was terminated at the 17-minute mark.

The mask was cleaned, dried and treated with another anti-fogging compound made by Acme Products, Inc. of South Haven, Michigan. The nose cup was installed in the mask, a full cylinder placed in the FBS and the test restarted.

No fogging occurred after two minutes in the cold chamber. After 4 minutes, a small band of fog approximately 3/4 inch wide appeared across the center of the lens. After 8 minutes the lens was completely covered with fog in the center and frost around the periphery. At the 11-minute mark, the nose cup was removed and all fog and frost completely disappeared. A layer of moisture could be seen coating the inside of the lens but visibility was unimpaired. The test was terminated after 15 minutes.

EXHIBIT I

225 ERIE STREET
LANCASTER, N.Y. 14086
TEL. 716 683-5100
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Engineering Report No. ER-1027

Development Test Procedure for the Firefighter's Breathing System

NASA Contract No. NAS9-13177

Dated: 21 June 1973
Revision A - dated 29 June 1973
Revision B - dated 8 February 1974

Prepared by: P. R. Bement
P. R. Bement
Test Engineer

Approved by: J. L. Sullivan
J. L. Sullivan
Engineering Manager - Commercial Products

Revisions

Letter/Date	
A 6/29/73	Para. 3.9 Conversion Chart Added equivalent NTPD flow for 125 LPM BTPS.
	Para. 3.6, 3.7 Removed reference to Scott Quality Control.
	Para. 4.1.1, Step 1 Figure 4 changed to Figure 1.
	Para. 4.1.1, Step 3 Redefined leakage test, was pressure decay test.
	Para. 4.1.1, Step 4 Changed flow of Item (1) from 2.0 scc/min. to 20 scc/min.
	Para. 4.1.2 Added flow at -1.25 mask pressure. Title changed to include "intermediate".
	Para. 4.1.3 Title changed to add "& Static Flow". Added static flows at +2.0 and 4.0 mask pressure.
	Para. 4.2 Change reference from Para. "4.2, Step 2" to Para. "4.1.4, Step 2".
	Para. 4.3.2 Added static purge capability test.

Revisions
(cont.)

<u>Para. 4.4, Proof Pressure</u>
Changed to show proof test on cylinder valve assembly. Was cylinder & valve assembly.

<u>Para. 4.5, Burst Pressure</u>
Changed to show burst test on cylinder valve assembly. Was cylinder & valve assembly.

<u>Para. 4.7, 4.8, 4.10, 4.17, 4.18</u>
Added words "wearing a turnout coat".

<u>Para. 4.12</u>
Revised procedure to burst device while at 220°F.

<u>Para. 4.15</u>
Removed 4000 psig and added "2000 & 800 psig".

<u>Para. 4.15.3, Step 2, Line 2</u>
Changed word "low" to "high".

<u>Para. 4.16.3, Step 2</u>
Added visual inspection following each shock.

<u>Para. 4.19.3, Inward Leakage, Step 2</u>
Changed -2.0 to -3.0.

<u>Para. 4.24 Inward Leakage</u>
Item (1) calibration to be based on 16 PPM; was 1500 PPM.

Revisions
(cont.)

Figure 1
Labeled Cylinder Valve on schematic.

Figure 2
Flowmeter relocated upstream of dummy head.

Figure 5
Removed "4500 psig".

Figure 9
Moved helium sniffer to breathing regulator.

Figure 13
Added figure to reflect addition of Paragraph 4.3.2.

Data Sheet #1
Page 1 - Step (3) Leakage; 1.5 scc/min. maximum added.
Page 2 - Changed title and added data for -1.25 inches mask pressure.
Page 3 - Changed title and added data for static flow check.

Data Sheet #2
Page 2 - Step (3) flow at 100 psig cylinder pressure; added 111.2 LPM NTPD.

Data Sheet #3
Added block for 800 psig inlet static flow check.

Data Sheet #5
Added requirement for total system weight.

Revisions
(cont.)

<u>Data Sheets #9, 10, 11, 12, 13, 14</u>
Added block for 800 psig inlet static flow check.

<u>Data Sheet #14</u>
Added block for visual check after each shock.

<u>Data Sheet #17</u>
Added columns for both inward and outward leakage and added specification limits for each.

<u>Data Sheet #19</u>
Added static flow check at 800 psig and exhalation valve check at +2 and +4 mask pressure.

<u>Data Sheet #20, 21, 22, 23</u>
Added specification limits.

All revisions were made to reflect changes agreed upon 6/21/73 at a meeting between NASA and Scott representatives, and experience with preliminary tests.

Revisions
(cont.)

Letter/Date

B
2/6/74

Para. 4.1.1

Step (1) 4000, was 4500.
Step (3) Changed 1.5 scc/min. to 10 scc/min.
Step (4) 4000, was 4500; and added "above the leakage value determined in Step (3) above".

Para. 4.1.2

Step (1) 4000, was 4500.

Para. 4.1.4

Step (3d) Eliminated "Record the pressure at which the low pressure alarm actuates" and substituted what was Step (e).
Step (4) Added step.
Step (5) Was Step (4); 4000 was 4500.
Step (6) Was Step (5).

Para. 4.3.1

Step (3d) Eliminated "Record the pressure at which the low pressure alarm actuates" and substituted what was Step (e).
Step (4) Added step.
Step (5) Was Step (4).

Para. 4.3.2

Step (1) Removed "a fully charged cylinder"; changed Figure 13 to 5.
Step (2) Added "supplying 4000 psig to the system".
Step (3) Eliminated "Continuously record both total flow from the exhalation valve and total mask pressure until cylinder pressure drops to 100 psig. Periodically

Revisions
(cont.)

record on the chart paper cylinder pressure." and substituted existing Step (3).

Step (4) Added.

Step (5) Added.

Para. 4.13

Step (1) 4000, was 4500.

Para. 4.16.3

Step (1) 4000 was 4500.

Step (2) 4000 was 4500.

Step (3) Eliminated "and then subject to the static flow test of Para. 4.15.1".

Para. 4.19.1

4000 was 4500.

Para. 4.19.5

Step (2) 4000 was 4500.

Step (4) 150 lpm was 250 lpm.

Step (5) 150 lpm was 250 lpm.

Step (7) 12 solenoid was 20 solenoid.

Para. 4.21

Step (1) 4000 was 4500.

Para. 4.22

Step (1) was "Place the FBS on a user and start up."

Step (2) was "Observe and record the pressure at which the depletion warning device actuates."

Step (3) was "Also note whether the device operates on the inhalation portion of breathing and when the purge valve is open."

C-2

Revisions
(cont.)

Para. 4.23

Second paragraph was "Adjust the purge valve to obtain successive flows of 10 and 75 lpm NTPD. At each of these flows, measure the alarm signal and frequency using a measurement bandwidth of 500 to 4000 Hz. Using the breathing machine to obtain dynamic flow conditions, again measure and record the alarm signal and frequency for peak flow cycles of 257 and 476 lpm NTPD. Repeat the above test series using a measurement frequency bandwidth of all frequencies except 500 to 4000 Hz.

Figure 13

Eliminated (static purge capability)

Data Sheets

Revised to reflect above changes.

All Revision B changes were made during the course of testing to either correct errors in the procedure or errors in test concept.

Paul Bement
February 6, 1974

TABLE OF CONTENTS

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(cont.)

1.0 INTRODUCTION

This procedure describes a series of functional and environmental tests to be performed on a Phase II development model of the Firefighter's Breathing System (FBS) designed and built on NASA Contract Number NAS9-13177 by Scott Aviation. All tests will be performed under the auspices of the Scott Aviation Engineering Department in their Test Laboratory or in nearby vendor facilities.

The overall objective of this test program is to furnish the basis for verifying the FBS meets the performance and design requirements of the NASA specification.

2.0 APPLICABLE DOCUMENTS

NASA Specification FBS-SP-001, Revision 2, dated November 3, 1971.

Titled: "Performance, Design and Cost Requirements for a Compressed Air Demand-type Fireman's Breathing System"

MIL-STD-810B, "Environmental Test Methods"

Compressed Gas Association Commodity Specification for Air, Number G-7.1

3.0 GENERAL

3.1 Test Medium

The breathing gas used will be pure, dry breathing air conforming to the requirements of the Compressed Gas Association Commodity Specification for Air, G-7.1, Type I (Grade D or higher quality).

3.2 Environmental Conditions

Unless otherwise specified, the ambient conditions for conducting the operational tests herein will be as follows:

(1) Temperature: $77^{o} \pm 18^{o}F$

(2) Relative Humidity: 90 percent or less

(3) Barometric Pressure: Local standard (28 to 32 inches of Hg)

3.3 Order of Tests

All verifications to be performed are shown in Table I and the sequence of system tests is shown in Table II.

The tests listed in Table I as demonstrations shall be demonstrated at the Test Readiness Review held prior to proceeding into the development testing.

The test philosophy used in establishing the test sequence listed in Table II was to establish the tests into groups and sequence the test groups. The individual tests within any one group may be scheduled to allow maximum utilization of test set-ups, personnel and equipment.

DEVELOPMENT TEST MATRIX - FBS

TABLE I

TEST	NASA Spec. FBS-SP-001 Paragraph Numbers	Scott Procedure ER-1027 Paragraph Numbers	TEST LEVEL (Component and/or System)							
			Cylinder and Valve Assy.	High Pressure Hose	Pressure Reducer	Low Pressure Hose	Breathing Regulator	Facemask	Backpack & Frame	System
Flow Requirements	3.1.1.3	4.1								X
Response Time	3.1.1.4	4.2								X
Purge Capability	3.1.1.5	4.3								X
Proof Pressure	3.1.1.6	4.4	X	X	X	X	X			
Burst Pressure	3.1.1.7	4.5			X	X	X			
System Weight	3.1.1.8	4.6								X
Donning/Doffing-Demonstration	3.1.1.11	4.7								X
Startup-Demonstration	3.1.1.12	4.8								X
Orientation-Demonstration	3.1.1.13	4.9								X
Controls-Demonstration	3.1.1.14	4.10								X
Pressure Vessel Replacement-Demonstration	3.1.1.15	4.11								X
Operating Environments	3.1.1.16	4.15								X
Nonoperating Environments	3.1.1.17	4.16								X
System Envelope-Demonstration	3.1.1.18	4.17								X
Comfort-Demonstration	3.1.1.19	4.18								X
Useful Life	3.1.1.21	4.19								X
System Leakage	3.1.1.23	4.13								X
Pressure Vessel Mounting-Demonstration	3.1.1.24	4.20							X	X
Leakage	3.1.2.1.2	4.21								X
Pressure Gage Accuracy	3.1.2.1.3	4.14	X							
Actuation	3.1.2.2.1	4.22								X
Overpressurization Protection	3.1.2.1.6	4.12	X							X
Signal Intensity	3.1.2.2.2	4.23								X
Signal Frequency	3.1.2.2.4	4.23								X
Inward Leakage	3.1.2.4.2	4.24					X	X		
Outward Leakage	3.1.2.4.3	4.25					X	X		
Visor Fogging-Demonstration	3.1.2.4.5	4.26								X
Weight	3.1.2.4.6	4.27					X	X		

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TABLE II

Sequence of Testing

Sequence	Test	Procedure Para. No.
1	COMPONENT TESTS	
	Overpressurization Protection	4.12
	Proof Pressure	4.4
	Mask Weight	4.27
	Mask Leakage - IN	4.24
	Mask Leakage - OUT	4.25
	Pressure Gage	4.14
2	PERFORMANCE TESTS	
	Flow Requirements	4.1
	Response Time	4.2
	Purge Flow	4.3
	System Weight	4.6
	Operating Leakage	4.13
	Stored Leakage	4.21
	Warning Actuation	4.22
	Warning Signal Intensity	4.23
	Warning Signal Frequency	4.23
3	ENVIRONMENTAL TESTS	
	Low Temperature	4.15.2
	High Temperature	4.15.3
	Relative Humidity	4.15.4
	Salt Fog	4.16.1
	Dust	4.16.2
	~~Impact Shock~~	4.16.3
	Static Flow Test (performed prior to and after each environmental test)	4.15.1

TABLE II
(cont.)

Sequence	Test	Procedure Para. No.
4	USEFUL LIFE TESTS	
	Life Cycling Test	4.19
5	PERFORMANCE TESTS	
	Same as Sequence 2	
6	COMPONENT TESTS (PARTIAL)	
	Overpressurization Protection	4.12
	Pressure Gage	4.14
7	BURST TESTS	
	Burst Pressure Tests	4.5

3.4 Test Instrumentation

3.4.1 Accuracy

The accuracy of instruments and test equipment used to control or monitor test parameters specified herein shall:

(a) Conform to laboratory standards whose calibration is traceable to the prime standards at the U. S. Bureau of Standards.

(b) Have an accuracy of at least one-tenth the tolerance for the test article variable to be measured.

3.4.2 Calibration and Certification

Prior to starting any test, Test Engineering shall review the instrumentation to ascertain that:

(a) Calibration and certification have been accomplished and are valid.

(b) The calibration time period will not elapse during a test of long duration. If this possibility exists, the applicable instrument will be replaced by one with a more recent calibration date.

(c) Equipment, such as strip chart recorders, have been checked for proper operation and accuracy prior to starting the test. These instruments shall also be checked periodically during testing to ensure that drift has not exceeded the specified tolerance.

3.5 Static Flow Test

A static flow test to determine the development test hardware is performing within specification tolerances will be performed before and after each environmental exposure. When the tests are conducted in series with no significant time interval between tests, the test after an environmental exposure will serve as verification of proper performance before the succeeding environmental exposure.

3.6 Test Notification

DCAS personnel shall be notified a minimum of three (3) days in advance of testing.

3.7 Test Rigor

The Development Test Program will be performed under strict control of environments and test procedures contained herein. Adjustments or tuning of the test hardware will not be permitted during these tests unless it is normal to in-service operation. Control shall be enforced by the witnessing of tests by DCAS personnel.

In the event of noncompliance with any of the requirements of this procedure, the NASA Technical Monitor will be notified of the nonconformance, any changes or adjustments made to the test hardware and the recommended retest prior to continuing the test program.

3.8 Test Log

A test log will be kept on the test hardware, beginning with the formal demonstrations at the Test Readiness Review and continuing chronologically through the test program. The log book shall accompany the test hardware and account for all periods of time including idle periods. The test log is intended to supplement the test data sheets. The log entries shall be complete, self-explanatory and include, but not be limited to, the following:

(a) Date and time of entry;

(b) Identity of test or inspection;

(c) Environmental data (if not included on test data sheets);

(d) Characteristics being investigated;

(e) Failure or unsatisfactory condition observations;

(f) Record of repair and maintenance;

(g) Record of unusual or questionable occurrences involving the equipment;

(h) Action taken to have "quick fixes" in test formalized as design changes;

(i) Identity of individual making entry.

3.9 Flow Computations

All flow values are expressed in liters per minute NTPD. Since the NASA specification expresses flow in liters per minute BTPS, the conversion is as follows:

$$\text{LPM NTPD} = \text{LPM BTPS} \left(0.0012484 \quad (P_B-47)\right)$$

where

LPM NTPD = liters per minute, normal temperature, pressure, dry

LPM BTPS = liters per minute, body temperature, pressure, saturated

P_B = Barometric Pressure

The above conversion was obtained from: Society of Automotive Engineers Document Aerospace Information Report Number AIR 825, titled "Oxygen Equipment for Aircraft", dated 2/25/65.

CONVERSION CHART

LPM BTPS	EQUIVALENT LPM NTPD
125	111.2
200	178
289	257.2
535	476.2

4.0 PROCEDURE

4.1 Flow Requirements

4.1.1 Inhalation Initiation

(1) Install the FBS in the test setup shown in Figure 1. Record test instrumentation description. Adjust regulated air supply to 4000 psig.

(2) With the cylinder valve of the FBS closed, slowly open the needle valve (1).

(3) Adjust the needle valve and create a negative pressure of 2.0 inches inside the mask area. Record the flow on flowmeter (3), which is the inward leakage. If leakage greater than 10 scc/min. exists, it should be corrected before proceeding.

(4) Open the cylinder valve of the FBS supplying 4000 psig regulated air to the system. Slowly open the needle valve (1) until a flow of 20 scc/min. above the leakage value determined in Step (3) above is indicated on flowmeter (3). Record the maximum negative pressure indicated by water column (2).

(5) Repeat Step 4 with a regulated air supply of 1000 and 570 psig.

4.1.2 Inhalation Flow at Intermediate and Maximum Specified Negative Pressure

(1) Install the FBS in the test setup shown in Figure 1, and apply a regulated pressure of 4000 psig to the cylinder valve.

(2) Open the cylinder valve and start up the FBS.

(3) Slowly open needle valve (1) until the pressure in the facepiece is -2.0 inches of water. Record the resulting flow on flowmeter (2).

(4) Repeat the above test for inlet pressures of 1000, 570 and 100 psig.

(5) Repeat Steps 3 and 4 above for a facemask pressure of -1.25 inches of water.

4.1.3 Exhalation Initiation & Static Flow

(1) Install the facemask and regulator in the test setup shown in Figure 2. Record test instrumentation description.

(2) Slowly increase the outlet pressure of regulator (1) until a flow is obtained on flowmeter (2).

(3) Record the pressure indicated by water column (3).

(4) Change the flowmeter to one of higher range and determine the resulting static flows for mask pressures of +2.0 and +4.0 inches of water.

4.1.4 Dynamic Flow Requirements

(1) Install the FBS with a fully-charged cylinder in the test setup shown in Figure 3. Record description of test instrumentation.

(2) Adjust the breathing machine (Scott P/N 22850) to obtain a peak flow of 257 lpm NTPD at approximately 34 cycles/minute.

(3) Open the cylinder valve and start the breathing machine. Continue to operate the breathing machine until the cylinder pressure drops to 100 psig. During this time, record the following:

(a) Continuously record inhalation and exhalation mask pressures.

(b) Continuously record mask flow rates.

(c) Each 5 minutes, monitor cylinder pressure and record.

(d) Total time from start of test until cylinder reaches 100 psig.

(4) Record the pressure at which the low pressure alarm actuates using the procedure of Para. 4.22.

(5) Recharge the cylinder to 4000 psig.

Increase the speed of the breathing machine to obtain a peak flow at 476 lpm NTPD. Repeat Step 3 above.

(6) Record the peak mask pressures obtained during the inhalation and exhalation portions of the breathing cycle.

4.2 Response Time

This characteristic is verified during the flow requirements test (Para. 4.1.4, Step 2) since the flow test was performed dynamically.

4.3 Purge Capability

4.3.1 Dynamic Purge Capability

(1) Install the FBS with a fully-charged cylinder in the test setup shown in Figure 3. Record description of test instrumentation.

(2) Adjust the breathing machine (Scott P/N 22850) to obtain a peak flow of 257 lpm NTPD at approximately 34 cycles/minute.

(3) Open the cylinder valve and fully open the purge valve, and start the breathing machine.

Continue to operate the breathing machine until the cylinder pressure drops to 100 psig. During this time, record the following:

(a) Continuously record inhalation and exhalation mask pressures.

(b) Continuously record mask flow rates.

(c) Each 5 minutes, monitor cylinder pressure and record.

(d) Total time from start of test until cylinder reaches 100 psig.

(4) Record the pressure at which the low pressure alarm actuates using the procedure of Para. 4.22.

(5) Increase the speed of the breathing machine to obtain a peak flow of 476 lpm NTPD. Repeat Step 3 above.

4.3.2 Static Purge Capability

(1) Install the FBS in the test setup shown in Fig. 5.

(2) Open the cylinder valve supplying 4000 psig to the system and fully open the purge valve.

(3) Draw flow through the flowmeter until the water column shows zero pressure.

(4) Record the resulting flow on the data sheet.

(5) Repeat the above test for inlet pressures of 3500, 3000, 2500, 2000, 1500, 1000 800, 500 and 100 psig.

4.4 Proof Pressure

(1) Pneumatically pressure test the following components to the pressures shown:

COMPONENT	PRESSURE (PSIG)
Cylinder Valve Assy.	6750
High-pressure hose	6750
Pressure reducer (high-pressure section)	6750
Pressure reducer (low pressure section)	187.5
Low-pressure hose	187.5
Breathing Regulator	187.5

(2) Following this exposure, assemble the components and subject to the test outlined in Para. 4.15.1.

4.5 Burst Pressure

(1) Hydrostatically pressure test the following components to the pressures shown:

COMPONENT	PRESSURE (PSIG)
Cylinder Valve Assy.	11,250
High-pressure hose	11,250
Pressure reducer (high-pressure side)	11,250
Pressure reducer* (low-pressure side)	312.5
Low-pressure hose	312.5
Breathing Regulator	312.5

(2) While pressurized, observe the components for signs of rupture or leakage. None is allowed.

*Relief valve to be blocked closed during this test.

4.6 System Weight

Weigh each component separately and also obtain a total FBS weight with and without cylinder.

4.7 Donning/Doffing - Demonstration Test

After a suitable training period, a subject wearing a turnout coat will be timed during the donning and doffing procedures to obtain the average for five (5) complete cycles. Donning time, which will include the facemask, will not exceed 15 seconds and doffing time will not exceed 3 seconds. Record results in test log.

4.8 Startup - Demonstration Test

Verify that a user wearing a turnout coat may perform the following steps in startup of the FBS and do so unassisted:

(1) Don the FBS being sure to check for proper mask fit.

(2) Open cylinder valve.

(3) Breathe unit to determine proper operation.

(4) Close cylinder valve and breathe unit down until low pressure alarm sounds.

(5) Again open cylinder valve. Unit is ready for operation.

Record results in test log.

4.9 Orientation - Demonstration Test

Verify that a user can obtain satisfactory flow for each of the six (6) different orientations shown in Figure 4. Record results in test log.

4.10 Controls - Demonstration Test

Verify that all controls are accessible to the wearer wearing a turnout coat and are arranged to minimize the possibility of inadvertent actuation. Record results in test log.

4.11 Pressure Vessel Replacement - Demonstration Test

Record the time of pressure vessel replacement for the following conditions:

(1) Remove large cylinder; replace with large cylinder.

(2) Remove large cylinder; replace with small cylinder;

(3) Remove small cylinder; replace with small cylinder;

(4) Remove small cylinder; replace with large cylinder.

The above will be performed by a subject previously trained to perform the task. Record results in the test log.

4.12 Overpressurization Protection

(1) Place the overpressurization protection device in a test adapter in preparation to pressurize.

(2) Immerse the device in a glycerine-water bath and raise the temperature of the bath to 220°F. Hold for a minimum of ten (10) minutes.

(3) Raise the pressure to the device to 3800 psig and hold for 30 seconds minimum.

(4) Thereafter increase the pressure at a rate less than 100 psig per minute until the frangible disc bursts. Record this pressure.

4.13 System Leakage

(1) With the cylinder of the FBS charged to 4000 psig, open the cylinder valve allowing the system to pressurize.

(2) Using Leak-Tek or an equivalent leakage indicator, check each component of the FBS for leakage. No leakage is allowed.

4.14 Pressure Gage Accuracy

(1) Install the pressure gage in a test block and connect to a test setup with a calibrated pressure gage and a regulated high-pressure air source.

(2) Slowly increase pressure in the test system stopping at each of the major divisions of the FBS gage and recording the corresponding pressure indicated on the calibrated gage.

(3) After reading all divisions in increasing order, slowly decrease the pressure and again record the corresponding pressures in decreasing order.

4.15 Operating Environments

All operating environments tested will be performed with the cylinder charged to 2000 and 800 psig.

4.15.1 Static Flow Test

This test will be performed as required before, during and/or after exposure to each of the operating environments:

(1) Install the FBS in the test setup shown in Figure 5, and adjust regulated air supply to 2000 psig.

(2) Open the cylinder valve and start up the FBS.

(3) Slowly open needle valve (1) until the flow from the facepiece is 5 LPM NTPD, shown on

flowmeter (2). Record the resulting mask pressure shown on the water column.

(4) Repeat Step 3 to obtain the pressures resulting from facepiece flows of 125 and 300 LPM, NTPD, and the flow for a facemask pressure of -2.0 inches of water.

(5) Vent the inlet pressure to 800 psig and repeat Steps 3 and 4 above.

4.15.2 Low Temperature Operation (Ref. MIL-STD-810B, Method 502, Procedure I)

(1) Subject the FBS to the static flow test of Para. 4.15.1.

(2) Place the FBS in an environmental temperature chamber and subject to the low temperature test as follows:

(a) Lower the chamber temperature to -60°F ± 5°F for a period of four (4) hours minimum.

(b) Visually inspect the unit while it is still at low temperature.

(c) Expose the FBS to an additional 8 hours minimum at $-60^{o}F \pm 5^{o}F$.

(d) Remove the FBS from the chamber and subject to the test of Para. 4.15.1 while still at low temperatures.

(e) After its return to ambient temperature, again visually inspect the FBS and subject to the test of Para. 4.15.1.

4.15.3 <u>High Temperature Operation</u> (Ref. MIL-STD-810B, Method 501, Procedure II)

(1) The data from the static flow test following low temperature operation will also be used as pre-high temperature operation baseline data.

(2) Place the FBS in an environmental chamber and subject to the high temperature test as follows:

(a) Raise the temperature of the chamber to $120^{o}F \pm 5^{o}F$ and hold for 6 hours minimum.

(b) Raise the temperature of the chamber to $154^{o}F \pm 5^{o}F$ within a time period of one (1) hour and then hold for an additional four (4) hours.

(c) Lower the internal chamber temperature to $120^{\circ}F \pm 5^{\circ}F$ within a time period of one (1) hour.

(d) Repeat Steps (a) through (c) two additional times making a total of three 12-hour cycles.

(e) Adjust the temperature of the chamber to $200^{\circ}F \pm 5^{\circ}F$ and hold for a period of 8 hours minimum.

(f) Remove the FBS from the chamber and subject to the static flow test of Para. 4.15.1.

(g) After its return to ambient temperature, again visually inspect the FBS and subject to the test of Para. 4.15.1.

4.15.4 Relative Humidity (Ref. MIL-STD-810B, Method 507, Procedure IV)

(1) Place the FBS in a temperature-humidity chamber.

(2) Dry the FBS at $110^{\circ}F \pm 5^{\circ}F$ for a period of 2 hours minimum.

(3) Condition the FBS at $77^{\circ}F \pm 5^{\circ}F$ and 50 percent relative humidity for 24 hours.

(4) Remove the FBS from the chamber and subject to the static flow test of Para. 4.15.1.

(5) Place the FBS back into the test chamber and subject it to five 24-hour cycles in accordance with Figure 12. A 24-hour cycle consists of 16 hours at $140^{O}F \pm 5^{O}F$ and approximately 8 hours at $86^{O}F \pm 5^{O}F$ including transition times. A relative humidity shall be maintained at 95 percent or greater at both temperatures. Each transition time shall be not greater than 1.5 hours. The relative humidity during each transition need not be controlled.

(6) After completion of the fifth cycle with the FBS in the chamber and the chamber at $86^{O}F \pm 5^{O}F$ and a relative humidity of 95 percent minimum, remove the FBS from the chamber and subject to the static flow test of Para. 4.15.1.

(7) Condition the FBS at $77^{O}F \pm 5^{O}F$ and 50 ± 5 percent relative humidity for not less than 12 hours nor more than 24 hours.

(8) While at $77^{O}F \pm 5^{O}F$ and 50 percent relative humidity, remove the FBS from the chamber and subject to the static flow test of Para. 4.15.1.

(9) Visually inspect the FBS.

4.16 Non-Operating Environments

4.16.1 Salt Fog

(1) Charge the cylinder to 4000 psig and subject the FBS to the static flow test of Para. 4.15.1.

(2) Expose the FBS to a salt fog environment according to MIL-STD-810B, Method 509, Procedure I.

(3) After the 48 hour drying period, again subject the FBS to the static flow test of Para. 4.15.1. Also note any visual defects such as corrosion resulting from the exposure to salt fog.

4.16.2 Dust

(1) Charge the cylinder to 4000 psig and subject the FBS to the static flow test of Para. 4.15.1.

(2) Expose the FBS to a dust environment according to MIL-STD-810B, Method 510, Procedure I.

(3) Return the FBS to Scott from the vendor facility at which dust exposure was performed and subject to the static flow test of Para. 4.15.1.

4.16.3 Impact Shock

CAUTION: This is a hazardous test and should be performed in an area properly equipped for high pressure and explosive test articles by properly trained personnel.

(1) Charge the FBS to 4000 psig and subject to the static flow test of Para. 4.15.1.

(2) Recharge the cylinder to 4000 psig and drop the FBS from a height of six (6) feet onto a flat rigid surface once on each of six (6) different points (Figure 11) for a total of six (6) drops. Visually inspect the unit after each drop.

(3) Following drop testing, inspect the unit and note any damage.

4.17 System Envelope - Demonstration Test

Don the FBS while wearing a turnout coat to verify the following:

(1) The unit is as closely conformal to the wearer as possible.

(2) Corners and edges are rounded.

(3) Protrusions are minimized.

These characteristics are necessary to reduce the possibility of snagging. Record results in test log.

4.18 Comfort - Demonstration Test

Don the FBS while wearing a turnout coat and wear for a period spent performing light work or resting. During and at the end of the period, record reactions, such as possible skin irritation, soreness or bruises, resulting from pressure points or abrasion. Repeat with two additional subjects (total of 3). Record results in test log.

4.19 Useful Life

4.19.1 High-Pressure Hose to Cylinder Valve Connector

Place a cylinder and connector in a cycling machine and connect and disconnect a total of 5,000 cycles. Stop each 500 cycles to pressurize internally to 4000 psig and check for external leakage.

4.19.2 Low-Pressure Hose to Pressure Reducer Disconnect

Connect and disconnect manually the low-pressure hose to pressure reducer disconnect a total of 1,000 times. At the 500 and 1,000 cycle points, pressurize internally to 125 psig and check the disconnect for external leakage.

4.19.3 Breathing Regulator to Facemask Connection

Mount the facemask to a dummy head, leak check in the manner later described, and remove and replace the breathing regulator from it a total of 5,000 times. Each 500 cycles leak check as follows:

Outward Leakage:

(1) Mount the mask/regulator assembly to a dummy head and apply tape to the face

seal assuring that any leakage will result from the mask/regulator seal. Also tape close the exhalation valve.

(2) Install this in the setup shown in Figure 2 and then pressurize the mask internally to three (3) inches of water. Record the flow shown on the flowmeter.

Inward Leakage:

(1) With the mask/regulator assembly still mounted to the dummy head, install in the test setup shown in Figure 1.

(2) Draw a negative pressure of -3.0 inches of water and record the leakage flow.

4.19.4 Cylinder Mounting in Backpack

Mount the backpack vertically and remove and replace the cylinder a total of 5,000 times. Following completion, inspect for evidence of damage.

4.19.5 <u>Operational Cycling</u>

(1) Install the gas controls of the FBS in the test setup shown in Figure 6.

(2) Open solenoid (1) applying 4,000 psig upstream of the cylinder valve.

(3) Close solenoid (1) and mechanically open the cylinder valve allowing the system to be pressurized.

(4) Open solenoid (2) and set needle valve (1) to allow a flow of 150 lpm NTPD. Close solenoid (2). This section simulates inhalation.

(5) Open solenoid (3) and set needle valve (2) to allow a flow of 150 lpm NTPD to exercise the exhalation valve of the breathing regulator. Close solenoid (3). This section simulates exhalation.

(6) Set timer to alternately open and close solenoids (2) and (3) at a rate of 20 cycles per minute.

(7) Allow solenoids (2) and (3) to cycle open and closed until pressure in the supply volume reaches approximately 500 psig. This should happen after approximately 12 solenoid (2) and (3) cycles and causes the low pressure warning to function.

(8) Mechanically close the cylinder valve.

(9) Repeat the above test a total of 5,000 times, stopping each 500 cycles to check for:

(a) Static flow characteristics per Para. 4.14.1;

(b) Exhalation valve flow characteristics;

(c) External leakage all fittings and connections;

(d) Low pressure alarm function.

(10) Any maintenance required during this series should be recorded.

4.19.6 Purge Valve

Apply 125 psig to the inlet of the breathing regulator and manually open and close the purge valve a total of 5,000 times, stopping each 500 cycles to check for:

(a) Leakage around the external portions of the purge valve;

(b) Leakage around the seat of the purge valve when it is in the closed position.

4.20 Pressure Vessel Mounting - Demonstration Test

This requirement shall be considered satisfied by the successful completion of Para. 4.12, Pressure Vessel Replacement.

4.21 Leakage (Cylinder Valve/Cylinder Assembly)

(1) Charge a cylinder and valve assembly to 4000 psig and immerse in a water bath (Figure 7).

(2) Collect the gas emitted from the assembly over a 24-hour period. This amount cannot exceed a rate of 0.5 scc/hour.

4.22 Actuation (Depletion Warning Device)

(1) Charge the cylinder of the FBS to 950 psig.

(2) With an accurate pressure gage installed between the cylinder valve and the high pressure hand disconnect, slowly breath the unit down to the point at which the depletion warning device actuates.

(3) Record this pressure.

4.23 Signal Frequency and Intensity

With the cylinder pressure of the FBS below the actuation pressure for the depletion warning device, perform the following test. Install the FBS in the test series, measure the level of the background noise.

Adjust the purge valve to obtain a peak reading on the sound intensity meter and record this intensity and the signal frequency shown on the oscilloscope.

4.24 Inward Leakage (Facemask)

NOTE: Appearing in Appendix B of this procedure is a report titled "Analysis of Utilization of Helium Leak Detector to Measure Face Mask Leakage". This report gives detailed information as to derivation of methods and techniques used to determine inward leakage.

(1) Calibrate the helium leak detector using a 16 PPM concentration of helium in air.

(2) Place the facemask/breathing regulator assembly on a user and complete the setup shown in Figure 9.

(3) Evacuate the plastic bag by squeezing or by vacuum and then flood with a gas mixture of 9 parts air and 1 part helium by volume.

(4) After a short period to allow the system to reach equilibrium, measure the inward leakage shown on the leak detector which is sampling the subject's exhaled gases and convert to a rate in scc/min. This rate cannot exceed 1.5 scc/min.

(5) The above test should be repeated once each on a panel of sixteen (16) subjects selected by the facial characteristics of face length and width according to methods derived from:

(a) "LASL Respirator Test Panel Representative of U. S. Male Facial Sizes" dated 1972, conducted by Los Alamos Scientific Laboratory, Hyatt, Hack, Moore & Richards.

(b) "Anthropometry for Respirator Sizing" Final Report April 30, 1972, Webb Associates, Yellow Springs, Ohio.
McConville, Churchill & Laubach

(c) A 1967 USAF Facial Dimensions Study

4.25 Outward Leakage (Facemask)

(1) Place a facemask, which has been modified to provide a tube for the subject to inhale and exhale through, along with a pair of nose pinchers, on a subject (Figure 10).

(2) Slowly increase the internal mask pressure to 3.0 inches of water.

(3) Note and record the amount of gas flowing into the mask shown on the flowmeter. This amount should not exceed 200 scc/min.

(4) Repeat the above test for each of the sixteen (16) subjects used to determine inward mask leakage in Para. 4.22.

4.26 Visor Fogging - Demonstration Test

Place the FBS on a subject and start up in the normal manner. Have the subject enter a chamber which is at -20 $\pm$ 5°F and remain inside until the cylinder is depleted. During the test period, alternate 1-minute periods of exercise and rest are required with the exercise period consisting of stepping onto and off a box 8.5 inches high at a rate of 30 cycles per minute. Note any mask fogging that takes place. Record results in test log.

4.27 Mask Weight

Weigh the facemask and breathing regulator assembly (without low-pressure hose). This weight must not exceed 1.25 pounds.

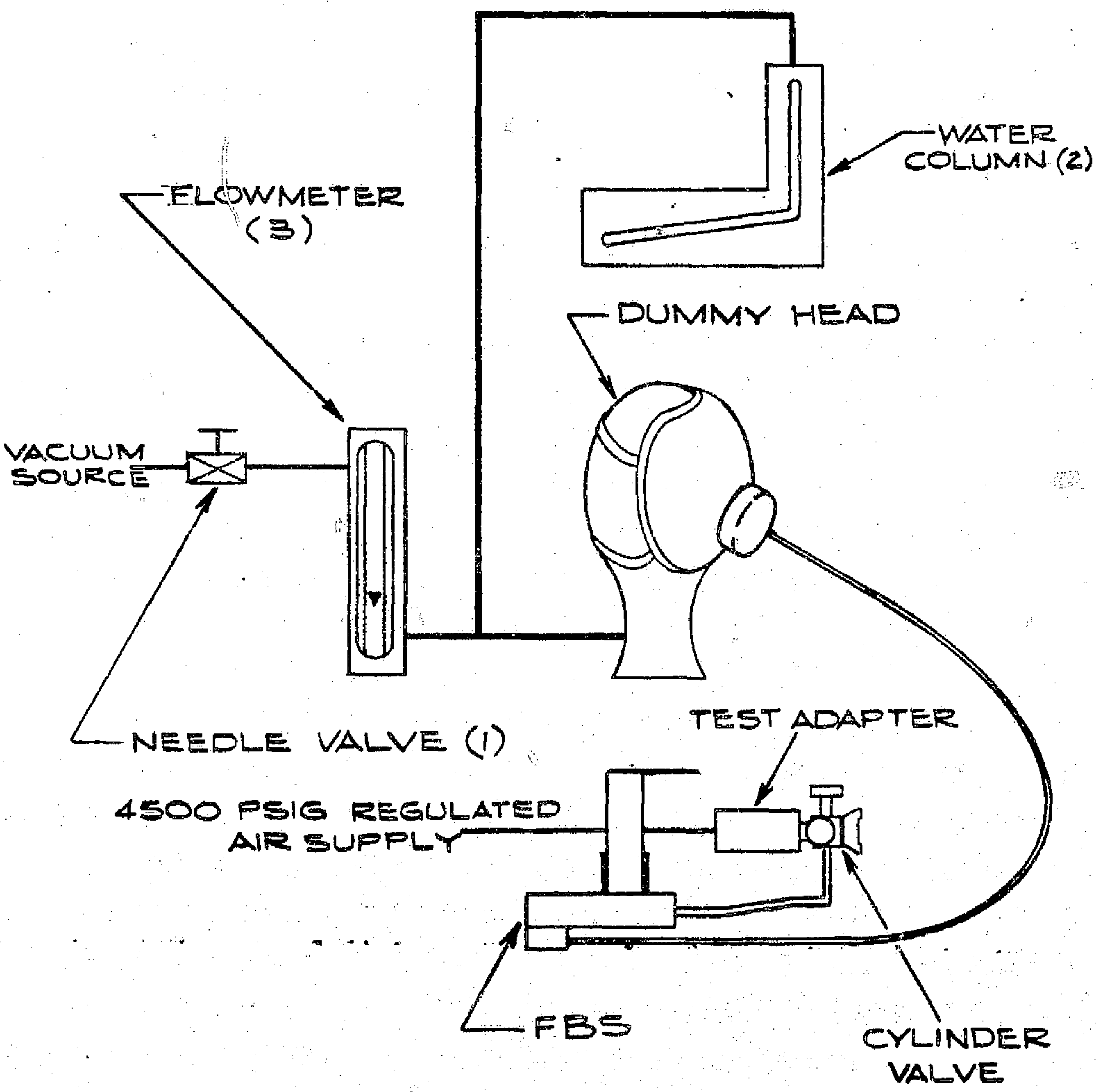


FIGURE 1.

Para. 4.1.1 Inhalation Initiation
Para. 4.12 Inhalation Flow

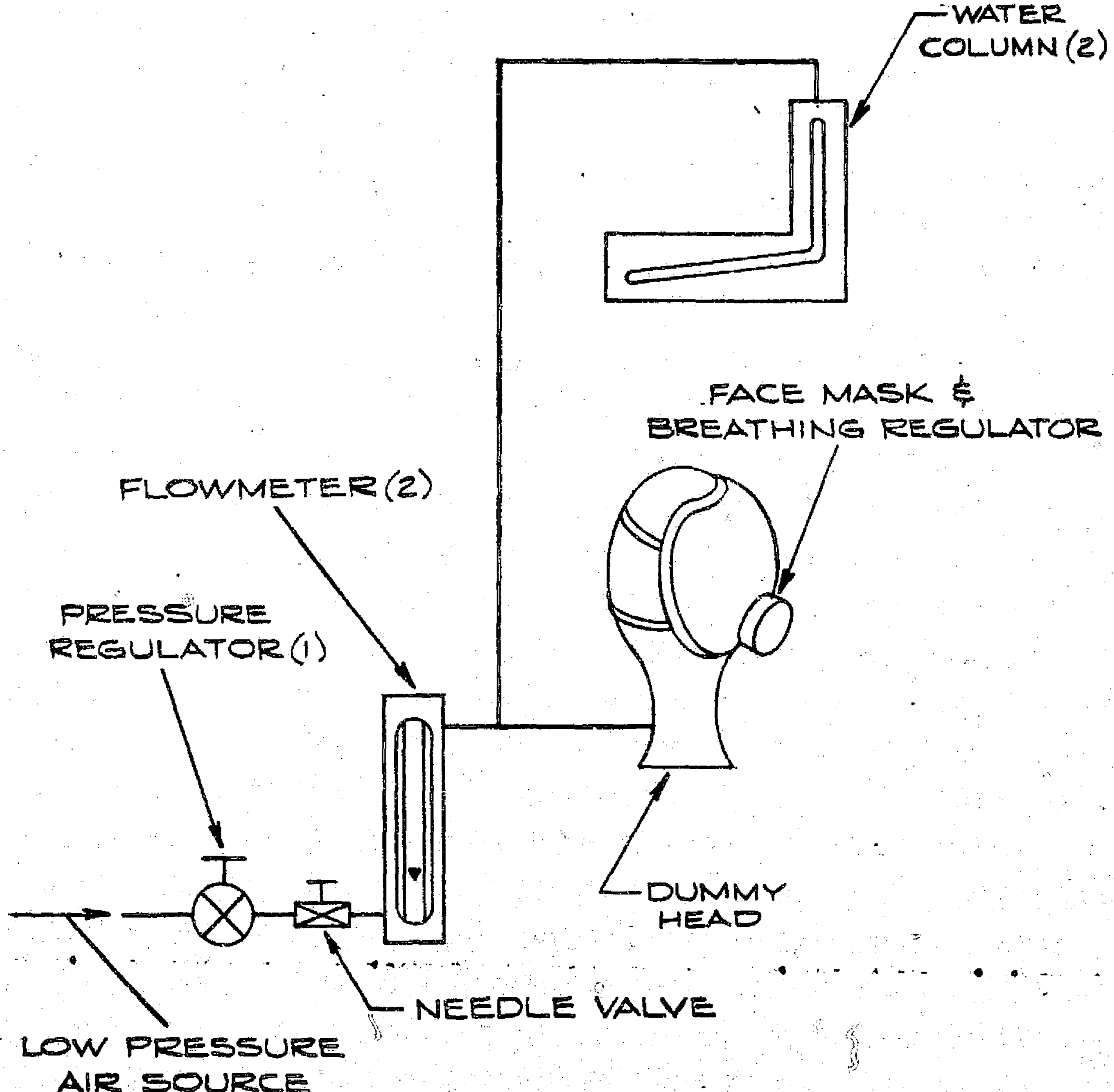


FIGURE 2.

Para. 4.13 Exhalation Initiation

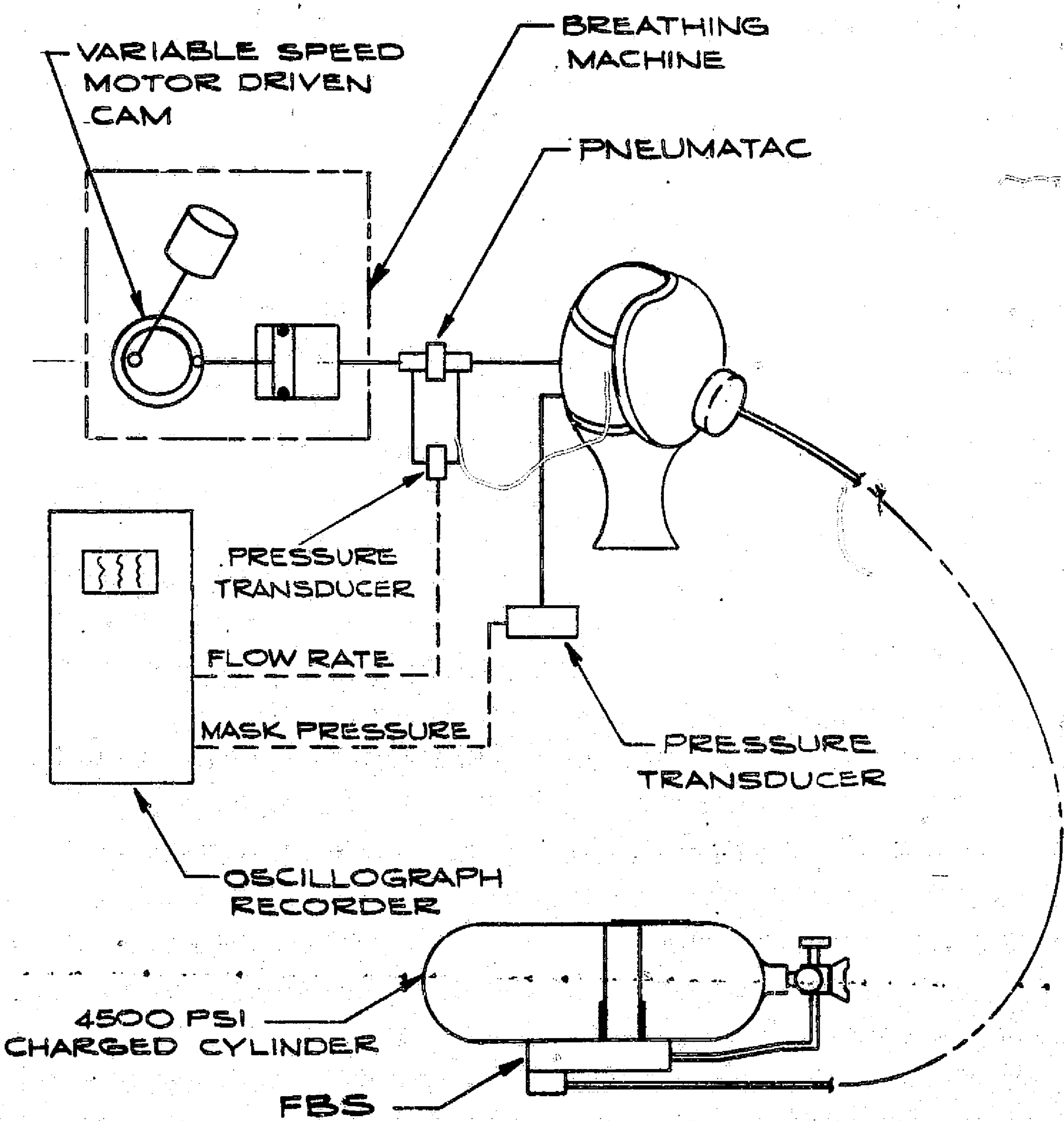


FIGURE 3.

Para. 4.1.4 Dynamic Flow Requirements
Para. 4.3 Purge Capability

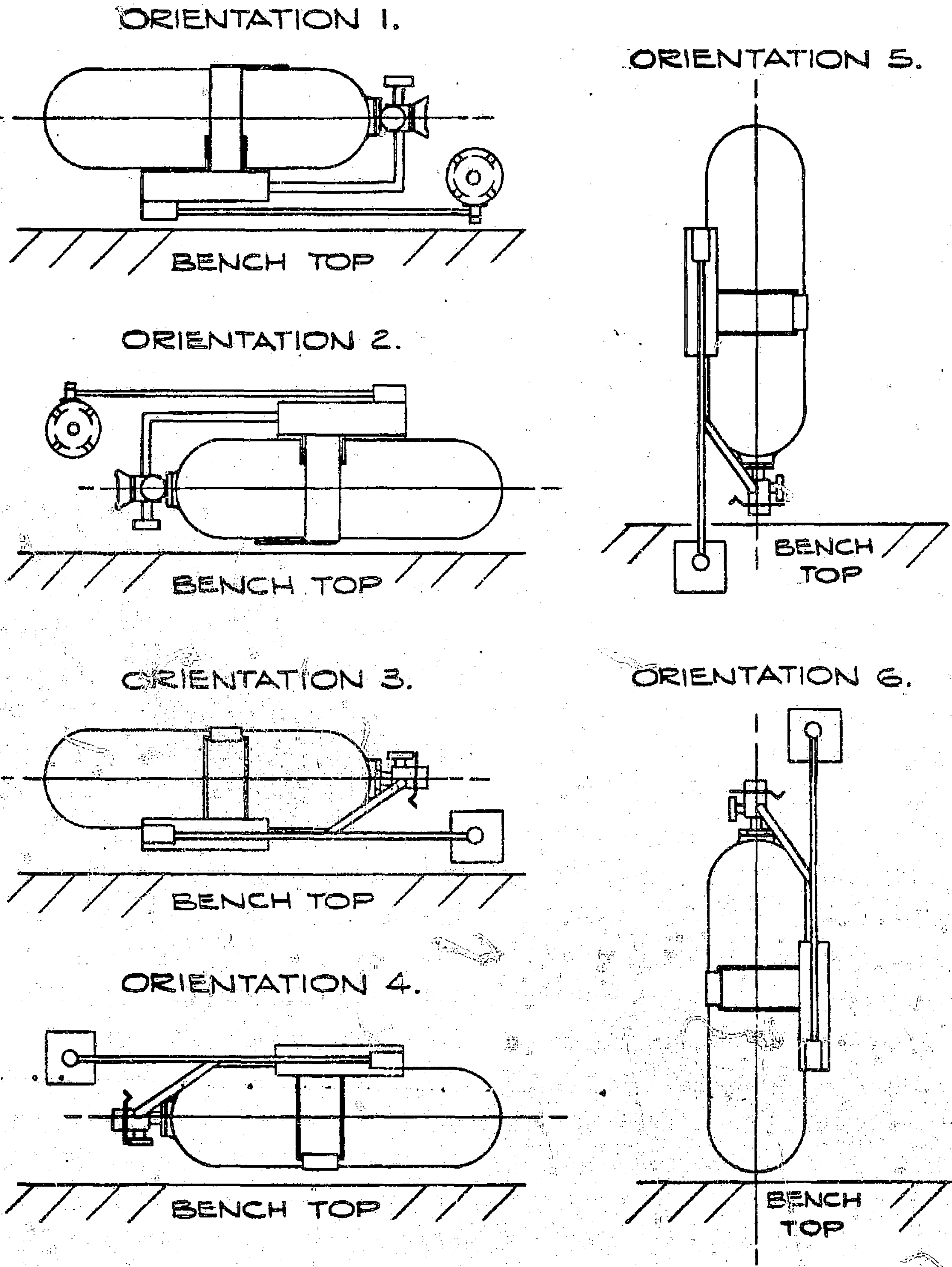


FIGURE 4.

Para. 4.9 Orientation

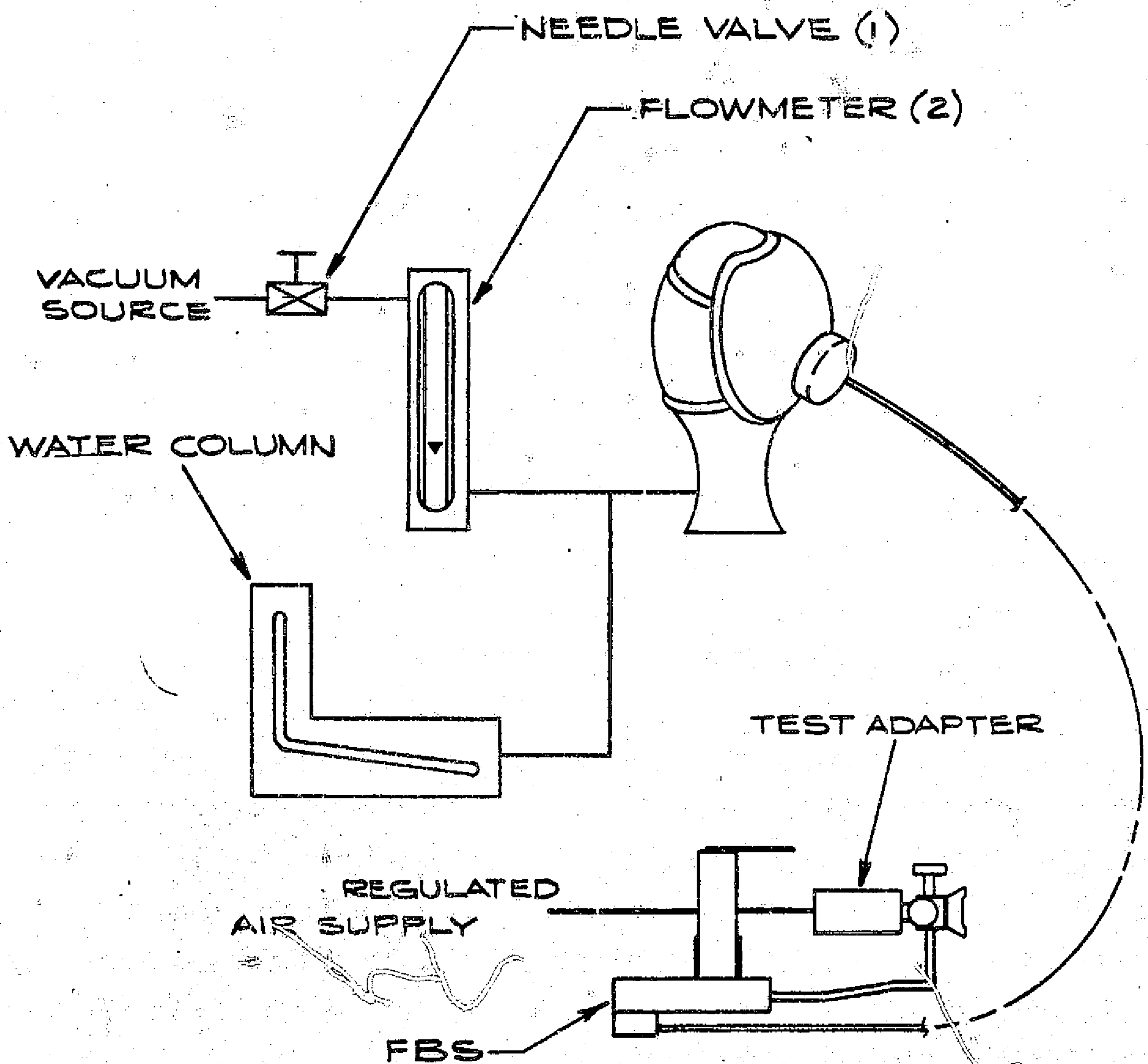
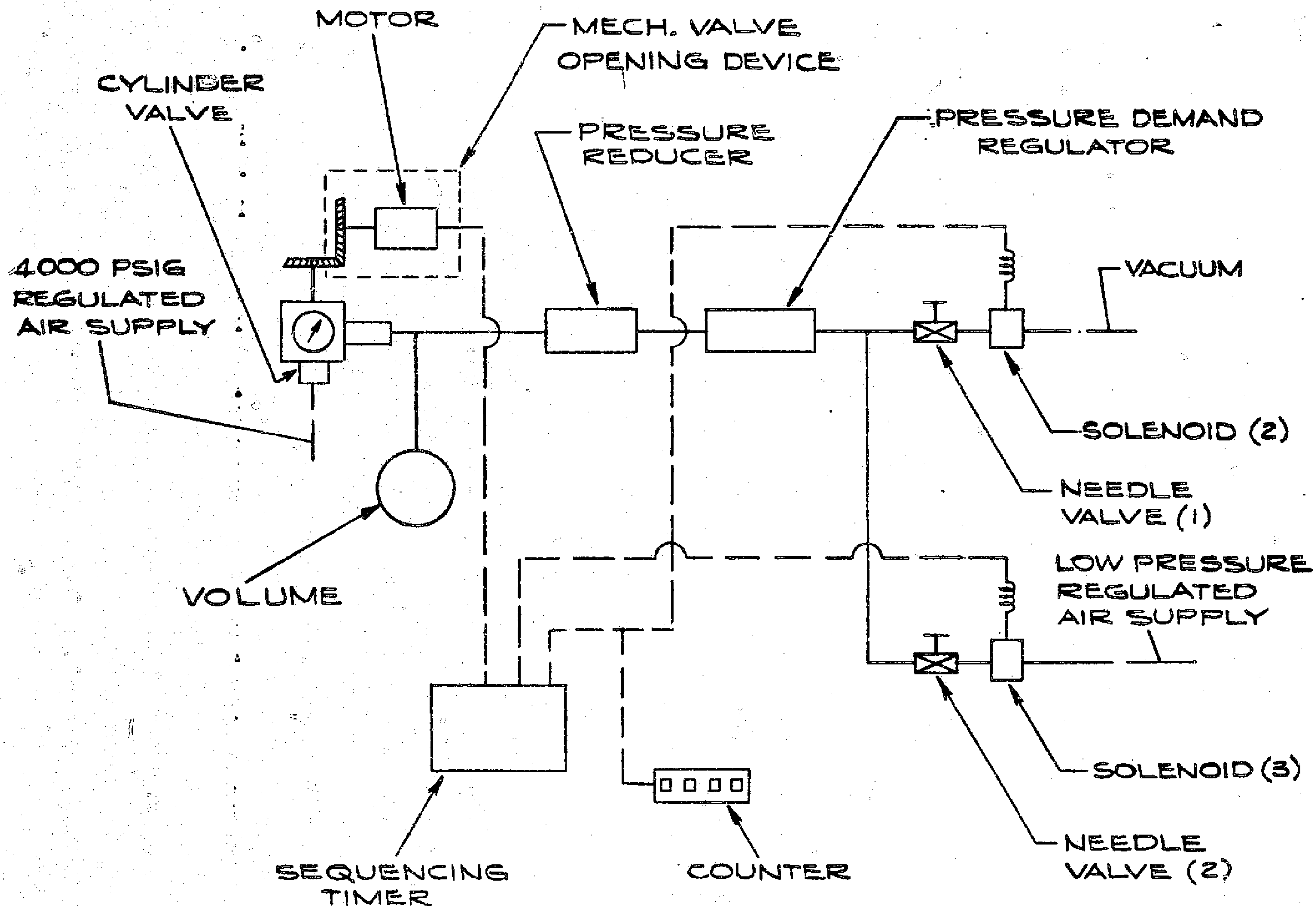


FIGURE 5.

Para. 4.15.1 Static Flow Test



Para. 4.19.5 Operational Cycling

FIGURE 6.

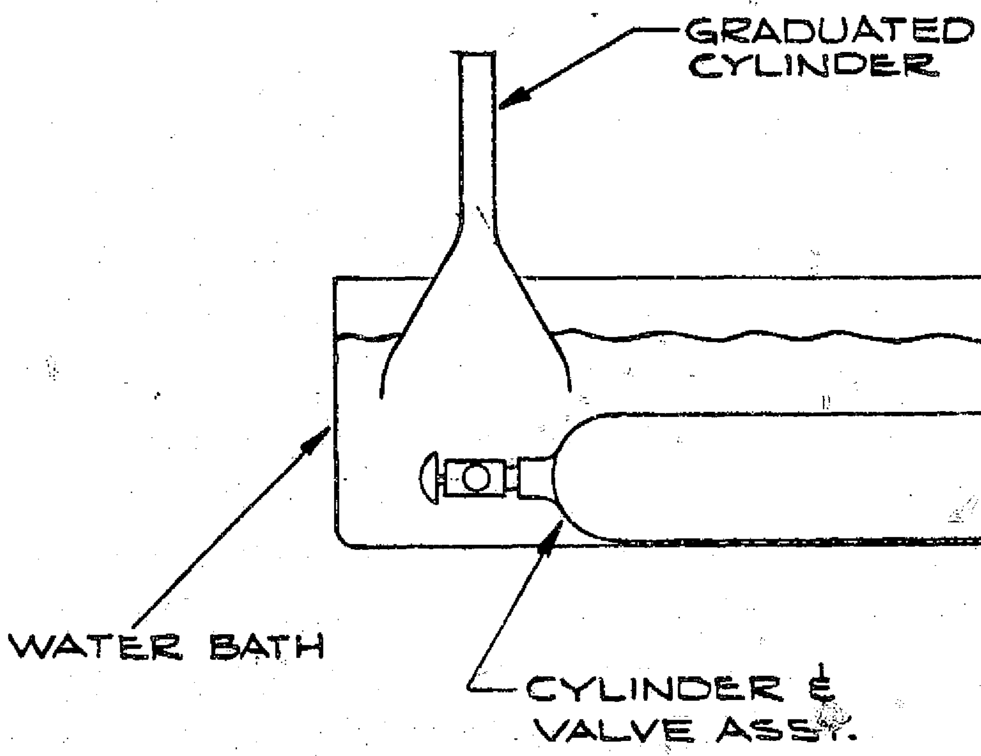


FIGURE 7.

Para. 4.21 Leakage

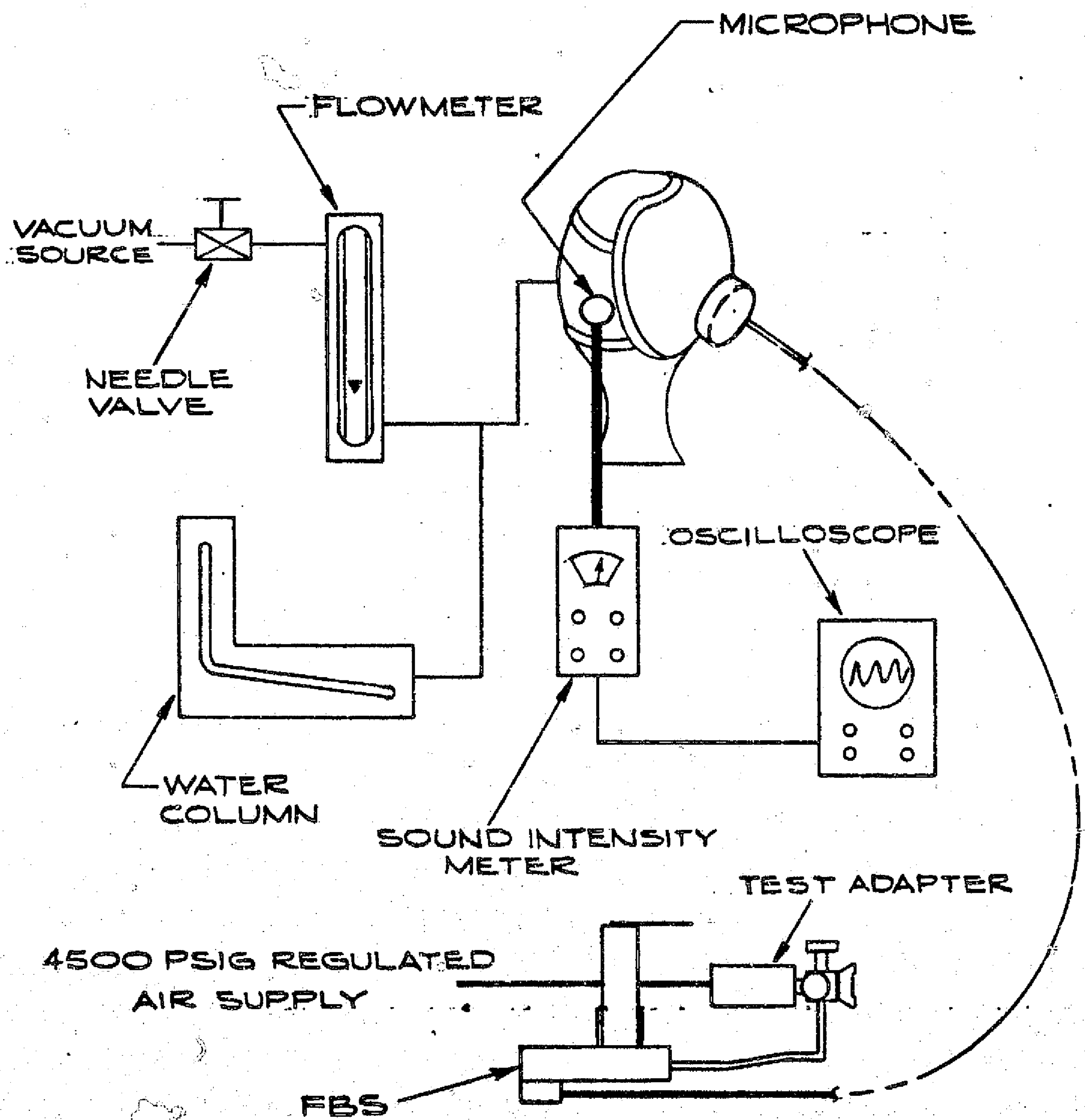


FIGURE 8.

Para. 4.23 Signal Frequency and Intensity

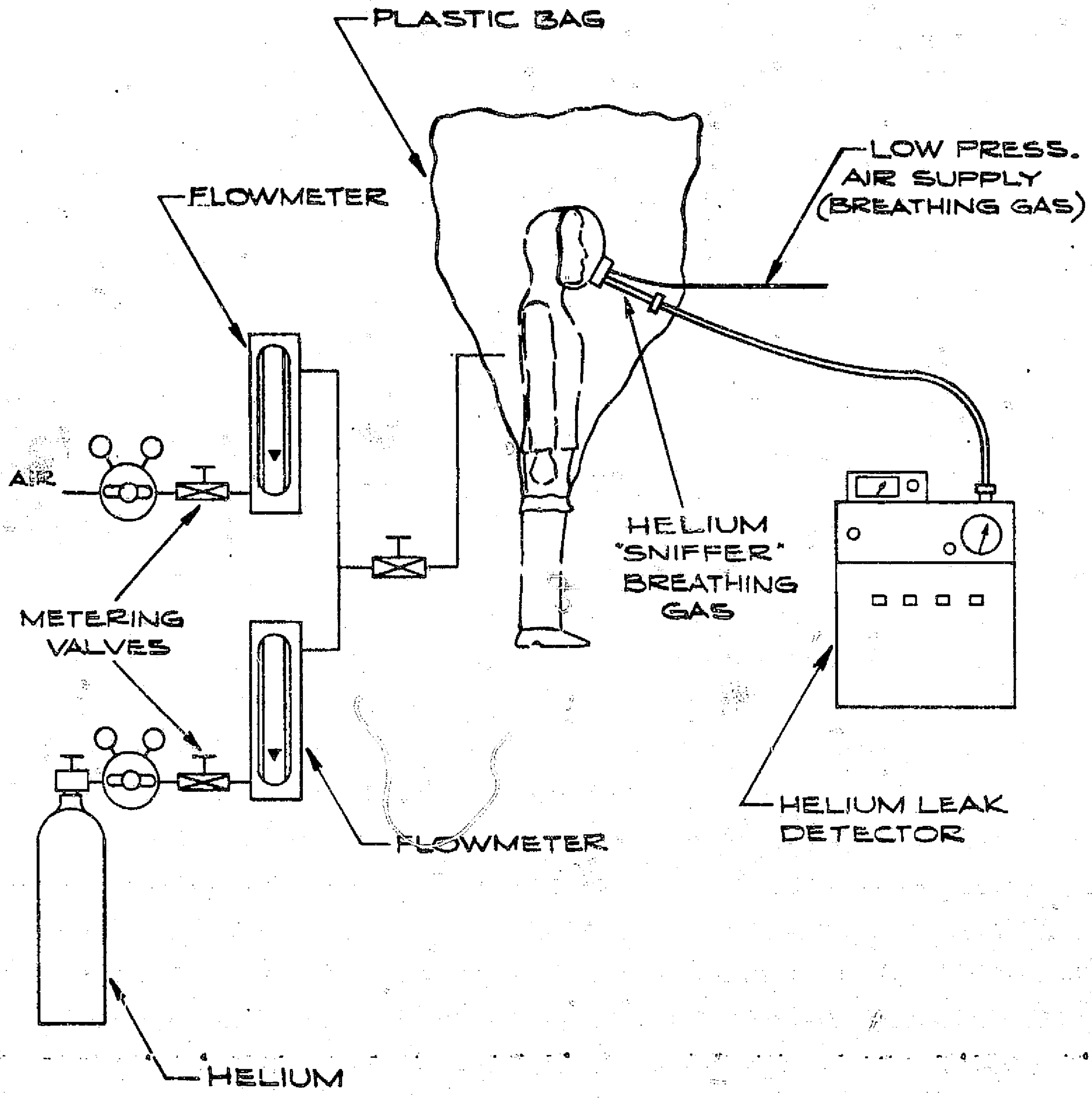


FIGURE 9.

Para. 4.24 Inward Leakage

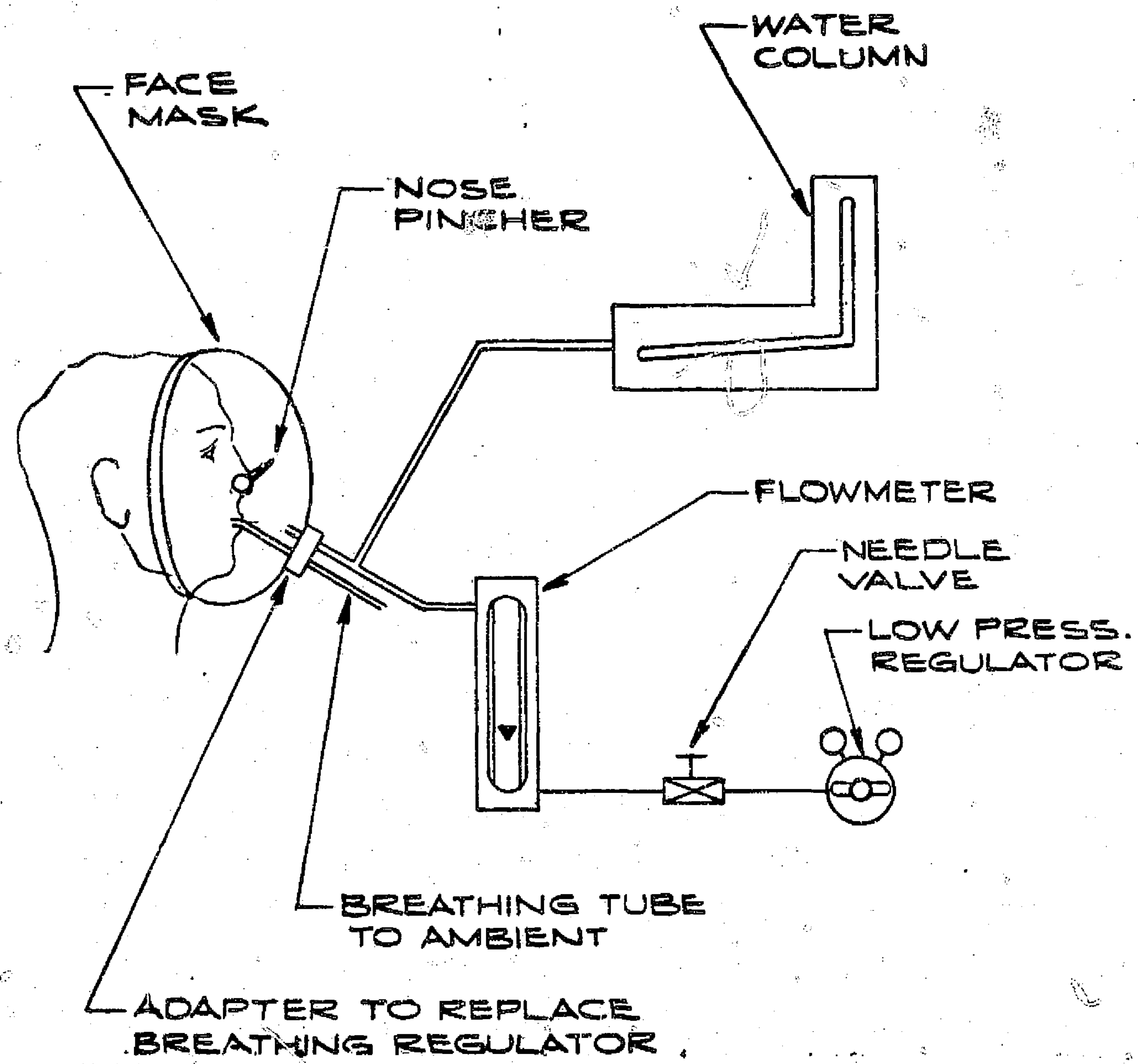


FIGURE 10.

Para. 4.25 Outward Leakage

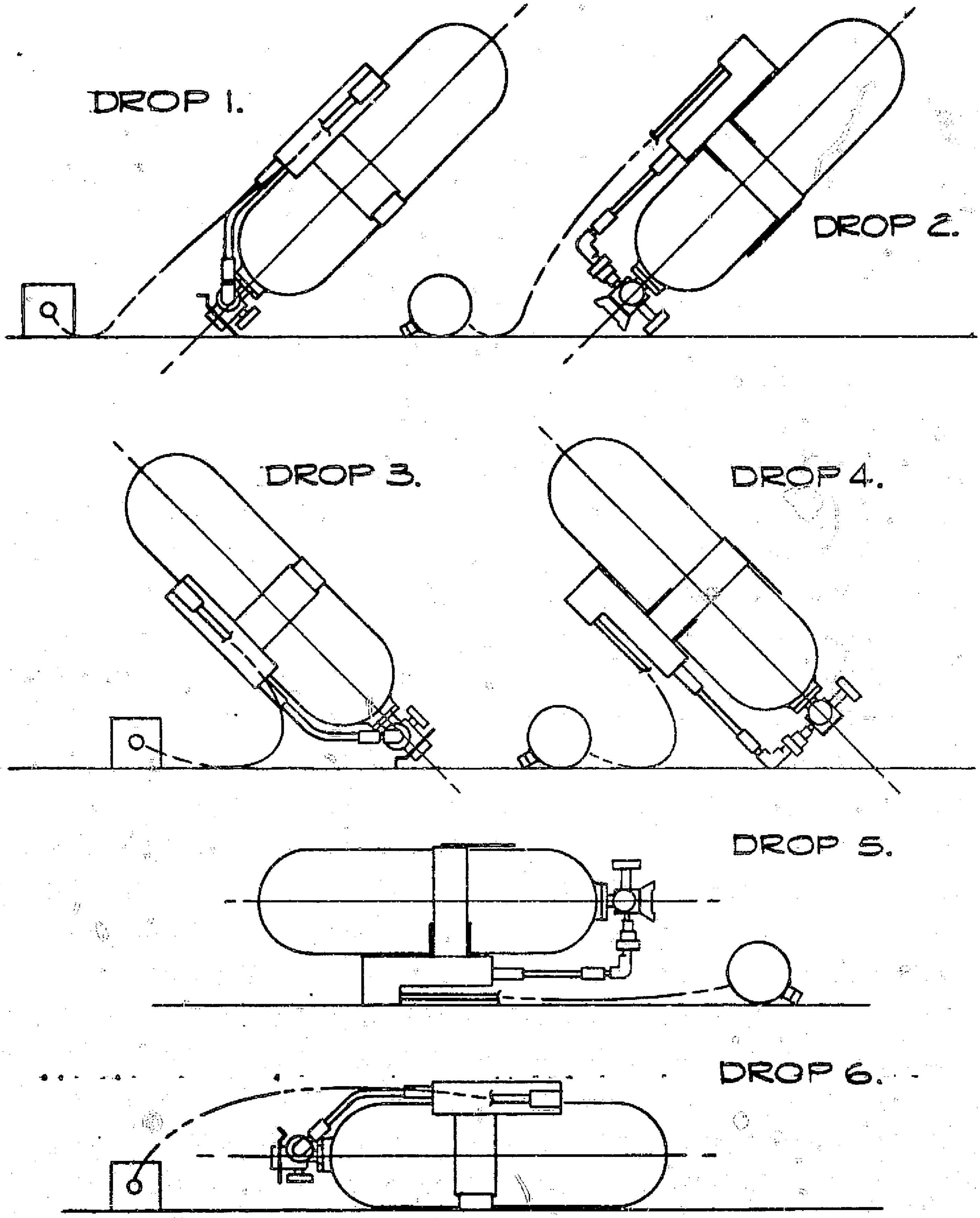


FIGURE 11.

Para. 4.16.3 Impact Shock

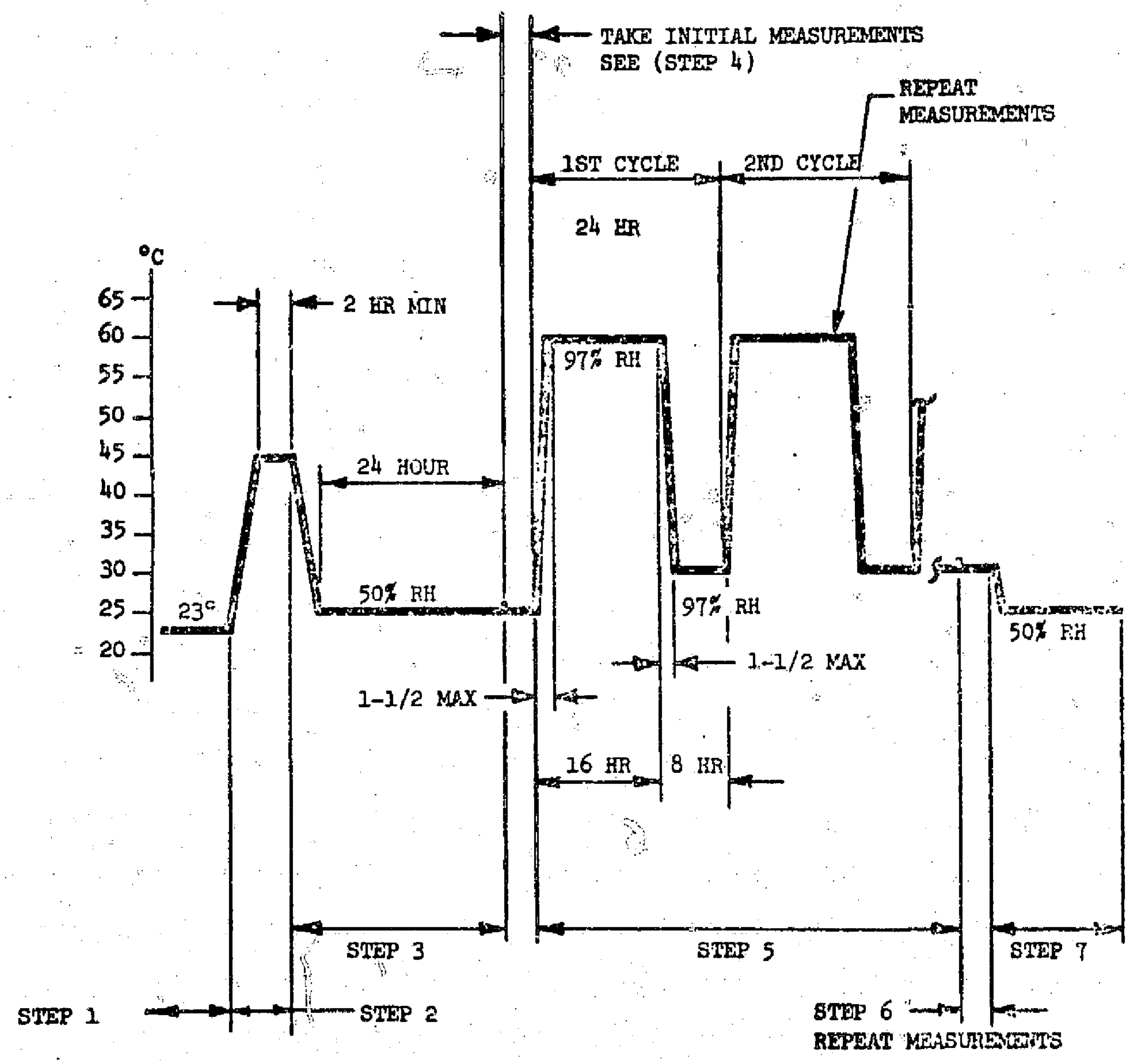


FIGURE 507-3. *Humidity cycle — Procedure IV.*

Figure 12

APPENDIX A

DATA SHEETS

DATA SHEET # 1

P/N ____________________
S/N ____________________
Date ____________________
Temperature ____________ Barometric Pressure ____________

TEST: FLOW REQUIREMENTS

Paragraph: 4.1

4.1.1 INHALATION INITIATION

Parameter	Required	Actual
Step (3) Leakage	10 scc/min. max.	
Step (4) Flow Initiation @ 4000 psig inlet	-0.1 to -0.5 inches water	
Step (5) Flow Initiation @ 1000 psig inlet	-0.1 to -0.5 inches water	
Step (5) Flow Initiation @ 570 psig inlet	-0.1 to -0.5 inches water	

Test Equipment:

4.1.2 INHALATION FLOW AT INTERMEDIATE AND MAXIMUM SPECIFIED NEGATIVE PRESSURE

Parameter	Resulting Flow LPM,NTPD
Step (3) Flow @ -2.0 inches water 4000 psig inlet	
Step (4) Flow @ -2.0 inches water 1000 psig inlet	
Step (4) Flow @ -2.0 inches water 570 psig inlet	
Step (4) Flow @ -2.0 inches water 100 psig inlet	
Step (5) Flow @ -1.25 inches water 4500 psig inlet	
Step (5) Flow @ -1.25 inches water 1000 psig inlet	
Step (5) Flow @ -1.25 inches water 570 psig inlet	
Step (5) Flow @ -1.25 inches water 100 psig inlet	

Test Equipment:

4.1.3 EXHALATION INITIATION & STATIC FLOW

Parameter	Required	Actual
Step (3) Exhalation Initiation	0.1 to 0.5 inches water	
Step (4) Exhalation Flow @ +2.0 inches water mask pressure	257 LPM NTPD minimum	
Step (4) Exhalation Flow @ +4.0 inches water mask pressure	476 LPM NTPD minimum	

Test Equipment:

4.1.4 DYNAMIC FLOW REQUIREMENTS

Parameter	Required	Actual
Step (3) Peak Inhalation Pressure	-1.25 inches Water Max.	
Step (3) Peak Exhalation Pressure	+2.0 Inches Water Max.	
Step (3) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	
Step (3) Total Time from High to Low Cylinder Pressure	N/A	
Step (4) Peak Inhalation Pressure	-2.0 inches Water Max.	
Step (4) Peak Exhalation Pressure	+4.0 inches Water Max.	
Step (4) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	
Step (4) Total Time from High to Low Cylinder Pressure	N/A	

Test Equipment:

Tested by: ______________________

Verified by: ______________________

DATA SHEET # 2

P/N ____________________
S/N ____________________
Date ____________________
Temperature ______________ Barometric Pressure ______________

TEST: DYNAMIC PURGE CAPABILITY

Paragraph: 4.3.1

Parameter	Required	Actual
Step (3) Peak Inhalation Pressure	-1.25 inches Water Max.	
Step (3) Peak Exhalation Pressure	+2.0 Inches Water Max.	
Step (3) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	
Step (3) Total Time from High to Low Cylinder Pressure	N/A	
Step (4) Peak Inhalation Pressure	-2.0 inches Water Max.	
Step (4) Peak Exhalation Pressure	+4.0 inches Water Max.	
Step (4) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	
Step (4) Total Time from High to Low Cylinder Pressure	N/A	

Test Equipment:

DATA SHEET # 2 (continued)

P/N ____________________
S/N ____________________
Date ____________________
Temperature ______________ Barometric Pressure ____________

TEST: STATIC PURGE CAPABILITY

Paragraph: 4.3.2

PARAMETER	REQUIRED	ACTUAL
Step (3) Flow at 4000 psig cylinder pressure	111.2 LPM NTPD	
3500		
3000		
2500		
2000		
1500		
1000		
800		
500		
100		

Tested by: ____________________

Verified by:

DATA SHEET # 3

P/N ____________________
S/N ____________________
Date ____________________
Temperature ______________ Barometric Pressure ______________

TEST: PROOF PRESSURE

Paragraph: 4.4

COMPONENT	PRESSURE (PSIG)	POST TEST INSPECTION
Cylinder & Valve Assy.	6750	
High-pressure Hose	6750	
Pressure Reducer (high-pressure section)	6750	
Pressure Reducer (low-pressure section	187.5	
Low-pressure Hose	187.5	
Breathing Regulator	187.5	

STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

Test Equipment:

Tested by: ____________________

Verified by: ____________________

DATA SHEET # 4

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ______________

TEST: BURST PRESSURE

Paragraph: 4.5

COMPONENT	PRESSURE (PSIG)	POST TEST INSPECTION
Cylinder & Valve Assy.	11,250	
High-Pressure Hose	11,250	
Pressure Reducer (high-pressure section)	11,250	
Pressure Reducer (low-pressure section)	312.5	
Low-Pressure Hose	312.5	
Breathing Regulator	312.5	

Test Equipment:

Tested by: ______________________

Verified by:

DATA SHEET # 5

P/N ____________________
S/N ____________________
Date ____________________
Temperature ____________ Barometric Pressure ____________

TEST: SYSTEM WEIGHT

Paragraph: 4.6

COMPONENT	WEIGHT (pounds)
Valve Assy. including Lock Ring and Seal	
High-Pressure Hose	
Pressure Reducer	
Low-Pressure Hose	
Breathing Regulator	
Face Mask	
Back Pack & Frame	

TOTAL FBS WEIGHT: ____________ lbs.
(10 lb. maximum)
(not including cylinders)

Test Equipment:

Tested by: ____________________

Verified by:

DATA SHEET # 6

P/N ____________________
S/N ____________________
Date ____________________
Temperature ____________ Barometric Pressure ____________

TEST: OVERPRESSURIZATION PROTECTION

Paragraph: 4.12

PARAMETER	REQUIRED	ACTUAL
Step (4) Burst Pressure Frangible Disc	4500-5000 PSIG	

Test Equipment:

Tested by: ____________________

Verified by:

DATA SHEET # 7

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________

Barometric Pressure ______________

TEST: SYSTEM LEAKAGE

Paragraph: 4.13

Parameter	Required	Actual
Step (2) System Leakage	No leakage	

Tested by: ______________________

Verified by: ______________________

DATA SHEET # 8

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ____________

TEST: PRESSURE GAGE ACCURACY

Paragraph: 4.14

Increasing Pressure:

Gage Reading	Required	Actual
10 x 100 psig	1000 ± 225 psig	
20 x 100 psig	2000 ± 225 psig	
30 x 100 psig	3000 ± 225 psig	
full	4000 ± 225 psig	
45 x 100 psig	4500 ± 225 psig	

Decreasing Pressure:

Gage Reading	Required	Actual
10 x 100 psig	1000 ± 225 psig	
20 x 100 psig	2000 ± 225 psig	
30 x 100 psig	3000 ± 225 psig	
full	4000 ± 225 psig	
45 x 100 psig	4500 ± 225 psig	

Test Equipment:

Tested by: ______________________

Verified by:

DATA SHEET # 9

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ____________

TEST: LOW TEMPERATURE OPERATION

Paragraph: 4.15.2

Chamber Data:

Step 2a -60 $\pm$ 5°F 4 hours minimum

Date __________ Time in __________ Temp. __________
Date __________ Time out __________ Temp. __________

Step 2b Visual Inspection

Remarks:

Step 2c -60 $\pm$ 5°F 8 hours minimum

Date __________ Time in __________ Temp. __________
Date __________ Time out __________ Temp. __________

Step 2d See data, Page 2.

Step 2e See data, Page 2.

Data Sheet #9 (continued)

PRE-TEST STATIC FLOW CHECK; Date ______________

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

LOW TEMPERATURE STATIC FLOW CHECK; Date ______________

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

POST LOW TEMPERATURE STATIC FLOW CHECK; Date ______________

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

Test Equipment:

Visual Inspection:

Tested by: ______________________

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DATA SHEET # 10

P/N ______________________
S/N ______________________
Date ______________________
Temperature ____________ Barometric Pressure ____________

TEST: HIGH TEMPERATURE OPERATION

Paragraph: 4.15.3

Chamber Data:

Step 2a 120 ± 5°F 6 hours minimum

Date __________ Time in __________ Temp. __________
Date __________ Time out __________ Temp. __________

Step 2b 154 ± 5°F 4 hours minimum

Date __________ Time in __________ Temp. __________
Date __________ Time out __________ Temp. __________

Step 2d 120 ± 5°F 6 hours minimum

Date __________ Time in __________ Temp. __________
Date __________ Time out __________ Temp. __________

154 ± 5°F 4 hours minimum

Date __________ Time in __________ Temp. __________
Date __________ Time out __________ Temp. __________

120 ± 5°F 6 hours minimum

Date __________ Time in __________ Temp. __________
Date __________ Time out __________ Temp. __________

154 ± 5°F 6 hours minimum

Date __________ Time in __________ Temp. __________
Date __________ Time out __________ Temp. __________

Step 2e 200 ± 5°F 8 hours minimum

Date ____________ Time in ____________ Temp. ____________
Date ____________ Time out ____________ Temp. ____________

Test Equipment:

PRE TEST STATIC FLOW CHECK; Date

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

HIGH TEMPERATURE STATIC FLOW CHECK; Date ____________

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

POST HIGH TEMPERATURE STATIC FLOW CHECK; Date ____________

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

POST TEST INSPECTION:

Tested by: ______________________

Verified by: ______________________

DATA SHEET # 11

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ______________

TEST: RELATIVE HUMIDITY

Paragraph: 4.15.4

Chamber Data:

Step 2 110 ± 5°F 2 hours minimum

Date __________ Time in __________ Temp. __________
Date __________ Time out __________ Temp. __________

Step 3 77 ± 5°F 50% R. H. 24 hours

Date __________ Time in __________ Temp. __________
Date __________ Time out __________ Temp. __________

Step 3 Cycle

Date __________ Time in __________
Date __________ Time out __________

Step 7 77 ± 5°F 50% R. H. 12 hours

Date __________ Time in __________
Date __________ Time out __________

PRE-TEST STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

RELATIVE HUMIDITY STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

POST RELATIVE HUMIDITY STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

Test Equipment:

Visual Inspection:

Tested by: ____________________

Verified by: ____________________

DATA SHEET # 12

P/N ____________________
S/N ____________________
Date ____________________
Temperature ______________ Barometric Pressure ______________

TEST: SALT FOG

Paragraph: 4.16.1

PRE SALT FOG STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

POST SALT FOG STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

Chamber Data: Date __________ Time in __________ Temp. __________
Date __________ Time out __________ Temp. __________

Humidity __________% R. H.

Test Equipment:

Post Test Inspection:

Tested by: ____________________

Verified by: ____________________

DATA SHEET # 13

P/N ____________________
S/N ____________________
Date ____________________
Temperature ____________________

Barometric Pressure ____________________

TEST: DUST

Paragraph: 4.16.2

PRE DUST EXPOSURE STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

POST DUST EXPOSURE STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

Chamber Data & Test Equipment

See data from vendor test lab.

Post Test Inspection:

Tested by: ____________________

Verified by: ____________________

DATA SHEET # 14

P/N ____________________
S/N ____________________
Date ____________________
Temperature ______________ Barometric Pressure ______________

TEST: IMPACT SHOCK

Paragraph: 4.16.3

PRE IMPACT SHOCK STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

POST IMPACT SHOCK STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

Test Equipment:

Visual Inspection Requirements:

Shock 1

Shock 2

Shock 3

Shock 4

Shock 5

Shock 6

Tested by: ______________________

Verified by: ____________________

DATA SHEET # 15

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ______________

TEST: HIGH PRESSURE HOSE TO CYLINDER VALVE CONNECTOR

Paragraph: 4.19.1

TOTAL CYCLES	INSPECTION CHARACTERISTICS
500	
1000	
1500	
2000	
2500	
3000	
3500	
4000	
4500	
5000	

Test Equipment:

Tested by: ______________________

Verified by: ______________________

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DATA SHEET # 16

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ______________

TEST: LOW PRESSURE HOSE TO PRESSURE REDUCER DISCONNECT

Paragraph: 4.19.2

TOTAL CYCLES	LEAKAGE (none allowed)
500	
1000	

Test Equipment:

Post-test Inspection:

Tested by: ______________________

Verified by: ______________________

DATA SHEET # 17

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ____________

TEST: BREATHING REGULATOR TO FACEMASK CONNECTION

Paragraph: 4.19.3

TOTAL NO. OF CYCLES	LEAKAGE	
	Inward 1.5 cc/min max	Outward 200 cc/min max
500		
1000		
1500		
2000		
2500		
3000		
3500		
4000		
4500		
5000		

Test Equipment:

Post-Test Inspection:

Tested by: ______________________

Verified by: ______________________

DATA SHEET # 18

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ______________

TEST: CYLINDER MOUNTING IN BACKPACK

Paragraph: 4.19.4

Unit Performance: _______ Acceptable _______ Unacceptable

Post-Test Inspection:

Tested by: ______________________

Verified by: ______________________

DATA SHEET # 19

P/N ____________________
S/N ____________________
Date ____________________
Temperature ______________ Barometric Pressure ______________

TEST: OPERATIONAL CYCLING

Paragraph: 4.19.5

INHALATION MASK FLOW

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

EXHALATION MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
	+2
	+4

Test Equipment:

DEPLETION ALARM ACTUATION __________ PSIG.

LEAKAGE (none allowed):

Tested by: ____________________

Verified by: ____________________

DATA SHEET # 20

P/N ____________________
S/N ____________________
Date ____________________
Temperature ______________ Barometric Pressure ______________

TEST: PURGE VALVE

Paragraph: 4.19.6

TOTAL CYCLES	LEAKAGE (none allowed)
500	
1000	
1500	
2000	
2500	
3000	
3500	
4000	
4500	
5000	

Test Equipment:

Post-Test Inspection:

Tested by: ______________________

Verified by:

DATA SHEET # 21

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ______________

TEST: LEAKAGE (CYLINDER VALVE/CYLINDER ASSEMBLY)

Paragraph: 4.21

Total leakage ______________ cc/24-hr.

Leakage Rate ______________ cc/hr.
(0.5 cc/hr. maximum)

Test Equipment:

Tested by: ______________________

Verified by: ______________________

DATA SHEET # 22

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ______________

TEST: ACTUATION (DEPLETION WARNING DEVICE)

Paragraph: 4.22

Actuation Pressure ______________ PSIG
(880 to 830 psig required)

Remarks:

Test Equipment:

Tested by: ______________________

Verified by: ______________________

DATA SHEET # 23

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ______________

TEST: SIGNAL FREQUENCY AND INTENSITY

Paragraph: 4.23

Background noise level ______________ dB.

MASK FLOW LPM, NTPD	SIGNAL INTENSITY dB (70 to 90 dB required)	SIGNAL FREQUENCY Hz

Test Equipment:

Tested by: ______________________

Verified by: ______________________

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DATA SHEET # 24

P/N ____________________
S/N ____________________
Date ____________________
Temperature ______________ Barometric Pressure ______________

TEST: INWARD LEAKAGE (FACEMASK)

Paragraph: 4.24

SUBJECT, NUMBER, Name, Date	LEAKAGE RATE (1.5 cc/min. max.) cc/min.	REMARKS
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		

Test Equipment:

Tested by: ____________________

Verified by:

DATA SHEET # 25

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ______________

TEST: OUTWARD LEAKAGE (FACEMASK)

Paragraph: 4.25

SUBJECT, NUMBER, Name, Date	LEAKAGE RATE (200 cc/min. max.) cc/min.	REMARKS
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		

Test Equipment:

Tested by: ______________________

Verified by:

DATA SHEET # 26

P/N ____________________
S/N ____________________
Date ____________________
Temperature ____________ Barometric Pressure ____________

TEST: MASK WEIGHT

Paragraph: 4.27

Weight of Mask/Regulator Assembly ____________ lbs.

1.25 lb. maximum allowed

Test Equipment:

Tested by: ____________________

Verified by: ____________________

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APPENDIX B

Report

"ANALYSIS OF UTILIZATION

of

HELIUM LEAK DETECTOR TO MEASURE FACE MASK LEAKAGE"

AVIATION

ENGINEERING REPORT

No. 1029

Dated May 1, 1973

ANALYSIS OF UTILIZATION OF HELIUM LEAK DETECTOR TO MEASURE FACE MASK LEAKAGE

Prepared By:

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ENG-4008 12/67

The literature usually gives the sensitivity of mass spectrometer type leak detectors in terms of either the minimum detectable leakage rate or the parts of Helium it will detect per so many parts of air or background gas. Typical values are 10^{-10} STD cc/sec and 1 part helium to 10,000,000 parts of air.

What the mass spectrometer actually measures is the partial pressure of helium in the ion source of the leak detector tube. Conversion of the partial pressure reading to leakage rates or ratio of air to helium is made by applying vacuum flow mechanics principles to the dynamic constants of the leak detector pumping system.

In its simplest and most direct mode of usage, the leak detector pumping system is connected directly to the Test article which is evacuated by the high vacuum pumping system within the leak detector, as shown in Figure 1. After the test vessel is completely evacuated and the pressure in the mass spectrometer tube has been reduced to the pressure level at which the unit will operate (approximately 10^{-4} torr), the mass spectrometer circuits are actuated and the test article probed with a small jet of helium. When the output meter moves up scale, the helium jet is moved until the response is maximized, and the deflection D_L recorded. The external valve is closed and the valve isolating the stand leak L_s is opened and the deflection DL_s of the output meter is recorded. The size of the leak in the test article is then estimated by the following relation:

(1) $$L = \frac{D_L}{D_s} \times L_s$$

L_s = Value of standard leak

D_L = Output meter deflection due to leak

D_s = Output meter deflection due to standard leak

By definition the minimum detectable leak is that which causes an output meter deflection which is equal to the noise and short time drift of the output meter reading. With a properly maintained leak detector this is usually taken as 0.02 times full scale on the most sensitive scale. In practice it is difficult to use this low a value. Usually 0.1 times full scale is a more realistic value for the minimum observable deflection over drift and background noise.

As previously stated the sensitivity is usually stated in terms of minimum detectable leak or parts of gas per part of helium which is detectable however the instrument is truly a partial pressure measuring device. We can arrive at a value of the limiting partial pressure we can detect from either of the standard ratings if the pumping speed and operating pressure are known. The total flow of gases through the leak detector pumping system is by continuity:

(2) $Q_t = P_p S_p = P_t S_t$

Q_t = Total flow of gas through system in torr lit/sec.

P_p = Pressure at inlet to diffusion pump - torr

S_p = Speed at inlet to pump, lit/sec.

P_t = Pressure at Mass Spec. tube in torr

S_t = Speed at Mass Spec. tube in lit/sec.

In high vacuum flow mechanics where the mean free path of the gas molecules is larger than the dimensions of the flow passagways, each of the gases in a mixture behaves as if the other gases were not present. Since helium has a molecular weight of 4 and air about 28, the pumping speed for helium will in theory be $\sqrt{\frac{28}{4}} = \sqrt{7} =$ 2.65 times great as the speed for air. While diffusion pumps rarely exhibit this ratio (for many reasons), if the flow passage causes a large pressure drop between the Mass Spec tube and the pump (greater than 10 to 1) which is usually the case, a ratio of about 2.5 is appropriate. Thus, equation (2) can be written for helium:

(3) $Q_{he} = P_{he} S_{he}$

Q_{he} = Flow of helium torr l/s

P_{he} = Partial pressure of helium in Mass Spec tube, torr

S_{he} = Pumping speed for helium at Mass Spec tube, lit/sec.

And of course:

(3a) $Q_{he} = P_{he} S_{he} = L$ Where L is the leak either in the test article or standard Leak.

If one knew the pumping speed of helium S_{he} then one could arrive at the minimum detectable partial pressure of helium by substitution in (3a). S_{he} is however hard to calculate or measure directly. Happily the partial pressure detection limit can be arrived from the sensitivity ratio of the Mass Spec and its known operating pressure level.

$$P_{he} = \frac{P_t}{R} \text{ - (Minimum)}$$

R = Sensitivity ratio

P_t = Total pressure in source

$$P_{he} = \frac{10^{-4}}{10^{7}} \text{ torr} = 10^{-11} \text{ torr (Minimum) in source}$$

Once we know P_{he} (Min) and L (Min), S_{he} can be obtained from (3) - - -

$$Q_{he} = L_{he} = P_{he} S_{he} \qquad Q_{he} = L_{he} = 10^{-10} \text{ Std. cc/sec.}$$

$$= 0.76 \times 10^{-10} \text{ torr l/s}$$

$$S_{he} = \frac{0.76 \times 10^{-10}}{10^{-11}} = 7.6 \text{ lit/sec} \quad P_{he} \text{ (Min)} = 10^{-11} \text{ torr}$$

C-3

As a practical matter most leak detector systems have effective pumping speeds at the Mass Spec tube of between 1 and 20 lit/sec and most of them have means by which the pumping speed can be varied, for example the Valve A can be used to throttle the flow between the Mass Spec tube and the pump. This can result in varying S_t and S_{he} over a wide range. The limiting case being the completely shutoff position which results in zero speed which can be used advantageously for certain applications where extreme leak rate sensitivity is required. It can be seen from eqn (3) that the minimum leak L which is detectable (and measurable) is reduced if S_{he} is reduced (by using throttling valve) and in some instruments a factor of 10 or more improvement can be realized. However, as a practical matter reducing S_{he} or S_t too much results in increased response and clean-up time which makes the instrument difficult to use.

Another useful leak detection technique utilizing a mass spec type leak detector is shown in Figure 2. In this type of system a flexible hose has one end connected to the inlet of the leak detector and the other end connected to a "sniffer" which usually consists of a small adjustable needle valve. In use the external and throttle valves are opened and the flexible hose up to the closed "sniffer" valve is evacuated to less than 10^{-4} torr at the Mass Spec tube. The "sniffer" needle valve is then opened until the pressure P_t is raised to satisfactory operating pressure level, usually between 1.0 and 2.0 10^{-4} torr. If air which contains about 2 parts of helium per million is introduced into the sniffer, the response of the system can be analyzed as follows:

Flow into system through "Sniffer" - (2)

$$Q_t = P_t S_t = 3.05 \times 1.0 \times 10^{-4} = 3.05 \times 10^{-4} \text{ torr l/s}$$

$$S_t = S_{he} \times \frac{1}{2.5} = \frac{7.6}{2.5} = 3.05 \text{ l/s}$$

$$P_t = 1.0 \times 10^{-4} \text{ torr}$$

Since the air is a mixture containing approximately 1 part of helium per 500,000 parts of air the flow of helium will be - - -

$$Q_{he} = \frac{Q_t}{500,000} = \frac{3.05 \times 10^{-4}}{5 \times 10^5} = 0.6 \times 10^{-9} \text{ torr lit/sec.}$$

This will result in a partial pressure of helium in the Mass Spec tube of - - -

$$P_{he} = \frac{Q_{he}}{S_{he}} = \frac{0.6 \times 10^{-9}}{7.6} = 0.79 \times 10^{-10} = 7.9 \times 10^{-11} \text{ torr}$$

Since the minimum detectable partial pressure of helium is 10^{-11} torr the output meter deflection will be 7.9 times the minimum observable deflection. The assumption is made that in a dilute mixture of helium in air that the flow through the sniffer is the same for both helium and air. This is not always true. Helium flow may be more or less than air through a given leak path depending on the geometry of the leak path. For this reason in analysis such as that made above is useful for estimating purposes only. In actual cases where quantitative results are necessary direct calibration on known mixtures at close to the expected leak rates is required.

It is useful to note that as long as P_t is held constant manipulation of Valve A will have no real effect on the sensitivity when the leak detector is operated in this mode.

The usual mode of operation for this technique is to pressurize the test article with either helium or helium enriched compressed air mixture and probe the exterior of the article. If the "sniffer" encounters an area of high helium concentration the output meter response indicates the presence of a leak. Careful moving of the "sniffer" results in maximizing the response and location of the leak. This technique, while not capable of the ultimate sensitivity of the direct vacuum method, is extremely useful in certain applications.

The problem at hand is to measure "in-leakage" of the face mask, regulator and exhalation valve of the FBS system being developed for NASA. It is proposed that a sample of the gas in the face mask be drawn through the "sniffer" when the mask is worn by a number of subjects inside a hood which contains a challenge atmosphere. The suitability of this technique is to be evaluated. The specified in-leakage rate is 1.5 cc/min. The breathing rate is assumed to be 10 l/m. A challenge atmosphere of 10% helium may be assumed.

The maximum allowable helium flow into the mask is - - -

$$q_1 = \frac{l}{m}$$

q_1 = helium flow into mask = max. allowable

l = mask leak rate - max. allowable

$$q_1 = \frac{2.5 \times 10^{-5}}{10} = 2.5 \times 10^{-6} \text{ l/s}$$

$l =$ 1.5 cc/min at atm pressure

$$l = \frac{1.5}{60 \times 1000}$$

$l = 2.5 \times 10^{-5}$ lit/sec at atm pressure

$m =$ ratio air to helium-challenge atmosphere
$= 10$

$$q_2 = \text{breathing rate} = 10 \text{ l/m} = \frac{10}{60} = 0.166 \text{ l/s}$$

Helium content of breathing gas - 2 parts/million

q_3 = helium flow rate due to breathing gas

$$= 0.166 \times 2 \times 10^{-6} = 0.33 \times 10^{-6} \text{ l/s}$$

Total helium flow into mask $= q_1 + q_3 = 2.83 \times 10^{-6}$ l/s

Mixture ratio M air to helium in mask

$$M = \frac{q_2}{q_1 + q_3} = \frac{0.166 \text{ l/s}}{2.83 \times 10^{-6}} = 0.06 \times 10^6$$

$$= 6 \times 10^4 \text{ (air to helium ratio)}$$

The inverse of M is 16 parts per million.

Since calculations showed that the Leak Detector would give a deflection of approximately 8 times minimum for air with 2 parts per million, we should get a deflection at maximum allowable leakage of $8 \times \frac{16}{2}$ or 64 times minimum. This should make it possible to get reasonably accurate quantitative results on mask leakage. The sensitivity could be improved by increasing challenge atmosphere helium concentration. A maximum improvement of a factor of 10 would be available if 100% helium were used.

Another factor to be considered is errors due to helium diffusion through the rubber and plastic parts of the face mask and the polycarbonate lens.

The permeability of natural rubber for air at 75°F is 4.9×10^{-8} atm cc/sec/cm^2/cm. Helium permeability is approximately $1.9/1.3 = 1.46$ times that of air. The face mask under consideration has approx. 13 sq. in. of 0.050" thick natural rubber subject to air permeation. The helium flow rate is estimated at:

$$q_4 = K_1 \frac{A}{t} \Delta P$$

$$= \frac{1.46 \times 4.9 \times 83.2}{0.13} \times \frac{0.1 \times 10^{-8}}{10^3}$$

$$= 4.56 \times 10^{-9} \text{ l/sec at 1 atm.}$$

$K = 4.9 \times 10^{-8}$ atm cc/sec/cm^2/cm for air (for 1 atm ΔP)

$K_1 = K \times 1.46$ (helium/air permeability ratio)

$A = 13 \text{ in}^2 \times 6.4 = 83.2 \text{ cm}^2$

$t = 0.05" = 0.05 \times 2.54 = 0.13$ cm

$\Delta P = 0.1$ atm

The lens of the face piece is made of polycarbonate comprising 67 in^2 of material with a thickness of 0.050 in. An estimate of the helium diffusion through the lens is:

$$q_5 = \frac{KA \Delta P}{t}$$

$$= \frac{5 \times 67 \times 6.4 \times 0.1}{0.13} \times \frac{10^{-8}}{10^3}$$

$$= 15.9 \times 10^{-9} \text{ l/sec at 1 atm}$$

K = Data for helium not available but data on air indicates a value of about 5×10^{-8} would be within an order of magnitude

The various sources of helium flow into the mask volume are:

$q_1 = 2.5 \times 10^{-6}$ l/s max. allowable mask leak rate.

$q_3 = 0.33 \times 10^{-6}$ l/s Helium content of breathing gas.

$q_4 = 0.004 \times 10^{-6}$ l/s Helium diffusion through elastomer.

$q_5 = 0.015 \times 10^{-6}$ l/s Helium diffusion through lens.

Since the contribution of helium permeation and helium content of breathing gas ($q_3 + q_4 + q_5 = 0.35 \times 10^{-6}$ l/s) totals only about 14% of the helium flow due to maximum allowable leakage, the method should be usable and subject to calibration.

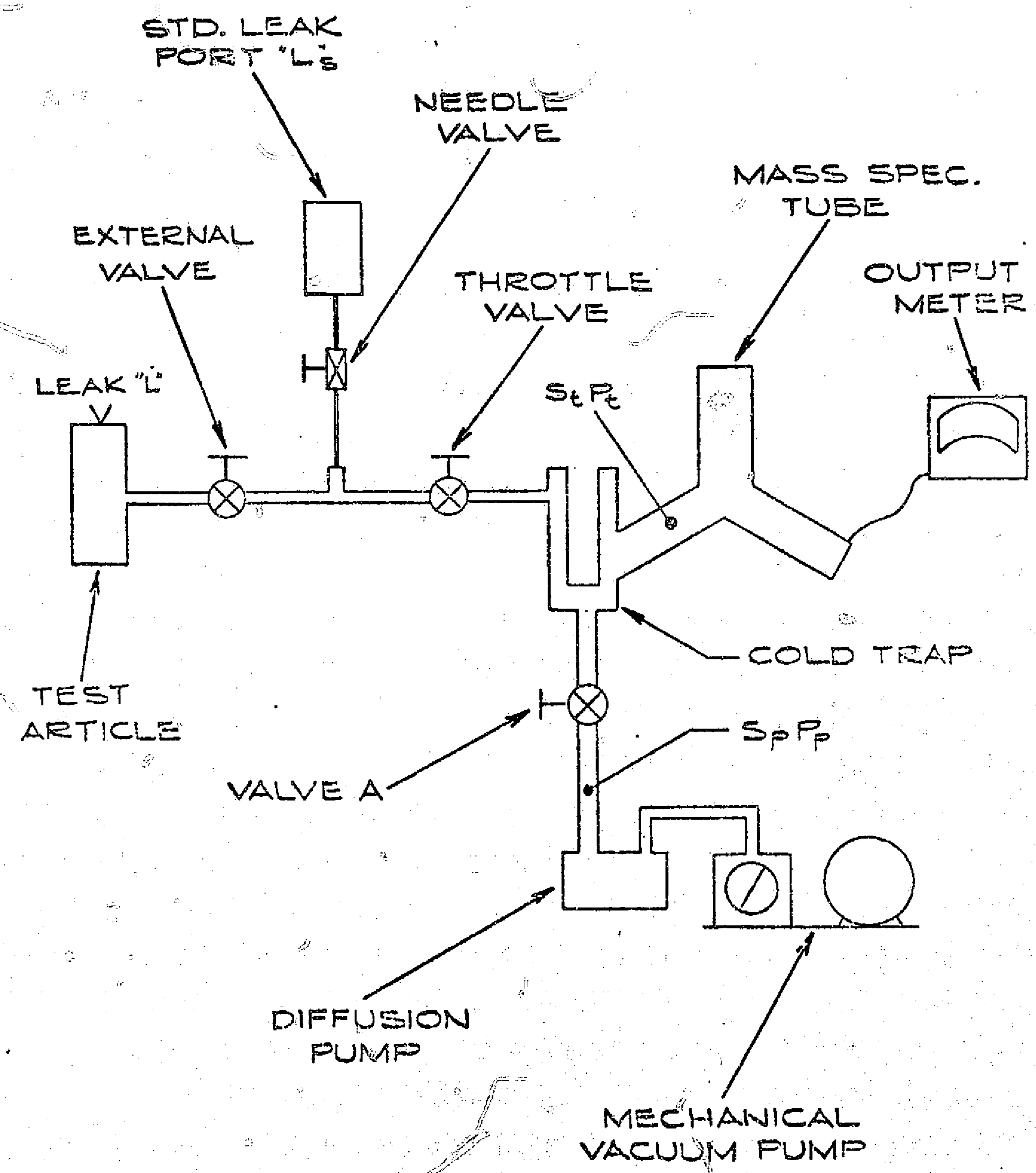

STD. LEAK
PORT "Ls"
NEEDLE
VALVE
MASS SPEC.
TUBE
EXTERNAL
VALVE
THROTTLE
VALVE
OUTPUT
METER
LEAK "L"
$S_t P_t$
COLD TRAP
TEST
ARTICLE
$S_p P_p$
VALVE A
DIFFUSION
PUMP
MECHANICAL
VACUUM PUMP

FIGURE 1.

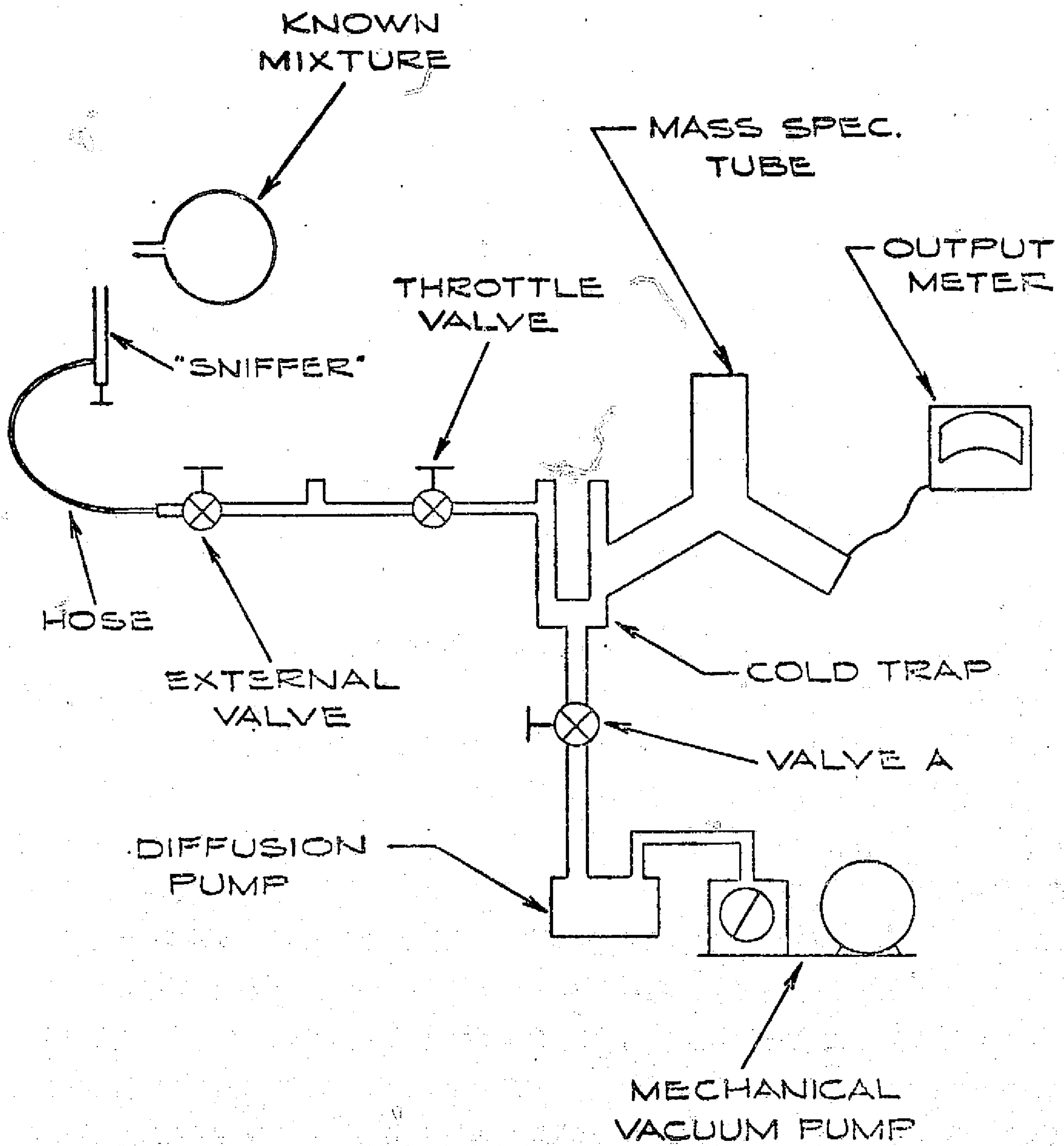
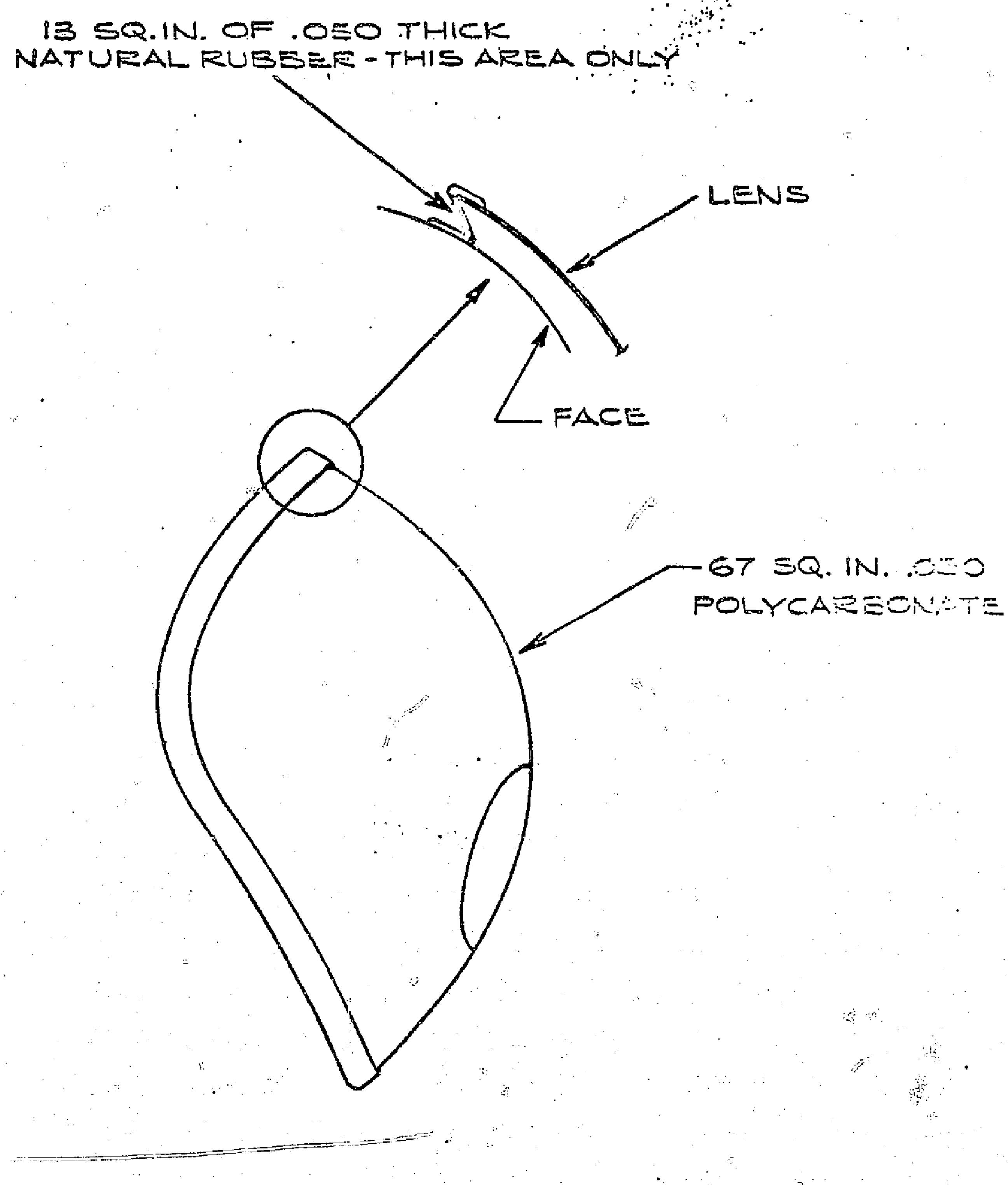

KNOWN
MIXTURE
MASS SPEC.
TUBE
OUTPUT
METER
THROTTLE
VALVE
"SNIFFER"
HOSE
EXTERNAL
VALVE
COLD TRAP
VALVE A
DIFFUSION
PUMP
MECHANICAL
VACUUM PUMP

FIGURE 2.



13 SQ.IN. OF .050 THICK
NATURAL RUBBER - THIS AREA ONLY
LENS
FACE
67 SQ. IN. .030
POLYCARBONATE

EXHIBIT II

ER-1027
Appendix A

DATA SHEET # 6

P/N 27215
S/N 2
Date 7-18-73
Temperature 74°F

Barometric Pressure 747 mmHg

TEST: OVERPRESSURIZATION PROTECTION

Paragraph: 4.12 SEQUENCE 1 PARA 4.1.1

PARAMETER	REQUIRED	ACTUAL
Step (4) Burst Pressure Frangible Disc	4500-5000 PSIG	4100

Test Equipment:
SEE LIST ITEM # 5

Tested by: Edward Pfister
Verified by: Paul R. Barrett

ER-1027
Appendix A

DATA SHEET # 3

P/N 27275
S/N 2
Date 8-16-73
Temperature 73 °F

Barometric Pressure 741 mmHg

TEST: PROOF PRESSURE

Paragraph: 4.4 Sequence 1 Para 4.1.2

COMPONENT	PRESSURE (PSIG)	POST TEST INSPECTION
Cylinder & Valve Assy.	6750	No Damage
High-pressure Hose	6750	No Damage
Pressure Reducer (high-pressure section)	6750	No Damage
Pressure Reducer (low-pressure section)	187.5	No Damage
Low-pressure Hose	187.5	No Damage
Breathing Regulator	187.5	No Damage

STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-0.52
125	-0.50
550	-1.25
300	-1.0
550	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-0.40
125	-0.80
275	-1.25
300	-1.32
565	-2.0

Alarm Actuation 850 psig

Test Equipment: Test Equipment List # 7, 8

Tested by: Edward Pfister

Verified by: Paul R. Bo[illegible]

DATA SHEET # 26

P/N 27275
S/N 2
Date 8-17-73
Temperature 71°F

Barometric Pressure 741 mm Hg

TEST: MASK WEIGHT

Paragraph: 4.27 SEQUENCE 1 PARA 4.1.4

Weight of Mask/Regulator Assembly 1 LB 1 OZ ~~lbs.~~

1.25 lb. maximum allowed

Test Equipment: LIST # 19

Tested by: Edward Pfister

Verified by: [signature]

DATA SHEET # 26

P/N 27275
S/N 2
Date 8-17-73
Temperature 71°F

Barometric Pressure 741 mm Hg

TEST: MASK WEIGHT

Paragraph: 4.27 SEQUENCE 1 PARA 4.1.4

Weight of Mask/Regulator Assembly 1 LB 1 OZ ~~lbs.~~

1.25 lb. maximum allowed

Test Equipment: LIST # 19

Tested by: Edward Pfister

Verified by: [signature]

DATA SHEET # 24

P/N

S/N

Date

Temperature

Barometric Pressure

TEST: INWARD LEAKAGE (FACEMASK)

Paragraph: 4.24

SUBJECT, NUMBER, Name, Date	LEAKAGE RATE (1.5 cc/min. max.) cc/min.	REMARKS
1		
2		
3		
4		
5	SEE EXHIBIT III FOR DATA	
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		

Test Equipment:

Tested by:

Verified by:

ER-1027
Appendix A

DATA SHEET # 25

P/N ______
S/N ______
Date ______
Temperature ______ Barometric Pressure ______

TEST: OUTWARD LEAKAGE (FACEMASK)

Paragraph: 4.25

SUBJECT, NUMBER, Name, Date	LEAKAGE RATE (200 cc/min. max.) cc/min.	REMARKS
1		
2		
3		III
4	SEE EXHIBIT	
5	FOR DATA	
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		

Test Equipment:

Tested by: ______

Verified by: ______

DATA SHEET # 8

P/N 27275
S/N 2
Date 7-20-74
Temperature 72'F
Barometric Pressure 747 mm Hg

TEST: PRESSURE GAGE ACCURACY

Paragraph: 4.14 SEQUENCE 1 PARA 4.1.5

Increasing Pressure:

Gage Reading	Required	Actual
10 x 100 psig	1000 ± 225 psig	950
20 x 100 psig	2000 ± 225 psig	1880
30 x 100 psig	3000 ± 225 psig	2800
full	4000 ± 225 psig	3800
45 x 100 psig	4500 ± 225 psig	4280

Decreasing Pressure:

Gage Reading	Required	Actual
10 x 100 psig	1000 ± 225 psig	1040
20 x 100 psig	2000 ± 225 psig	1900
30 x 100 psig	3000 ± 225 psig	2850
full	4000 ± 225 psig	3800
45 x 100 psig	4500 ± 225 psig	4280

Test Equipment: List # 4

Tested by: Edward Pfister

Verified by: Paul R. Bu[illegible]

DATA SHEET # 1

P/N 27275
S/N 2
Date 8-16-73
Temperature 73°F

Barometric Pressure 741 mm Hg

TEST: FLOW REQUIREMENTS

Paragraph: 4.1
Sequence 2 Para 4.2.1

4.1.1 INHALATION INITIATION

Parameter	Required	Actual
Step (3) Leakage	10 scc/min. max.	3.6
Step (4) Flow Initiation @ 4000 psig inlet	-0.1 to -0.5 inches water	-0.36
Step (5) Flow Initiation @ 1000 psig inlet	-0.1 to -0.5 inches water	-0.38
Step (5) Flow Initiation @ 570 psig inlet	-0.1 to -0.5 inches water	-0.34

Test Equipment: List # 2, 9

4.1.2 INHALATION FLOW AT INTERMEDIATE AND MAXIMUM SPECIFIED NEGATIVE PRESSURE

Parameter	Resulting Flow LPM,NTPD
Step (3) Flow @ -2.0 inches water 4000 psig inlet	550
Step (4) Flow @ -2.0 inches water 1000 psig inlet	450
Step (4) Flow @ -2.0 inches water 570 psig inlet	615
Step (4) Flow @ -2.0 inches water 100 psig inlet	225
Step (5) Flow @ -1.25 inches water 4500 psig inlet	480
Step (5) Flow @ -1.25 inches water 1000 psig inlet	445
Step (5) Flow @ -1.25 inches water 570 psig inlet	330
Step (5) Flow @ -1.25 inches water 100 psig inlet	225

Test Equipment: List # 4, 9, 1

4.1.3 EXHALATION INITIATION & STATIC FLOW

Parameter	Required	Actual
Step (3) Exhalation Initiation	0.1 to 0.5 inches water	+ 0.15
Step (4) Exhalation Flow @ +2.0 inches water mask pressure	257 LPM NTPD minimum	390
Step (4) Exhalation Flow @ +4.0 inches water mask pressure	476 LPM NTPD minimum	600

Test Equipment: List # 1, 2, 9

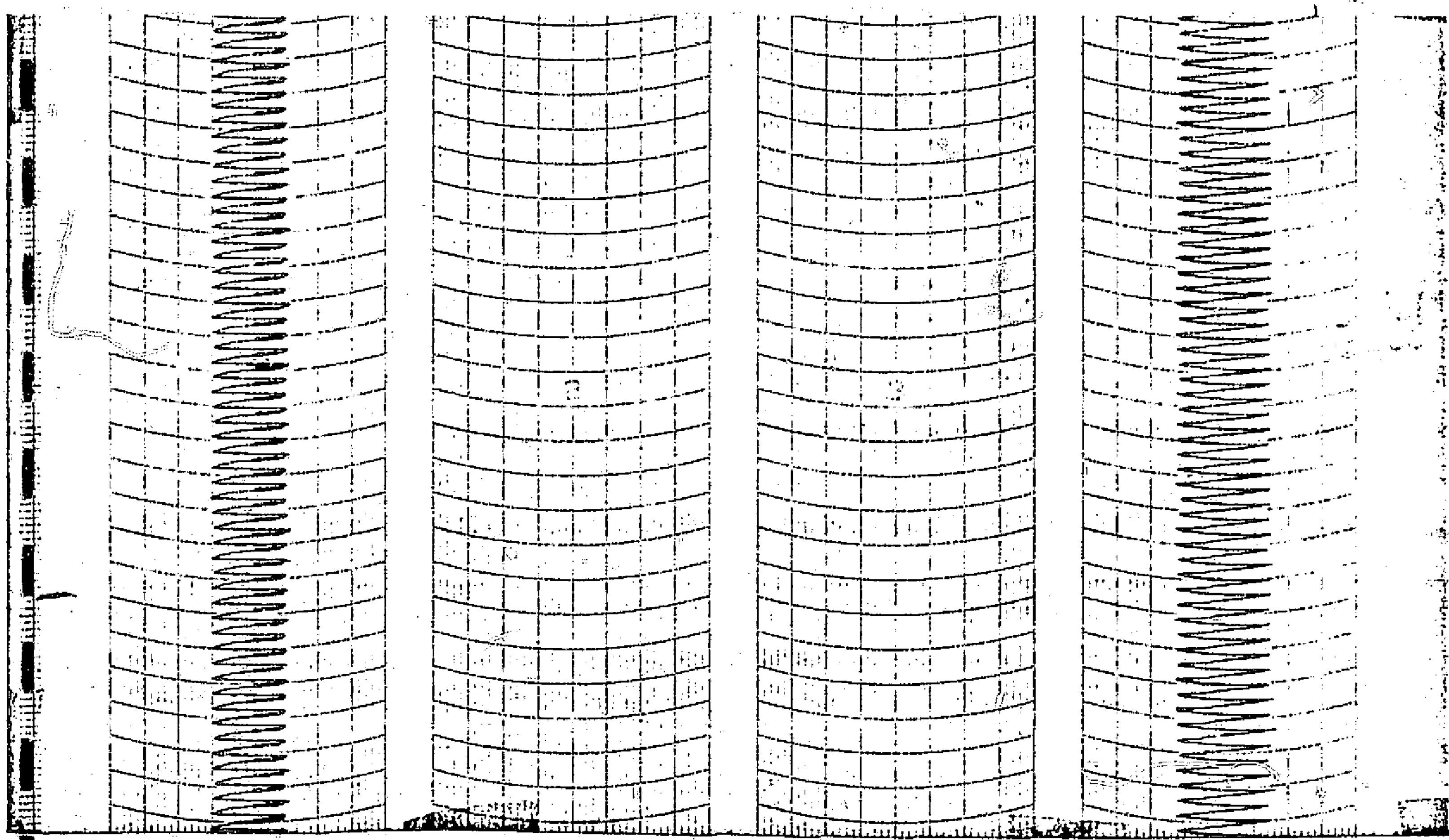
4.1.4 DYNAMIC FLOW REQUIREMENTS

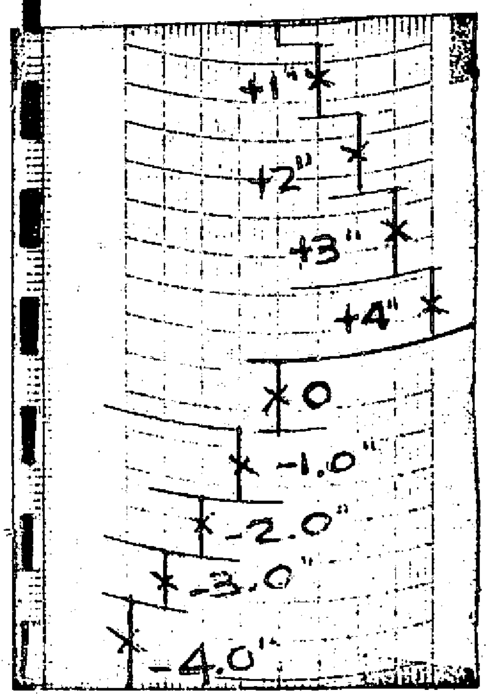
Parameter	Required	Actual
Step (3) Peak Inhalation Pressure	-1.25 inches Water Max.	-1.0
Step (3) Peak Exhalation Pressure	+2.0 Inches Water Max.	+1.2
Step (3) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	830
Step (3) Total Time from High to Low Cylinder Pressure	N/A	13 MIN 20 SEC
Step (4) Peak Inhalation Pressure	-2.0 inches Water Max.	-1.2
Step (4) Peak Exhalation Pressure	+4.0 inches Water Max.	+2.5
Step (4) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	840
Step (4) Total Time from High to Low Cylinder Pressure	N/A	8 MIN 10 SEC

Test Equipment: List # 2, 4, 9, 14, 15, 16, 18

Tested by: Edward Pfister

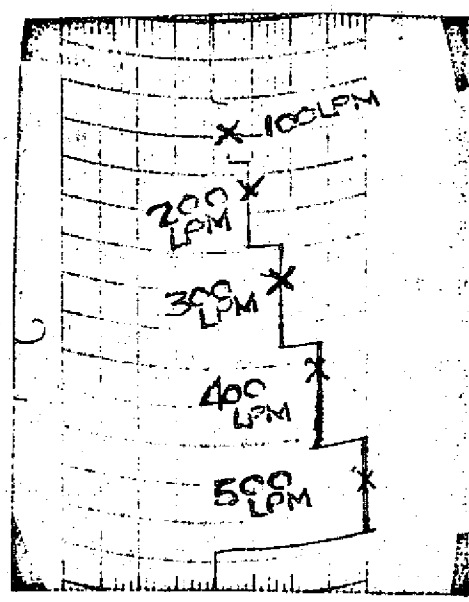
Verified by: Paul R. Benst





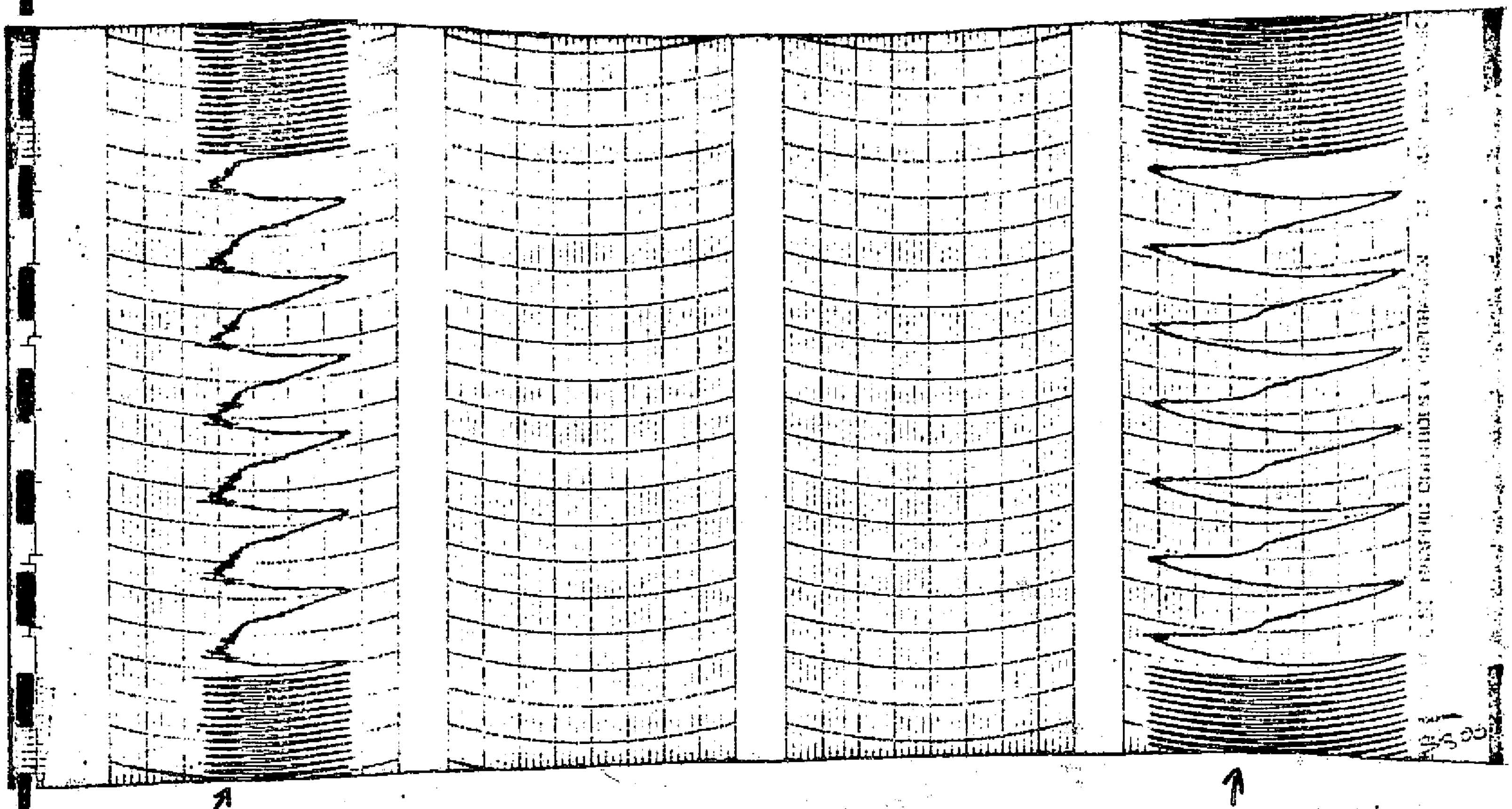
Mask Pressure
Inches of Water
Calibration

Peak Mask Flow
LPM NTPD
Calibration



Dynamic Flow Requirements
Peak Flow & Mask Pressure
257 LPM Peak Flow
Purge Valve Closed

8/16/73



Mask Pressure

Mask Flow

NOTE: Calibration appears on the page showing 257 LPM peak flow chart.

Dynamic Flow Requirements
Peak Flow & Mask Pressure
476 LPM Peak Flow
Purge Valve Closed

8/16/73

Appendix A

DATA SHEET # 2

P/N 27275
S/N 2
Date 8-16-73
Temperature 73°F

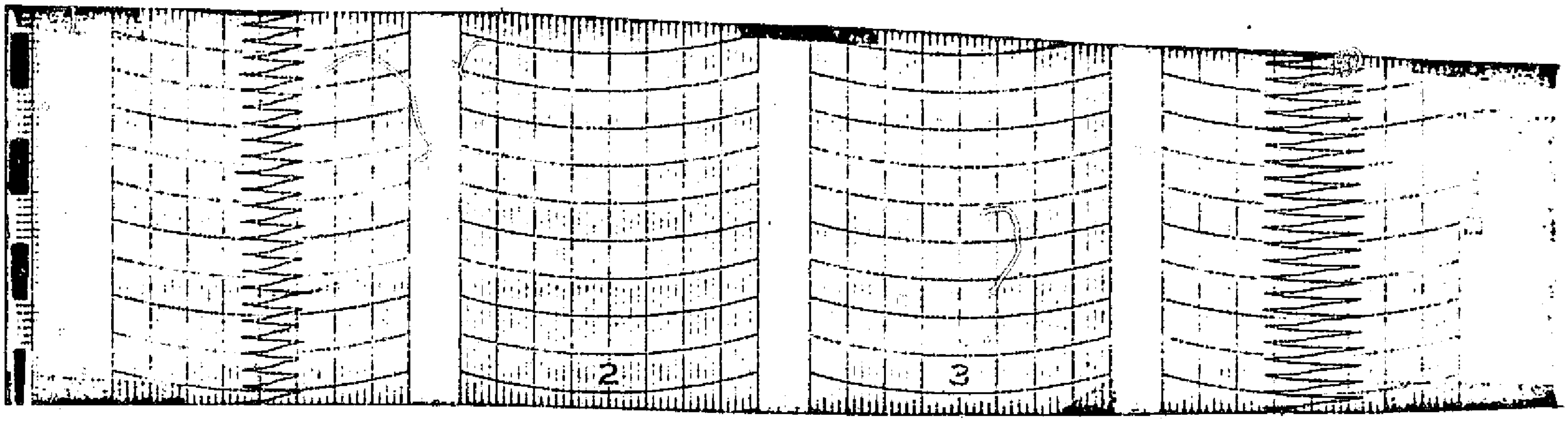
Barometric Pressure 741 mmHg

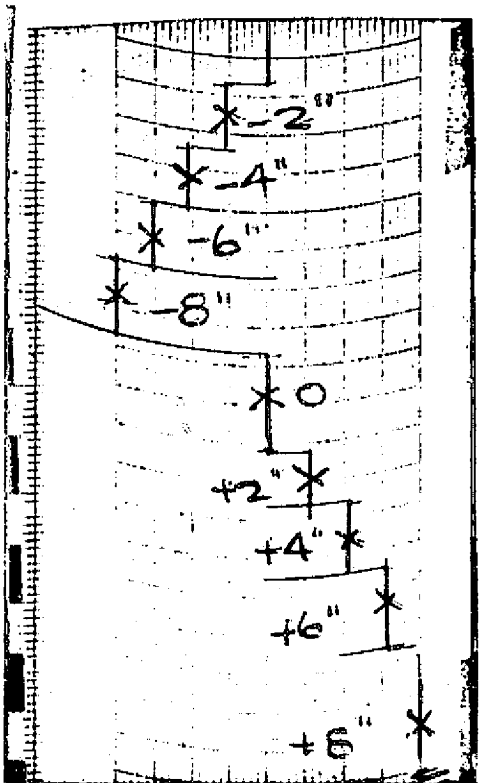
TEST: DYNAMIC PURGE CAPABILITY

Paragraph: 4.3.1 Sequence 2 Para 4.2.3

Parameter	Required	Actual
Step (3) Peak Inhalation Pressure	-1.25 inches Water Max.	-1.0
Step (3) Peak Exhalation Pressure	+2.0 Inches Water Max.	+2.4
Step (3) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	840
Step (3) Total Time from High to Low Cylinder Pressure	N/A	5 min 57 sec
Step (4) Peak Inhalation Pressure	-2.0 inches Water Max.	-1.0
Step (4) Peak Exhalation Pressure	+4.0 inches Water Max.	+4.5
Step (4) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	830
Step (4) Total Time from High to Low Cylinder Pressure	N/A	3 min 50 sec.

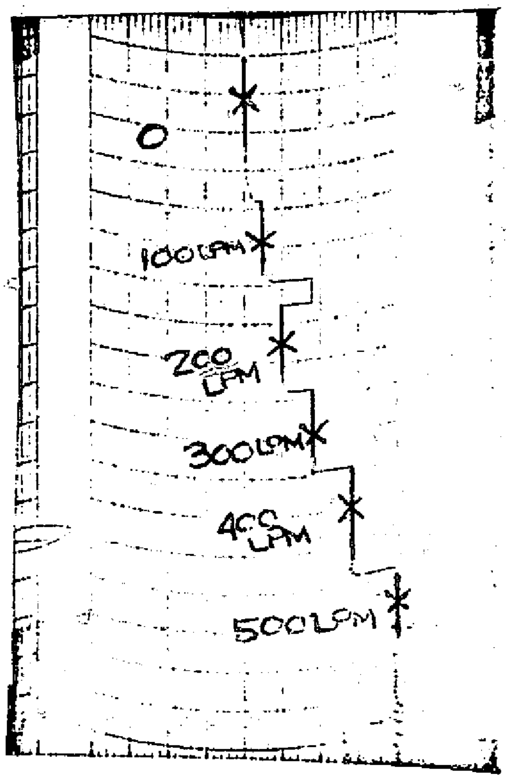
Test Equipment: List # 2, 4, 9, 14, 15, 16, 18





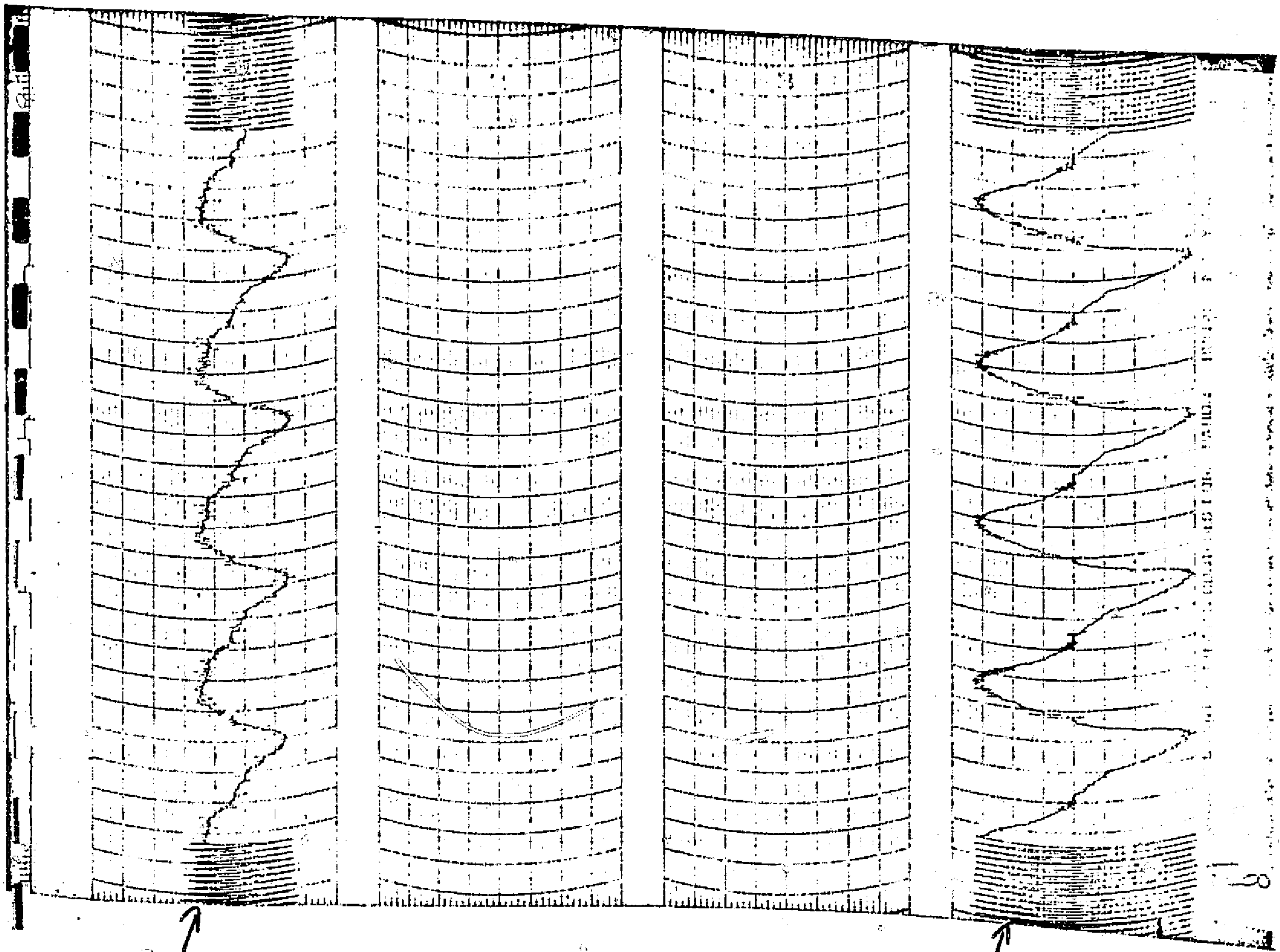
Mask Pressure
Inches of Water
Calibration

Peak Mask Flow
LPM, NTPD
Calibration



Dynamic Purge Flow
Peak Flow & Mask Pressure
257 LPM Peak Flow
Purge Valve Fully Open

8/16/73



Mask Pressure

Mask Flow

NOTE: Calibration appears on the page showing 257 LPM peak purge flow chart.

Dynamic Purge Flow
Peak Flow & Mask Pressure
476 LPM peak flow
Purge Valve Fully Open

8/16/73

DATA SHEET # 2 (continued)

P/N 27275
S/N 2
Date 8-17-73
Temperature 71°F

Barometric Pressure 746 mmHg

TEST: STATIC PURGE CAPABILITY

Paragraph: 4.3.2 SEQUENCE 2, PARA 4.2.3

PARAMETER	REQUIRED	ACTUAL
Step (3) Flow at 4000 psig cylinder pressure	111.2 LPM NTPD	280
3500		200
3000		200
2500		200
2000		200
1500		185
1000		185
800		200
500		240
100		175

Tested by: Edward Pfister

Verified by: Paul P. Bent

DATA SHEET # 5

P/N 27275
S/N 2
Date 8-17-73
Temperature 71 °F
Barometric Pressure 741 mm Hg

TEST: SYSTEM WEIGHT

Paragraph: 4.6 SEQUENCE 2 PARA 4.2.4

COMPONENT	WEIGHT (pounds)
Valve Assy. including Lock Ring and Seal	0.85
High-Pressure Hose	0.80
Pressure Reducer	1.80
Low-Pressure Hose	0.27
Breathing Regulator	0.35
Face Mask	0.61
Back Pack & Frame	3.50

TOTAL FBS WEIGHT: 8.18 lbs.
(10 lb. maximum)
(not including cylinders)

Test Equipment: LIST # 19

Tested by: Edward Pfister

Verified by: Paul R. B[illegible]

DATA SHEET # 7

P/N 27275
S/N 2
Date 8-16-73
Temperature 73°F

Barometric Pressure 741 mm Hg

TEST: SYSTEM LEAKAGE

Paragraph: 4.13 ~~R~~ SEQUENCE 2 PARA 4.2.5

Parameter	Required	Actual
Step (2) System Leakage	No leakage	0

Tested by: Edward Pfister

Verified by: Paul R. Barnett

DATA SHEET # 21

P/N 27275
S/N 2
Date 8-16-73
Temperature 73°F

Barometric Pressure 741 mmHg

TEST: LEAKAGE (CYLINDER VALVE/CYLINDER ASSEMBLY)

Paragraph: 4.21 SEQUENCE 2 PARA 4.2.6

Total leakage 0 cc/24-hr.

Leakage Rate 0 cc/hr.
(0.5 cc/hr. maximum)

Test Equipment: LIST # 17

Tested by: Edward Pfister

Verified by: Paul P. Brandt

DATA SHEET # 22

P/N 27275
S/N 2
Date 6-22-73
Temperature 71°F

Barometric Pressure 746 mmHg

TEST: ACTUATION (DEPLETION WARNING DEVICE)

Paragraph: 4.22 SEQUENCE 2 PARA 4.2.7

Actuation Pressure 850 PSIG
(880 to 830 psig required)

Remarks:

Test Equipment: LIST # 3

Tested by: Edward Pfister

Verified by: Paul R. Bennett

DATA SHEET # 23

P/N 27275
S/N 2
Date 8-22-73
Temperature 71°F

Barometric Pressure 746 mm Hg

TEST: SIGNAL FREQUENCY AND INTENSITY

Paragraph: 4.23 SEQUENCE 2 PARA 4.2.8

Background noise level 70 dB.

MASK FLOW LPM, NTPD	SIGNAL INTENSITY dB (70 to 90 dB required)	SIGNAL FREQUENCY Hz
55	103	~~37~~ 3570

Test Equipment: LIST # 1, 9, 20, 21

Tested by: Edward Pfister

Verified by: Paul R. Burst

DATA SHEET # 10

P/N 77275
S/N 2
Date 8-18-73
Temperature —

Barometric Pressure —

TEST: HIGH TEMPERATURE OPERATION

Paragraph: 4.15.3 SEQUENCE 3 PARA 4.3.1

Chamber Data:

Step 2a 120 ± 5°F 6 hours minimum

Date 8-18-73 Time in 11:45 AM Temp. 120
Date 8-18-73 Time out 5:45PM Temp. 120

Step 2b 154 ± 5°F 4 hours minimum

Date 8-18-73 Time in 6:45PM Temp. ~~150~~ 155
Date 8-18-73 Time out 10:45PM Temp. 155

Step 2d 120 ± 5°F 6 hours minimum

Date 8-18-73 Time in 11:45PM Temp. 120
Date 8-19-73 Time out 5:45AM Temp. 120

154 ± 5°F 4 hours minimum

Date 8-19-73 Time in 6:45AM Temp. 150
Date 8-19-73 Time out 10:45AM Temp. 152

120 ± 5°F 6 hours minimum

Date 8-19-73 Time in 11:45AM Temp. 120
Date 8-19-73 Time out 5:45PM Temp. 120

154 ± 5°F 6 hours minimum

Date 8-19-73 Time in 6:45PM Temp. 155
Date 8-19-73 Time out 10:45PM Temp. 155

Step 2e   200 ± 5°F   8 hours minimum

Date 8-19-73   Time in 11:30 PM   Temp. 200°F
Date 8-20-73   Time out 8:30 AM   Temp. 200°F

Test Equipment: List * 1, 3, 9, 10, 11, 12

PRE TEST STATIC FLOW CHECK; Date 8-17-73

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.38
125	-.55
550	-1.25
300	-.90
550	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.42
125	-.82
265	-1.25
300	-1.36
615	-2.0

HIGH TEMPERATURE STATIC FLOW CHECK; Date 8-20-73

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.35
125	-.78
335	-1.25
300	-1.2
525	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	~~-.5~~ -.34
125	-.86
293	-1.25
300	-1.38
625	-2.0

POST HIGH TEMPERATURE STATIC FLOW CHECK; Date 8-20-73

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.40
125	-.78
580	-1.25
300	-.95
595	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.32
125	-.75
545	-1.25
300	-1.0
625	-2.0

POST TEST INSPECTION: ALL GAS HAD LEAKED FROM THE CYLINDER THROUGH THE FUSIBLE PLUG.

Tested by: Edward Pfister

Verified by: [illegible signature]

ER-1027
Appendix A

DATA SHEET # 9

P/N 27275
S/N 2
Date 7-27-73
Temperature –

Barometric Pressure –

TEST: LOW TEMPERATURE OPERATION

Paragraph: 4.15.2 SEQUENCE 3 PARA. 4.3.2

Chamber Data:

Step 2a -60 ± 5°F 4 hours minimum

Date 7-26-73 Time in 11:00 AM Temp. -60°F
Date 7-26-73 Time out 3:00 PM Temp. -60°F

Step 2b Visual Inspection

Remarks: LOW PRESS HOSE STIFF

Step 2c -60 ± 5°F 8 hours minimum

Date ~~3:00 PM~~ 7-26-73 Time in 3:00 PM Temp. -60°F
Date 7-27-73 Time out 8:30 AM Temp. -60°F

Step 2d See data, Page 2.

Step 2e See data, Page 2.

Data Sheet #9 (continued)

PRE-TEST STATIC FLOW CHECK; Date 7-26-73

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.46
125	-.76
370	-1.25
300	-1.08
560	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.46
125	-.68
350	-1.25
300	-1.18
600	-2.0

LOW TEMPERATURE STATIC FLOW CHECK; Date 7-27-73

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.02
125	-.52
390	-1.25
300	-.97
610	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.06
125	-.80
340	-1.25
300	-1.18
610	-2.0

ALARM 740 PSIG   LEAK AT VENT HOLES IN PRESSURE REDUCER. LOW PRESSURE DISCONNECT LEAK.

POST LOW TEMPERATURE STATIC FLOW CHECK; Date ____________

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

NOT RUN ↑

Test Equipment: List #1, 3, 9, 10, 11, 12

Visual Inspection:

Tested by: Edward Pfister

Verified by: [signature]

DATA SHEET # 9

P/N 27275
S/N 2
Date 7-31-73
Temperature —

Barometric Pressure —

TEST: LOW TEMPERATURE OPERATION

Paragraph: 4.15.2 SEQUENCE 3 PARA 4.3.2
-48 °F SPECIAL TEST

Chamber Data:

Step 2a -60 ± 5°F 4 hours minimum

Date		Time in		Temp.	
Date		Time out		Temp.	

Step 2b Visual Inspection

Remarks:

Step 2c ~~-60~~ -48 ± 5°F 8 hours minimum

Date	7-30-73	Time in	4:00 PM	Temp.	-48 °F
Date	7-31-73	Time out	8:30 AM	Temp.	-48 °F

Step 2d See data, Page 2.

Step 2e See data, Page 2.

Data Sheet #9 (continued)

PRE-TEST STATIC FLOW CHECK; Date 7-26-73

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.46
125	-.76
370	-1.25
300	-1.08
560	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.46
125	-.68
350	-1.25
300	-1.18
600	-2.0

LOW TEMPERATURE STATIC FLOW CHECK; Date 7-31-73

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.23
125	-.74
380	-1.25
300	-1.08
540	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.31
125	-.84
350	-1.25
300	-1.03
625	-2.0

840 PSIG ALARM ACTUATED
LEAK IN LOW PRESSURE DISCONNECT.

POST LOW TEMPERATURE STATIC FLOW CHECK; Date ________

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

Test Equipment: List # 1, 3, 9, 10, 11, 12

Visual Inspection:

Tested by: Edward Pfister

Verified by: [illegible]

DATA SHEET # 9

P/N 27275
S/N 2
Date 8-20-73
Temperature –   Barometric Pressure –

TEST: LOW TEMPERATURE OPERATION

Paragraph: 4.15.2 SEQUENCE 3 PARA 4.3.2
-40°F TEST

Chamber Data:

Step 2a ~~-60~~ -40 $\pm$ 5°F 4 hours minimum

Date 8-20-73 Time in 11:00 AM Temp. ~~3:00 PM~~ -40°F
Date 8-20-73 Time out 3:00 PM Temp. -40°F

Step 2b Visual Inspection

Remarks: LOW PRESSURE HOSE STIFF
DUST CAPS IN VENT HOLES FELL OUT OF PRESSURE
REGULATOR

Step 2c ~~-60~~ -40 $\pm$ 5°F 8 hours minimum

Date 8-20-73 Time in 3:00 PM Temp. -40°F
Date 8-21-73 Time out 8:30 AM Temp. -40°F

Step 2d See data, Page 2.

Step 2e See data, Page 2.

Data Sheet #9 (continued)

PRE-TEST STATIC FLOW CHECK; Date 8-20-73

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	~~5~~ -.40
125	-.78
580	-1.25
300	-.95
575	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.32
125	-.75
915	-1.25
300	-1.0
625	-2.0

LOW TEMPERATURE STATIC FLOW CHECK; Date 8-21-73

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.44
125	-.50
615	-1.25
300	-.80
655	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.44
125	-.80
370	-1.25
300	-1.18
665	-2.0

POST LOW TEMPERATURE STATIC FLOW CHECK; Date 8-21-73

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.44
125	-.50
570	-1.25
300	-.80
570	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.40
125	-.84
260	-1.25
300	-1.32
625	-2.0

Test Equipment: List # 1, 3, 9, 10, 11, 12

Visual Inspection:

Tested by: Edward Pfister

Verified by: [illegible]

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Appendix A

DATA SHEET # 11

P/N 27275
S/N 2
Date 8.22.73
Temperature —

Barometric Pressure —

TEST: RELATIVE HUMIDITY

Paragraph: 4.15.4 SEQUENCE 3 PARA 4.3.3

Chamber Data:

Step 2 110 ± 5°F 2 hours minimum

Date 8.22.73 Time in 9:45AM Temp. 110°F
Date 8.22.73 Time out 11:45AM Temp. 110°F

Step 3 77 + 5°F 50% R. H. 24 hours

Date 8.22.73 Time in 11:45AM Temp. 77°F
Date 8-23-73 Time out 11:45AM Temp. 77°F

Step 3 Cycle

Date 8-23-73 Time in 1:45PM
Date 8-28-73 Time out 1:45PM

Step 7 77 ± 5°F 50% R. H. 12 hours

Date 8-28-73 Time in 3:30PM
Date 8-29-73 Time out ~~8~~:30 ~~AM~~

PRE-TEST STATIC FLOW CHECK 8-23-73

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.24
125	-.76
555	-1.25
300	-1.06
560	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.22
125	-.70
305	-1.25
300	-1.22
625	-2.0

RELATIVE HUMIDITY STATIC FLOW CHECK 8-28-73

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.32
125	-.68
560	-1.25
300	-.92
568	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.32
125	-.80
300	-1.25
300	-1.26
620	-2.0

POST RELATIVE HUMIDITY STATIC FLOW CHECK 8-29-73

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.34
125	-.74
560	-1.25
300	-.92
570	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.28
125	-.68
300	-1.25
300	-1.25
625	-2.0

Test Equipment: List # 1, 3, 9, 10, 11, 12

Visual Inspection: a) Corrosion in waist buckle (buckle is operable)
b) Hose ferrule & fitting @ 1/4" pipe end corroded
c) Corrosion about breathing regulator swivel fitting
d) Cadmium plate screws on backpack corroded.
e) Moisture under gage lens

Tested by: [signature]

Verified by: [signature]

DATA SHEET # 12

P/N 27275
S/N 2
Date 8-31-73
Temperature —
Barometric Pressure —

TEST: SALT FOG

Paragraph: 4.16.1 SEQUENCE 3 PARA. 4.3.4

PRE SALT FOG STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.34
125	-.74
560	-1.25
300	-.92
570	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.28
125	-.68
300	-1.25
300	-1.25
625	-2.0

POST SALT FOG STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.45
125	-.56
550	-1.25
300	-.93
555	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.38
125	-.70
300	-1.25
300	-1.23
620	-2.0

Chamber Data: Date 8-29-73 Time in 9:30 AM Temp. 98°F
Date 8-31-73 Time out 9:30 AM Temp. 98°F

Humidity 99 % R. H.

Test Equipment: LIST # 1, 3, 9, 13

Post Test Inspection:

Tested by: Edward Pfister

Verified by: Paul R. Burnett

DATA SHEET # 14

P/N 27275
S/N 2
Date 9-7-73
Temperature —
Barometric Pressure —

TEST: IMPACT SHOCK

Paragraph: 4.16.3 SEQUENCE 3 PARA. 4.3.6

PRE IMPACT SHOCK STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.44
125	-.78
520	-1.25
300	-.80
530	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.38
125	-.76
540	-1.25
300	-.92
560	-2.0

POST IMPACT SHOCK STATIC FLOW CHECK

NOT RUN

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

Test Equipment: 1, 3, 9

Visual Inspection Requirements:

Shock 1 a) GAGE LENS POPPED OUT
b) BAR ABOVE GAGE BENT DOWN CONTACTING GAGE
c) CYLINDER SURFACE SCRATCHED

Shock 2 a) CYLINDER VALVE HANDLE BROKEN
b) SURFACE OF CYLINDER AGAIN SCUFFED

Shock 3 a) RETAINER TAB ON CYLINDER VALVE STRAIGHTENED
b) CYLINDER SCUFFED AGAIN

Shock 4 THREADED NIPPLE OF CYLINDER VALVE BROKE AT THE ROOT OF THREAD

Shock 5 CYLINDER STRAP OPENED & CYLINDER PARTIALLY SEPARATED FROM BACK PACK

Shock 6 a) FIVE SCREWS SHEARED FROM COVER OF PRESSURE REDUCER
b) CYLINDER SURFACE GOUGED
c) PRESSURE REDUCER DENTED IN TWO PLACES BY CYLINDER STRAP
d) THE COVER OF THE BREATHING REGULATOR SLIGHTLY CRUSHED
e) LEFT SHOULDER STRAP AND WAIST BELT PARTIALLY CUT.

Tested by: DAYTON T. BROWN INC.

Verified by: Paul R. [signature]

DATA SHEET # 14

P/N 27275
S/N 2
Date 12-12-73
Temperature —
Barometric Pressure —

TEST: IMPACT SHOCK

Paragraph: 4.16.3 SEQUENCE 3 PARA 4.3.6
RETEST

PRE IMPACT SHOCK STATIC FLOW CHECK

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.78
125	-1.02
170	-1.25
300	-1.5
410	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.85
125	-1.1
150	-1.25
300	-1.4
96	-2.0

POST IMPACT SHOCK STATIC FLOW CHECK

NOT RUN

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	
125	
	-1.25
300	
	-2.0

Test Equipment: LIST # 1, 3, 9

Visual Inspection Requirements:

Shock 1 a) GAGE LENS POPPED OFF
b) GAGE CASE DEFORMED BE BENDING OF PLATE OVERHANGING GAGE
c) GAGE INOPERABLE

Shock 2 CYLINDER VALVE HANDLE CRACKED

Shock 3 BREATHING REGULATOR CRUSHED

Shock 4 RESIN COATING ON DOME END OF CYLINDER CRACKED BUT NOT HAZARDOUS.

Shock 5 a) LOW PRESSURE DISCONNECT INOPERABLE
b) CYLINDER STRAP POPPED OPEN AND COULD NOT RECLOSE TIGHTLY.

Shock 6 a) CYLINDER VALVE HANDLE BROKE INTO MANY PIECES
b) GAGE FACE SEPARATED FROM GAGE
c) CYLINDER VALVE POPPED OPEN.

Tested by: DAYTON T. BROWN INC.

Verified by: [signature]

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DATA SHEET # 15

P/N 27275
S/N 2
Date 9-19-73 THRU 9-27-73
Temperature —　　　Barometric Pressure —

TEST: HIGH PRESSURE HOSE TO CYLINDER VALVE CONNECTOR

Paragraph: 4.19.1　SEQUENCE 4 PARA 4.4.1

TOTAL CYCLES	INSPECTION CHARACTERISTICS
500	NO LEAKAGE
1000	NO LEAKAGE
1500	NO LEAKAGE
2000	NO LEAKAGE
2500	NO LEAKAGE TEFLON COATING LEAVING FROM THREADS
3000	NO LEAKAGE
3500	NO LEAKAGE
4000	NO LEAKAGE
4500	< 1.0 cc/min LEAK. SET SCREW OF PROBE TIGHTENED
5000	NO LEAKAGE

Test Equipment: List # 3

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Tested by: Edward Pfister

Verified by: Paul R. Bennett

DATA SHEET # 16

P/N 27275
S/N 2
Date 10-4-73
Temperature —
Barometric Pressure —

TEST: LOW PRESSURE HOSE TO PRESSURE REDUCER DISCONNECT

Paragraph: 4.19.2 SEQUENCE 4 PARA 4.4.2

TOTAL CYCLES	LEAKAGE (none allowed)
500	NO LEAKAGE
1000	2cc/MIN LEAK. *

* INTERNAL O-RING WORN. ORING WAS REPLACED AND LEAKAGE CEASED.

Test Equipment: LIST # 3

Post-test Inspection: NO DAMAGE NOTED OTHER THAN INTERNAL O-RING.

Tested by: Edward Pfister

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DATA SHEET # 17

P/N 27275
S/N 2
Date 9-25-73 TO 9-27-73
Temperature —   Barometric Pressure —

TEST: BREATHING REGULATOR TO FACEMASK CONNECTION

Paragraph: 4.19.3 SEQUENCE 4 PARA 4.4.3

TOTAL NO. OF CYCLES	LEAKAGE	
	Inward 1.5 cc/min max	Outward 200 cc/min max
500	NONE	NONE
1000	NONE	NONE
1500	NONE	NONE
2000	NONE	NONE
2500	NONE	NONE
3000	NONE	NONE
3500	NONE	NONE
4000	NONE	NONE
4500	NONE	NONE
5000	NONE	< 2 cc/min *

Test Equipment: LIST # 2, 9

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Post-Test Inspection:
*a) LEAK AT RIGHT SIDE CENTER OF SEAL.
b) VISUAL INSPECTION DID NOT ~~[illegible]~~ REVEAL APPARENT WEAR IN SEAL
c) BRASS LATCH WAS GROOVED BY HEAD OF LOCKING SCREW BUT LATCH PERFORMANCE WAS UNAFFECTED

Tested by: Edward Pfister

Verified by: Paul R. [illegible]

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Appendix A

DATA SHEET # 18

P/N 27275
S/N 2
Date 10-1-73 TO 10-9-73
Temperature —
Barometric Pressure —

TEST: CYLINDER MOUNTING IN BACKPACK

Paragraph: 4.19.4 SEQUENCE 4 PARA 4.4.4

Unit Performance: ✓ Acceptable ____ Unacceptable

Post-Test Inspection: RUBBER STRIPS GROUNDING CYLINDER SLIGHTLY WORN AT TOP. DOES AFFECT PERFORMANCE

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Tested by: Edward Pfister

Verified by: Paul P. Benst

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Appendix A

DATA SHEET # 19

P/N 27275
S/N 2
Date 10-12-73
Temperature 73 °F

Barometric Pressure 742 MMHG

TEST: OPERATIONAL CYCLING

Paragraph: 4.19.5 SEQUENCE 4 PARA 4.4.5
PRE-TEST

INHALATION MASK FLOW

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.52
125	-.70
560	-1.25
300	-.92
570	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.56
125	-.72
600	-1.25
300	-.94
670	-2.0

EXHALATION MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
250	~~+2~~ +1.1
500	~~+4~~ +2.7

Test Equipment: LIST # 1, 3, 9

DEPLETION ALARM ACTUATION 870 PSIG.

LEAKAGE (none allowed): NONE

Tested by: Edward Pfister

Verified by: Paul R. Brandt

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Appendix A

DATA SHEET # 19

P/N 27275
S/N 2
Date 11-1-73
Temperature —

Barometric Pressure —

TEST: OPERATIONAL CYCLING

Paragraph: 4.19.5 SEQUENCE 4 PARA 4.4.5
POST 5000 CYCLE TEST

INHALATION MASK FLOW

2000 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.54
125	-.58
300	-1.25
300	-1.25
500	-2.0

800 PSIG INLET	
MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
5	-.52
125	-.71
330	-1.25
300	-1.13
570	-2.0

EXHALATION MASK FLOW LPM, NTPD	MASK PRESSURE INCHES OF WATER
250	~~+2~~ +1.4"
500	~~+4~~ +2.8

Test Equipment: List # 1, 3, 5

DEPLETION ALARM ACTUATION 860 PSIG.

LEAKAGE (none allowed): NONE

Tested by: Edward Pfister

Verified by: Paul R. Bount

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Appendix A

DATA SHEET # 20

P/N 27275
S/N 2
Date 10-8-73
Temperature ______ Barometric Pressure —

TEST: PURGE VALVE

Paragraph: 4.19.6 SEQUENCE 4 PARA 4.4.6

TOTAL CYCLES	LEAKAGE (none allowed)
500	NONE
1000	NONE *
1500	NONE
2000	NONE
2500	NONE
3000	NONE
3500	NONE
4000	NONE
4500	NONE
5000	NONE

* FLOW DECREASED @ 1150 CYCLES TO 38 LPM. UNIT TORN DOWN, CLEANED AND REASSEMBLED

Test Equipment: LIST # 1, 8

Post-Test Inspection: NO DAMAGE EVIDENT

Tested by: Edward Pfister

Verified by: [illegible]

DATA SHEET # 1

P/N 27275
S/N 2
Date 11-30-73
Temperature —
Barometric Pressure —

TEST: FLOW REQUIREMENTS

Paragraph: 4.1 SEQUENCE 5 PARA 4.5.1

4.1.1 INHALATION INITIATION

Parameter	Required	Actual
Step (3) Leakage	10 scc/min. max.	6.4
Step (4) Flow Initiation @ 4000 psig inlet	-0.1 to -0.5 inches water	-0.5
Step (5) Flow Initiation @ 1000 psig inlet	-0.1 to -0.5 inches water	-0.5
Step (5) Flow Initiation @ 570 psig inlet	-0.1 to -0.5 inches water	-0.45

Test Equipment: List # 2,9

4.1.2 INHALATION FLOW AT INTERMEDIATE AND MAXIMUM SPECIFIED NEGATIVE PRESSURE

Parameter	Resulting Flow LPM,NTPD
Step (3) Flow @ -2.0 inches water 4000 psig inlet	500
Step (4) Flow @ -2.0 inches water 1000 psig inlet	470
Step (4) Flow @ -2.0 inches water 570 psig inlet	560
Step (4) Flow @ -2.0 inches water 100 psig inlet	330
Step (5) Flow @ -1.25 inches water 4500 psig inlet	260
Step (5) Flow @ -1.25 inches water 1000 psig inlet	250
Step (5) Flow @ -1.25 inches water 570 psig inlet	120
Step (5) Flow @ -1.25 inches water 100 psig inlet	140

Test Equipment: List # 4, 9, 1

4.1.3 EXHALATION INITIATION & STATIC FLOW

Parameter	Required	Actual
Step (3) Exhalation Initiation	0.1 to 0.5 inches water	+0.2
Step (4) Exhalation Flow @ +2.0 inches water mask pressure	257 LPM NTPD minimum	380
Step (4) Exhalation Flow @ +4.0 inches water mask pressure	476 LPM NTPD minimum	550

Test Equipment: List 1, 2, 9

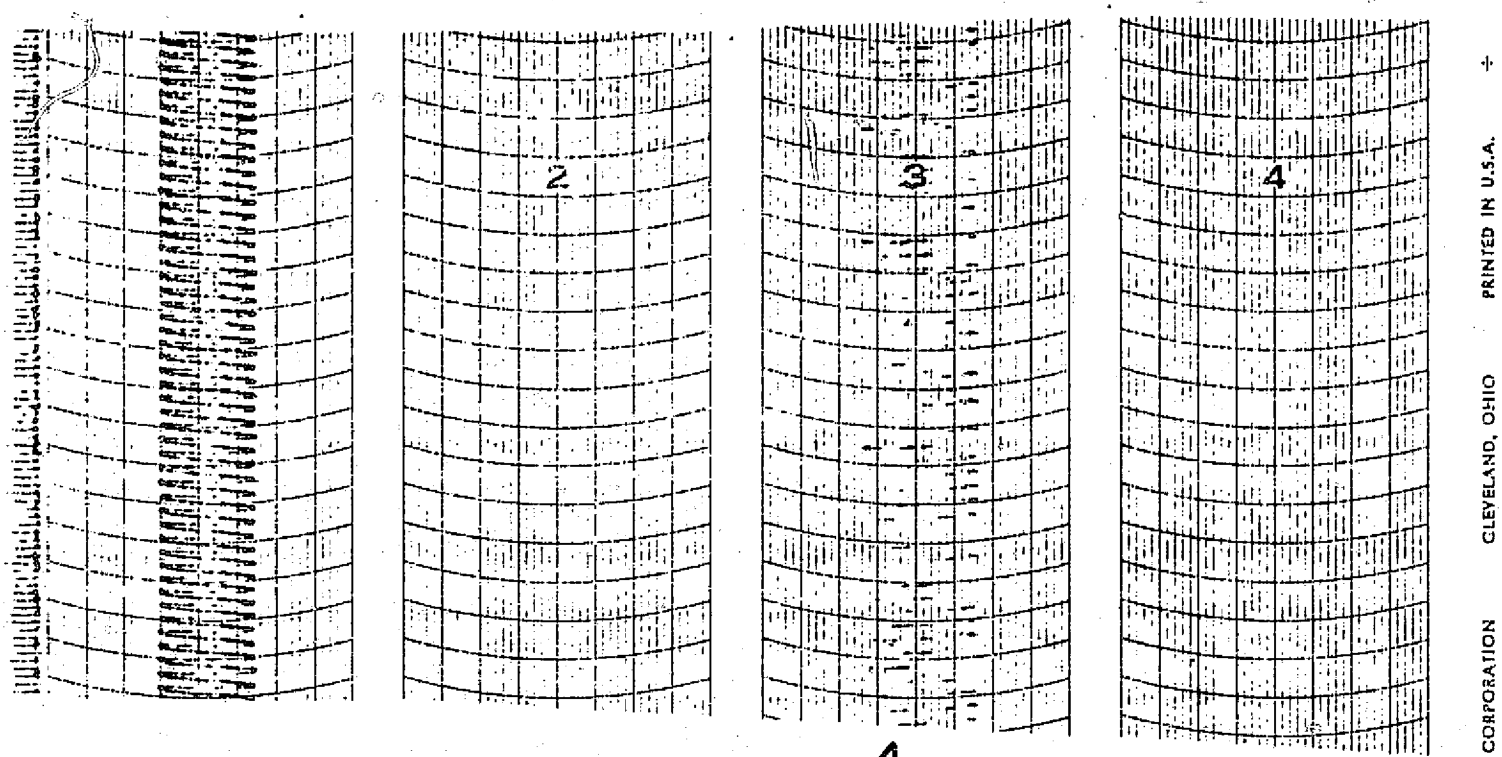
4.1.4 DYNAMIC FLOW REQUIREMENTS

Parameter	Required	Actual
Step (3) Peak Inhalation Pressure	-1.25 inches Water Max.	-1.4
Step (3) Peak Exhalation Pressure	+2.0 Inches Water Max.	+1.0
Step (3) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	850
Step (3) Total Time from High to Low Cylinder Pressure	N/A	13 MIN 50 SEC
Step (4) Peak Inhalation Pressure	-2.0 inches Water Max.	-2.0
Step (4) Peak Exhalation Pressure	+4.0 inches Water Max.	+1.9
Step (4) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	850
Step (4) Total Time from High to Low Cylinder Pressure	N/A	6 MIN 50 SEC

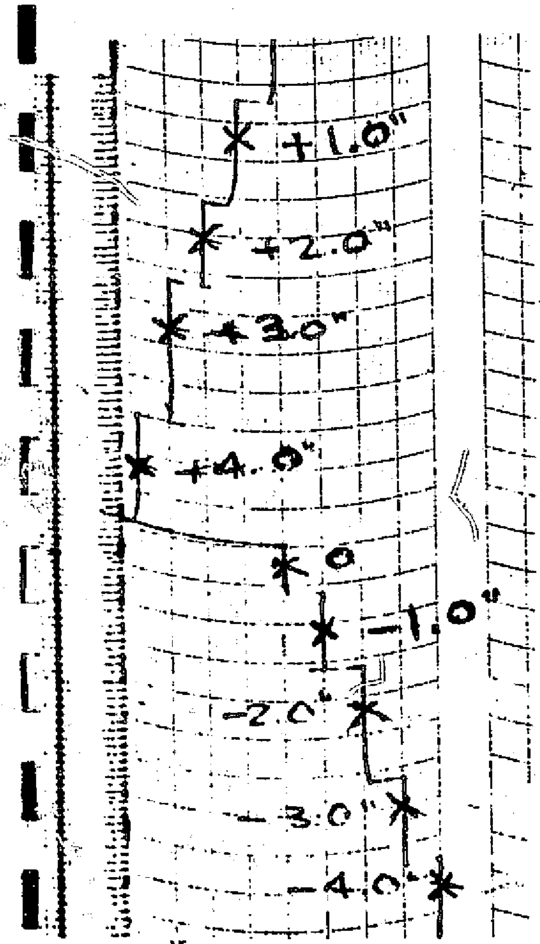
Test Equipment: List # 2, 4, 9, 14, 15, 16, 18

Tested by: Edward Pfister

Verified by: Paul P. [illegible]



NOTE: Pen on flow channel inoperative.



Mask Pressure
Inches of Water
Calibration

Dynamic Flow Requirements
Peak Flow & Mask Pressure
257 LPM Peak Flow
Purge Valve Closed

12/3/73

DATA SHEET # 2

P/N 27275
S/N 2
Date ~~11-30-73~~ 12-5-73
Temperature —
Barometric Pressure —

TEST: DYNAMIC PURGE CAPABILITY

Paragraph: 4.3.1 SEQUENCE 5 PARA 4.5.3

Parameter	Required	Actual
Step (3) Peak Inhalation Pressure	-1.25 inches Water Max.	-1.20
Step (3) Peak Exhalation Pressure	+2.0 Inches Water Max.	+2.2
Step (3) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	850
Step (3) Total Time from High to Low Cylinder Pressure	N/A	5 MIN 7 SEC
Step (4) Peak Inhalation Pressure	-2.0 inches Water Max.	-2.0
Step (4) Peak Exhalation Pressure	+4.0 inches Water Max.	+4.0
Step (4) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	850
Step (4) Total Time from High to Low Cylinder Pressure	N/A	3 MIN 25 SEC

Test Equipment: List # 2, 4, 9, 14, 15, 16, 18

DATA SHEET # 2 (continued)

P/N 27275
S/N 2
Date 11-30-73
Temperature — Barometric Pressure —

TEST: STATIC PURGE CAPABILITY

Paragraph: 4.3.2 SEQUENCE 5, PARA 4.5.3

PARAMETER	REQUIRED	ACTUAL
Step (3) Flow at 4000 psig cylinder pressure	111.2 LPM NTPD	165
3500		170
3000		175
2500		170
2000		170
1500		170
1000		180
800		200
500		210
100		180

Tested by: Edward Pfister

Verified by: R. P. Bent

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DATA SHEET # 7

P/N 27275
S/N 2
Date 11 30-73
Temperature —
Barometric Pressure —

TEST: SYSTEM LEAKAGE

Paragraph: 4.13 SEQUENCE 5 PARA 4.5.5.

Parameter	Required	Actual
Step (2) System Leakage	No leakage	NONE

Tested by: Edward Pfister

Verified by: Paul R. Barst

DATA SHEET # 21

P/N 27215
S/N 2
Date 11-30-73
Temperature —
Barometric Pressure —

TEST: LEAKAGE (CYLINDER VALVE/CYLINDER ASSEMBLY)

Paragraph: 4.21 SEQUENCE 5 PARA 4.5.6

Total leakage 0 cc/24-hr.

Leakage Rate 0 cc/hr.
(0.5 cc/hr. maximum)

Test Equipment: LIST #17

Tested by: Edward Pfister

Verified by: Paul P. Bent

DATA SHEET # 22

P/N 27275
S/N 2
Date 11-30-73
Temperature —
Barometric Pressure —

TEST: ACTUATION (DEPLETION WARNING DEVICE)

Paragraph: 4.22 SEQUENCE 5 PARA 4.5.7

Actuation Pressure 850 PSIG
(880 to 830 psig required)

Remarks:

Test Equipment: List # 3

Tested by: Edward Pfister

Verified by: Paul R. Scott

DATA SHEET # 23

P/N 27275
S/N 2
Date 1-30-73
Temperature —

Barometric Pressure —

TEST: SIGNAL FREQUENCY AND INTENSITY

Paragraph: 4.23 SEQUENCE 5 PARA 4.5.8

Background noise level 62 dB.

MASK FLOW LPM, NTPD	SIGNAL INTENSITY dB (70 to 90 dB required)	SIGNAL FREQUENCY Hz
55	98	3570

Test Equipment: List # 1, 9, 20, 21

Tested by: Edward Pfister

Verified by: Paul R. [illegible]

DATA SHEET # 6

P/N 27275
S/N 2
Date ~~[illegible]~~ 12-11-73
Temperature —

Barometric Pressure —

TEST: OVERPRESSURIZATION PROTECTION

Paragraph: 4.12 SEQUENCE 6 PARA 4.6.1

PARAMETER	REQUIRED	ACTUAL
Step (4) Burst Pressure Frangible Disc	4500-5000 PSIG	4100

Test Equipment: List # 5

Tested by: Edward Pfister

Verified by: [illegible]

DATA SHEET # 8

P/N 27275
S/N 2
Date 11-30-73
Temperature —

Barometric Pressure —

TEST: PRESSURE GAGE ACCURACY

Paragraph: 4.14 SEQUENCE 6 PARA 4.6.2

Increasing Pressure:

Gage Reading	Required	Actual
10 x 100 psig	1000 ± 225 psig	950
20 x 100 psig	2000 ± 225 psig	1960
30 x 100 psig	3000 ± 225 psig	2880
full	4000 ± 225 psig	3800
45 x 100 psig	4500 ± 225 psig	4250

Decreasing Pressure:

Gage Reading	Required	Actual
10 x 100 psig	1000 ± 225 psig	1050
20 x 100 psig	2000 ± 225 psig	1980
30 x 100 psig	3000 ± 225 psig	2860
full	4000 ± 225 psig	3800
45 x 100 psig	4500 ± 225 psig	4250

Test Equipment: List #4

Tested by: Edward Pfister

Verified by: Paul R. Best

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Appendix A

DATA SHEET # 4

P/N 27275
S/N 2
Date 12-11-73
Temperature —
Barometric Pressure —

TEST: BURST PRESSURE

Paragraph: 4.5 SEQUENCE 7 PARA 4.7

COMPONENT	PRESSURE (PSIG)	POST TEST INSPECTION
Cylinder & Valve Assy.	11,250	NO DAMAGE
High-Pressure Hose	11,250	NO DAMAGE
Pressure Reducer (high-pressure section)	11,250	NO DAMAGE
Pressure Reducer (low-pressure section)	312.5	NO DAMAGE
Low-Pressure Hose	312.5	NO DAMAGE
Breathing Regulator	312.5	NO DAMAGE

Test Equipment: List # 3, 6, 8

Tested by: Edward Pfister

Verified by: [illegible]

EXHIBIT III

SCOTT ATO
225 ERIE STREET
LANCASTER, N.Y. 14086
TEL. 716 683-5100
TELEX 91-394

Engineering Report No. ER-1039

Firefighter's Breathing System

NASA Contract No. NAS9-13177

Facepiece-to-Face Leakage Development Tests
Paragraphs 4.24 and 4.25 (ER-1027)

Dated: 14 February 1974

Prepared by: D. W. Watkins, Jr.
D. W. Watkins, Jr.
Staff Engineer

Approved by: J. L. Sullivan
J. L. Sullivan
Manager of Engineering-
Health/Safety Products

1.0 INTRODUCTION

Inward leakage sealing characteristics of the Firefighter's Breathing System (FBS) facemask were determined experimentally by utilizing a test panel of 16 selected subjects, exposing each to a challenge atmosphere while wearing the mask and determining the amount of challenge atmosphere leakage into the mask.

Outward leakage sealing characteristics of the mask were determined experimentally by pressurizing the space between the subject's face and mask to a given level above ambient and measuring the outward flow of air to ambient.

The tests, procedures and setups are described in Scott Engineering Report No. ER-1027.

2.0 CONCLUSIONS:

1. Of the 16-man panel, 9 had inward leakage rates greater than 1.5 standard cubic centimeters per minute (sccm) while at rest. When talking, only 5 subjects had leakage rates greater than 1.5 sccm.
2. The highest inward leakage rate was 4.6 sccm while the subject (No. 16) was breathing at an average rate of 12.3 liters per minute (lpm). This very low level of leakage would permit working in a contaminated atmosphere of 2600 times the 8-hour Threshold Limit Value (TLV).
3. The FBS facemask provides a protection factor of better than 2600 when tested with 16 subjects fitting the criteria of the National Institute of Occupational Safety and Health (NIOSH) for a panel representing a range of typical male full facemask users.
4. Outward leakage results indicated that 5 subjects had rates greater than the required 200 sccm at 3 inches of water ("H_2O) pressure.

5. Of the 5 subjects with outward leakage rates above 200 sccm, only one (No. 24, the individual with the smallest face) has inward leakage rates above 1.5 sccm, both at rest and talking.

3.0 TEST PROTOCOL AND RESULTS

3.1 Inward Leakage (Paragraph 4.24; ER-1027)

3.1.1 Procedure

The test procedure consists of exposing a test subject, wearing the test mask, to a challenge atmosphere containing a controlled amount of helium, and then measuring the amount of helium leaking into the mask. The test setup is shown in Figure 1.

The detailed procedure followed was:

"Inward Leakage (Facemask)

"NOTE: Appearing in Appendix B of this procedure is a report titled "Analysis of Utilization of Helium Leak Detector to Measure Face Mask Leakage". (This report gives detailed information as to derivation of methods and techniques used to determine inward leakage.)

"(1) Calibrate the helium leak detector using a 16 PPM concentration of helium in air.

"(2) Place the facemask/breathing regulator assembly on a user and complete the setup shown in Figure 1.

"(3) Evacuate the plastic bag by squeezing or by vacuum and then flood with a gas mixture of 9 parts air and 1 part helium by volume.

"(4) After a short period to allow the system to reach equilibrium, measure the inward leakage shown on the leak detector which is sampling the subject's exhaled gases and convert to a rate in scc/min. This rate cannot exceed 1.5 scc/min.

"(5) The above test should be repeated once each on a panel of sixteen (16) subjects selected by the facial characteristics of face length and width according to methods derived from:

(a) "LASL Respirator Test Panel Representative of U. S. Male Facial Sizes" dated 1972, conducted by Los Alamos Scientific Laboratory; Hyatt, Hack, Moore & Richards.

(b) "Anthropometry for Respirator Sizing" Final Report April 30, 1972, Webb

Associates; Yellow Springs, Ohio.

McConville, Churchill & Laubach.

(c) A 1967 USAF Facial Dimensions Study."

<u>Note</u>: Appendix B referred to above is Scott Engineering Report No. ER-1029 and is briefly summarized below.

(6) Helium concentrations in all gas samples - challenge, leakage and calibration - were determined using a VEECO helium leak detector. The VEECO is a mass spectrometer system, Figure 2, which senses helium partial pressure and is calibrated to read helium concentrations in parts per million (ppm). Calibration gas concentrations were chosen to be 5, 20, 35 and 50 ppm, in addition to the 16 ppm noted in (1) above. Ambient air normally has 5 ppm helium at all times. Calibration runs with helium additions of 11, 15, 30 and 45 ppm confirmed the 5 ppm background level. Using a challenge atmosphere of 10% helium (100,000 ppm) permitted ready detection of inward leakage rates of less than 1 sccm.

To assure accuracy, the VEECO was calibrated between each subject. Comparison of day-to-day raw data established repeatability. The VEECO system can detect changes of less than 1 ppm of helium. Since for these data the interest is in delta values of 15 ppm, there is an implied accuracy of greater than 10%. The referenced report provides detailed explanation mass spectrometry sensitivity.

For example, subject #16 had a breathing rate (respiratory minute volume) of 12.3 lpm and leakage of 42 ppm at rest and 19 ppm while talking. The respective leakage rates are:

(a) (observed ppm -5) x breathing rate x helium dilution x conversion factors = leakage rate in sccm.

(b) (observed ppm -5) x lpm x 10^{-2} = sccm leakage.

(c) $\frac{(42-5)}{1,000,000} \times 12.3 \times \frac{10}{1} \times 1000 = 4.6$ sccm.

(d) $(19-5) \times 12.3 \times 10^{-2} = 1.7$ sccm.

SUBJECT NAME	NO.	DATE	BREATHING RATE LPM	LEAKAGE AT REST PPM	LEAKAGE AT REST SCCM	LEAKAGE TALKING PPM	LEAKAGE TALKING SCCM	REMARKS
Paul Bement	1	9/14/73	12.2	9	0.5	6	<0.5	
Gene Giorgini	14	9/14/73	14.0	13	1.1	13	1.1	
John Sullivan	20	9/17/73	10.7	24	2.0	19	1.5	
Carl Erbach	9	9/17/73	11.1	13	0.9	10	0.6	
Joe Trinkwalder	5	9/13/73	14.8	23	2.7	19	2.1	
Ray Rusek	25	9/18/73	14.8	23	2.7	15	1.5	
Dick Kaczmarek	30	9/18/73	10.7	32	2.8	14	0.8	
Henry Filipiak	31	9/18/73	13.3	18	1.7	16	1.5	
Dave Lechner	19	9/19/73	10.7	34	3.1	20	1.6	
Buster Eidenier (smallest face)	24	9/19/73 (Hand held facepiece prior to data to get leak rate down.)	8.5	32	2.3	28	2.0	Facepiece pulled very tight; subject uncomfortable.
Bob Planter	16	9/19/73 (Despite tight straps, leakage above desired value of 1.5.)	12.3	42	4.6	19	1.7	Finger pressure in cheek area
Pat Griffin	21	9/20/73	13.1	15	1.2	14	1.1	
Rolly Flick	13	9/20/73	14.4	15	1.4	16	1.6	
Elmer Grimm	12	9/21/73 (Unable to get positive pressure seal.)	12.6	18	1.6	12	.9	Mask pulled very tight.
Norm Laschinger	18	9/21/73 (Unable to get above 1" H_2O positive pressure at 200 sccm.)	13.4	13	1.1	8	.4	
Tom Cleary	32	9/21/73	13.8	10	.7	8	.4	

3.1.3 Discussion

Breathing rate was determined by recording the total air consumed by a subject divided by the duration of consumption. For short periods during the test, the subject was asked to force ventilate; this latter rate was not measured.

During the test, the subject remained at rest except for short periods when he was asked first to talk, second to force ventilate, and third to induce a leak. Prior to the test, the subject adjusted the mask and then if there was leakage indicated by the VEECO, the subject readjusted the mask while in the challenge atmosphere.

The data recorded "at rest" was taken after the VEECO readings had stabilized. The "talk" readings followed the "at rest" data. At the end of the test, the individual was asked to induce a leak to further verify that the measuring system was operating. (There were no failures of measuring the induced leak. It is of interest to note that indication of leakage - meter going off scale - occurred within seconds after the leak was induced.)

Leakage at rest was higher than leakage while talking for all subjects except one (#13). The lower leakage while talking is attributed to the seal constantly being moved and being resealed on a dynamic face.

None of the subjects had either hair or unusual features such as a scar or crease transversing the sealing area of the mask. Subject #24 had the smallest face, still within the limits of the NIOSH panel requirements. For this test, the mask was sealed tightly to face to effect the best seal. For two cases, the mask was pulled tight enough to be mildly uncomfortable, which was noted in Remarks. It should be noted that a specified leakage of 1.5 sccm for a breathing rate of 10 lpm represents a 0.015% leakage or an equivalent protection factor of over 6600.

3.2 Outward Leakage

3.2.1 Procedure

Pressure above ambient is applied between the subject's face and a specially modified mask. Leakage outward to atmosphere is measured. The subject's breathing is isolated from the pressurized volume and does not affect the leakage measurement.

The detailed procedure from Scott Report No. ER-1027 is as follows:

"4.25 Outward Leakage (Facemask)

"(1) Place a facemask, which has been modified to provide a tube for the subject to inhale and exhale through, along with a pair of nose pinchers, on a subject (Figure 3).

"(2) Slowly increase the internal mask pressure to 3.0 inches of water.

"(3) Note and record the amount of gas flowing into the mask shown on the flowmeter. This amount should not exceed 200 scc/min.

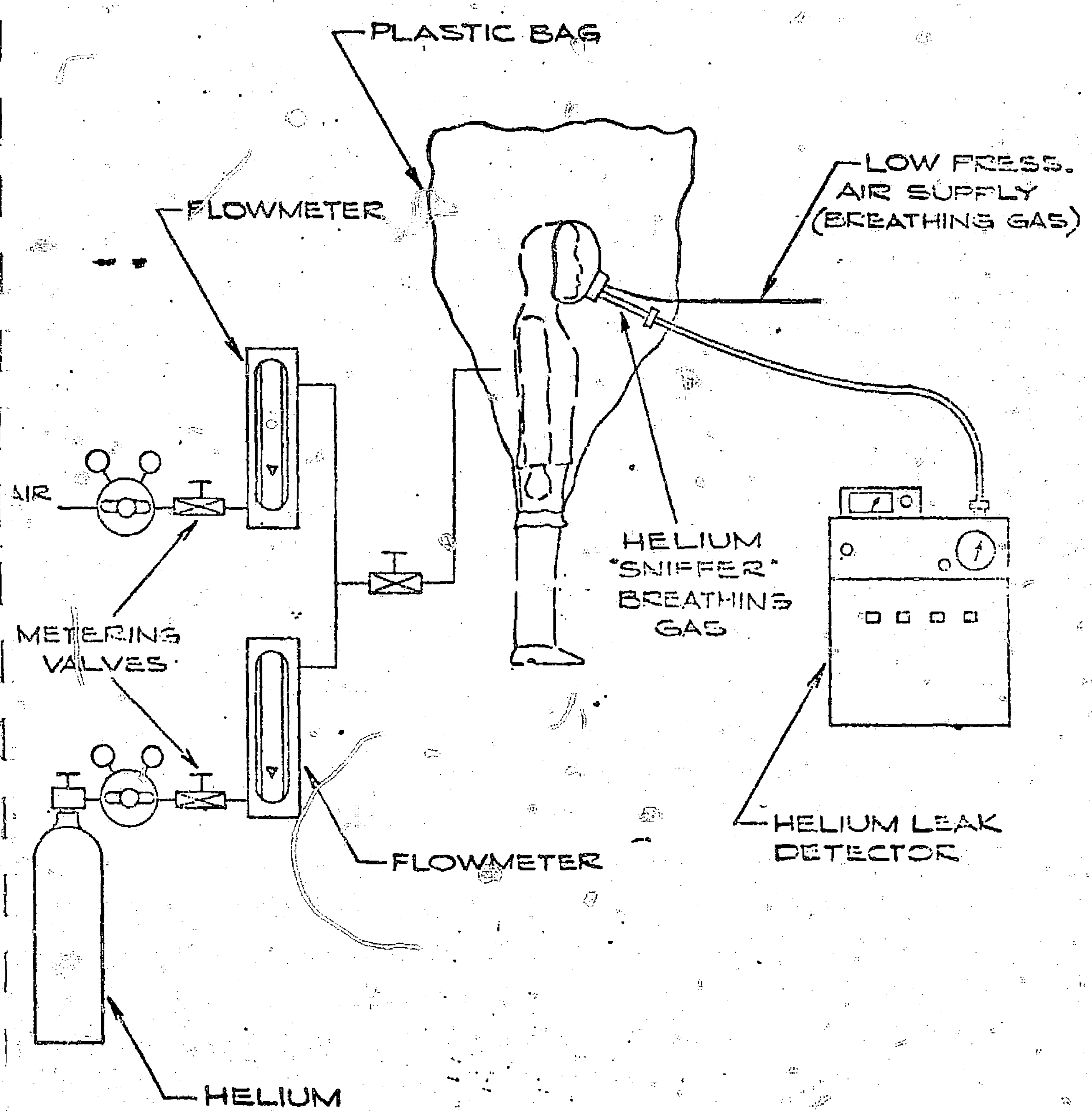
"(4) Repeat the above test for each of the sixteen (16) subjects used to determine inward mask leakage in Para. 4.24."

3.2.3 Discussion

Five of the sixteen subjects had outward leakage greater than specification. As a refinement of the test procedure, it was found desirable to record either the leakage at 3" H_2O pressure or to record the highest pressure that could be obtained at 200 sccm flow. It should be noted that subject #9, while recorded in the Δp column, meets the requirements since the Δp necessary to obtain 200 sccm flow was greater than 2" H_2O.

Both subjects #12 and #18, while having high positive pressure outward leakage, demonstrated relatively low inward leakage rates. Both individuals have very hollow cheeks.

NAME	NO.	DATE	LEAKAGE RATE @ 3" H_2O CC/MIN.	OR	" H_2O @ 200 CC/MIN.	REMARKS
Paul Bement	1	9/14	20			
Gene Giorgini	14	9/14	50			
John Sullivan	20	9/17	15			
Carl Erbach	9	9/17			3.9	
Joe Trinkwalder	5	9/17	15			
Ray Rusek	25	9/18	15			
Dick Kaczmarek	30	9/18	40			
Henry Filipiak	31	9/18			1½	Small face, mask pulled tignt.
Dave Lechner	19	9/19	50			
Buster Eidenior	24	9/19			1	Smallest face, mask pulled tight.
Bob Planter	16	9/19	200		3	
Pat Griffin	21	9/20	250			
Rolly Flick	13	9/20	50			
Elmer Grimm	12	9/21			.2	Smaller Face, mask tight.
Norm Laschinger	18	9/21			1.0	
Tom Cleary	32	9/21	50			



Para. 4.2.4
Inward Leakage

FIGURE 1

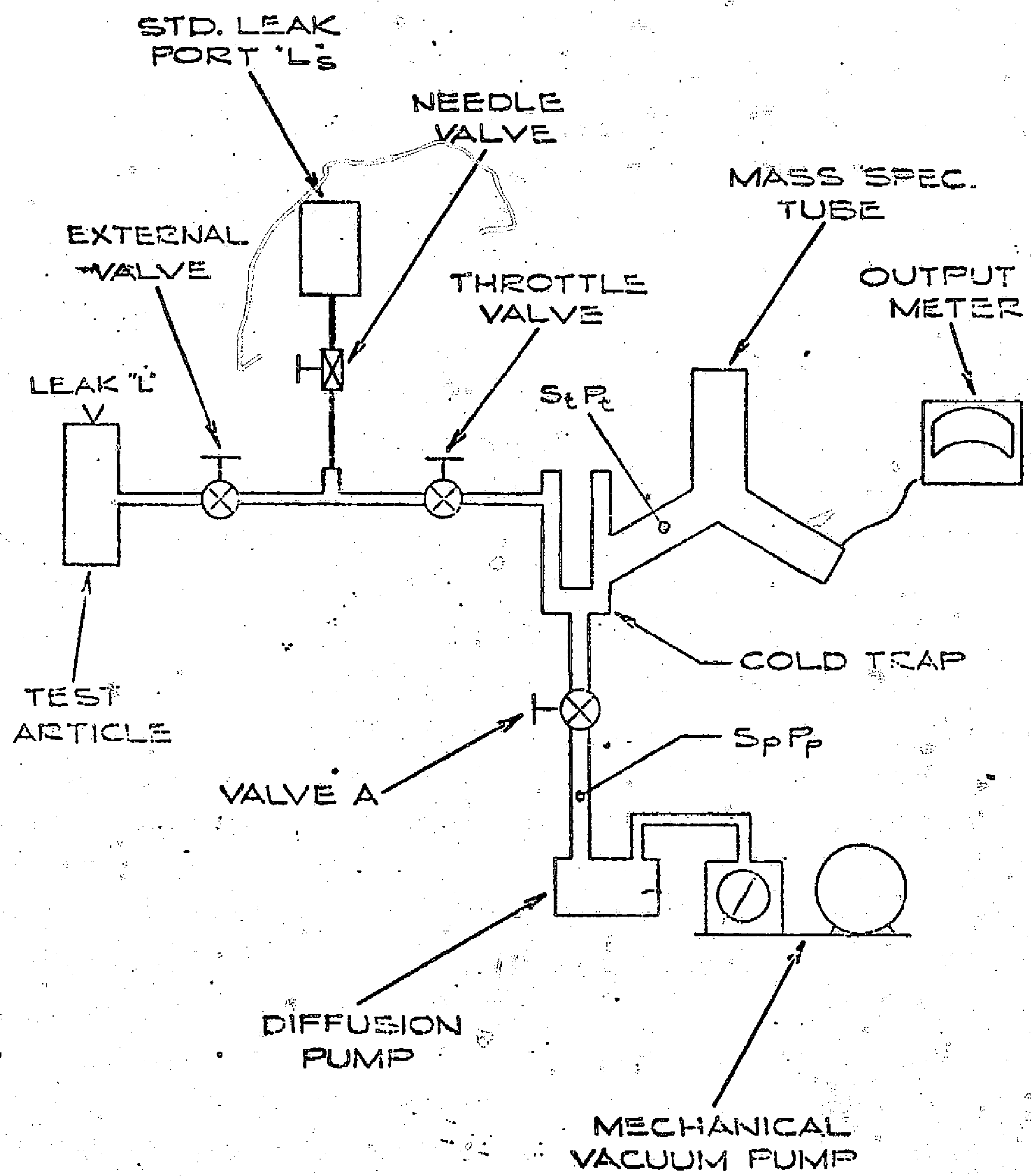
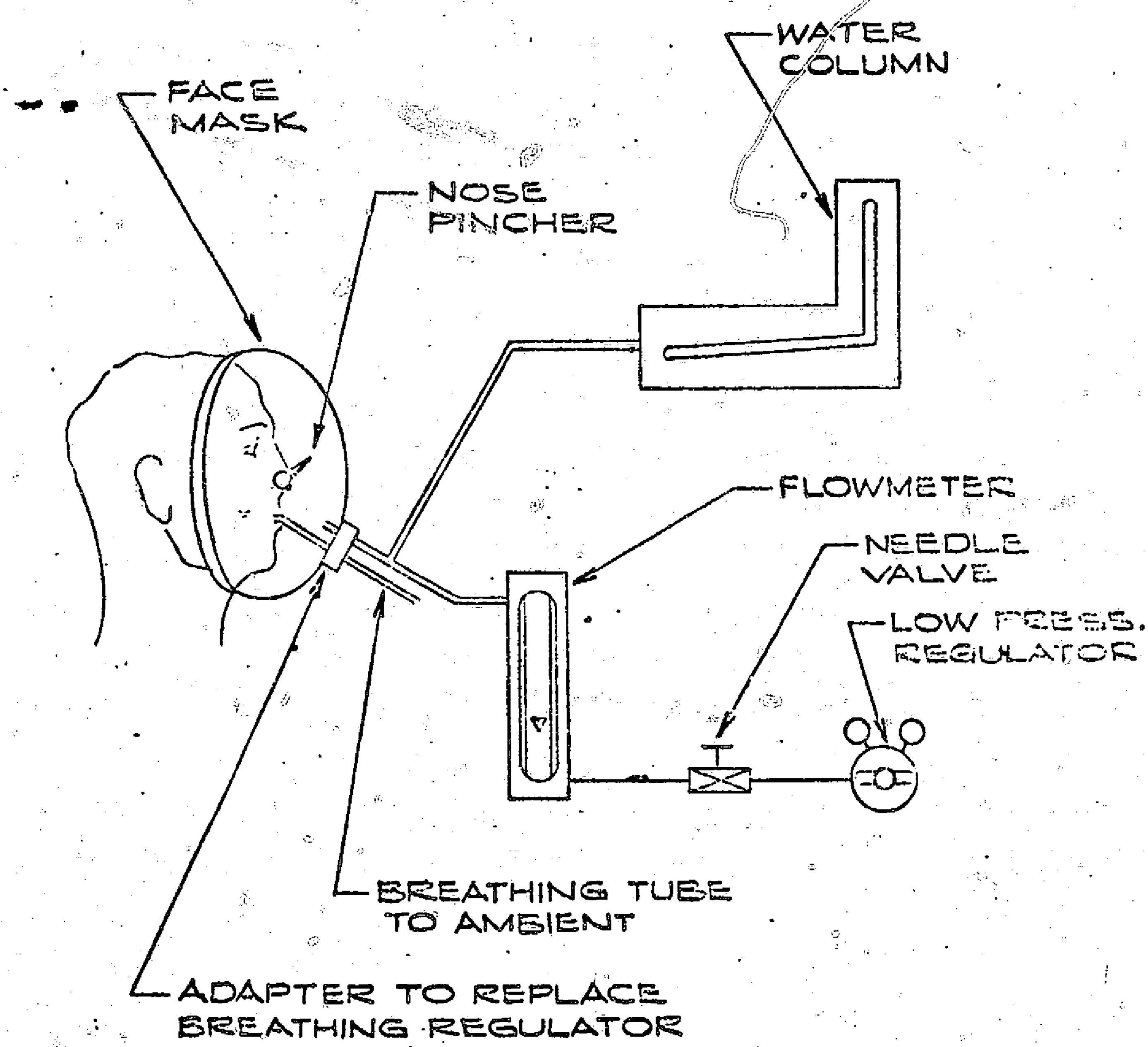

STD. LEAK
PORT 'L's
NEEDLE
VALVE
MASS SPEC.
TUBE
EXTERNAL
VALVE
THROTTLE
VALVE
OUTPUT
METER
LEAK "L"
$S_t P_t$
COLD TRAP
TEST
ARTICLE
$S_P P_P$
VALVE A
DIFFUSION
PUMP
MECHANICAL
VACUUM PUMP

FIGURE 2



Para. 4.25 FIGURE 3
Outward Leakage

EXHIBIT IV

RECEIVED
SEP 24 1973
ENG.

DAYTON T. BROWN INC.

Testing Laboratories Division

CHURCH STREET, BOHEMIA, L.I., N.Y. 11716

AREA CODE 516 LT 9-6300

TEST REPORT No. DTB04R73-1417

DAYTON T. BROWN, INC. JOB No. 400173-00-000

CUSTOMER	SCOTT AVIATION 225 ERIE STREET LANCASTER, NEW YORK
SUBJECT	SAND AND DUST AND DROP TEST PROGRAM PERFORMED ON ONE (1) FIREMAN'S BREATHING SYSTEM, SYSTEM NUMBER 2

ATTENTION: Mr. P. Bement

This report contains: Three (3) Pages and Two (2) Enclosures

PREPARED BY	E. J. Blom *E.J. Blom*
PROJECT ENGINEER	P. B. McNally *P.B. McNally*
Donald E. [illegible] Department Manager	*D. Schaefer*
DATE	13 September 1973

THE DATA CONTAINED IN THIS REPORT WAS OBTAINED BY TESTING IN COMPLIANCE WITH THE APPLICABLE TEST SPECIFICATION AS NOTED

TABLE OF CONTENTS

ADMINISTRATIVE INFORMATION:

Customer: Scott Aviation
Lancaster, New York

Test Item Description: One (1) Fireman's Breathing System

Part Number(s): None

Serial Number(s): System Number 2

Date(s) Received: 5 September 1973

Date(s) Shipped: 7 September 1973

Customer Representative(s) Present During Portions of Test:

Name	Affiliation
Mr. Paul Bement	Scott Aviation

GENERAL TEST INFORMATION

The test item was nonoperating during this test.

The test item successfully completed all phases of testing.

Test data pertinent to this test program will remain on file at Dayton T. Brown, Inc., for ninety (90) days.

REFERENCES:

(a) Customer Purchase Order Number 46505C

(b) Dayton T. Brown, Inc. Job Number 400173-00-000

(c) Government Contract Number Not Applicable

(d) Test Specification Sand and Dust: MIL-STD-810B
Drop: Scott Test Procedure TP ER-1027

TEST PROGRAM SUMMARY:

TEST	REPORT ENCLOSURE	TEST ITEM DESCRIPTION	DATE STARTED	DATE COMPLETED	REMARKS
Sand & Dust	1	Fireman's Breathing System	5 Sept	6 Sept	See Report Enclosure
Drop	2		7 Sept	7 Sept	See Report Enclosure

Enclosure 1

Sand And Dust Testing

And Results

TEST REQUIREMENTS

Sand and Dust Testing in accordance with MIL-STD-810B, Method 510, Procedure I.

TEST PROCEDURE With the unit pressurized to 4500 psig the following sequence of testing was performed.

Step 1: A pretest visual inspection of the test item was performed.

Step 2: The test item was installed in a test chamber, no closer than four inches from the chamber walls or any other object or material capable of furnishing protection. The test item was oriented so that the most vulnerable or critical parts were exposed to the dust stream.

Step 3: Chamber controls were adjusted to maintain an internal chamber temperature of 23°C (73°F) and a relative humidity of less than 22 percent. The dust velocity was adjusted to 1,750 $\pm$ 250 feet per minute. The dust concentration was set at 0.3 $\pm$ 0.2 grams per cubic foot. These conditions were maintained for six hours.

Step 4: Dust feed was halted and the air velocity was reduced to 300 $\pm$ 200 feet per minute. The internal chamber temperature was raised to 63°C (145°F) and the relative humidity was adjusted to less than 10 percent. These conditions were maintained for approximately sixteen hours.

Step 5: While maintaining an internal temperature of 63°C (145°F), the air velocity was raised to 1,750 $\pm$ 250 feet per minute. The dust concentration was adjusted to 0.3 $\pm$ 0.2 grams per cubic foot. These conditions were maintained for six hours.

Step 6: Chamber controls were turned off and the test item was permitted to return to standard ambient conditions.

Step 7: The test item was removed from the chamber and any accumulated dust was removed by brushing, wiping or shaking.

Step 8: A post test visual inspection of the test item was performed.

Step 9: The unit was checked for proper operation.

TEST RESULTS

A Pretest Visual Inspection of the test item revealed no anomalies.

All testing was performed within the limits of the referenced specification.

A post Test Visual Inspection revealed a surface residue of Sand & Dust.

At the conclusion of the Sand and Dust Test the unit was still pressurized to 4500 PSIG.

TEST EQUIPMENT

TEST

*	ITEM	MANUFACTURER	MODEL	S/N	ACCURACY
X	Sand and Dust Chamber	Tenney Engineering Company	4' x 10'	2656	-
X	Temperature Recorder/Controller	Bristol	TE-1T500 F-3B	661087	± 2°F
	Density Indicator/Controller	Tenney Engineering Company	565	4-19-57	± 4%
X	Density Indicator/Controller	Dayton T. Brown	0 to $.5 gm/ft^3$	D.T.B. 57-12	Data
X	Anemotherm	Anemostat Corp. of America	60	DTB 43-3	100 to 8,000 fpm ±5% ind.
X	Thermometer	0-220°F	DTB 39-255	± 2°F	
	Thermo Couple	Thermoelectric	20 gauge	D.T.B.	± .75°F
	Thermo Couple	Thermoelectric	20 gauge	D.T.B.	± .75°F
	Thermo Couple	Thermoelectric	20 gauge	D.T.B.	± .75°F
	Thermo Couple	Thermoelectric	20 gauge	D.T.B.	± .75°F

* X Indicates equipment used.

Test equipment utilized for the program reported herein was within its assigned interval of calibration. Details are on file at Dayton T. Brown, Inc. and will be made available upon request.

Enclosure 2

Drop Test and Results

TEST REQUIREMENTS

Drop testing in accordance with Scott Aviation Test Procedure TP ER-1027.

TEST PROCEDURE

A Pretest Visual Inspection was performed.

With the unit pressurized to 4500 psig, the unit was dropped from a height of six (6) feet onto a flat concrete surface, one (1) drop per orientation noted by Figure 1 of this Enclosure.

A Post Test Visual Inspection of the test item was performed.

TEST RESULTS

A Pretest Visual Inspection of the test item revealed no anomalies.

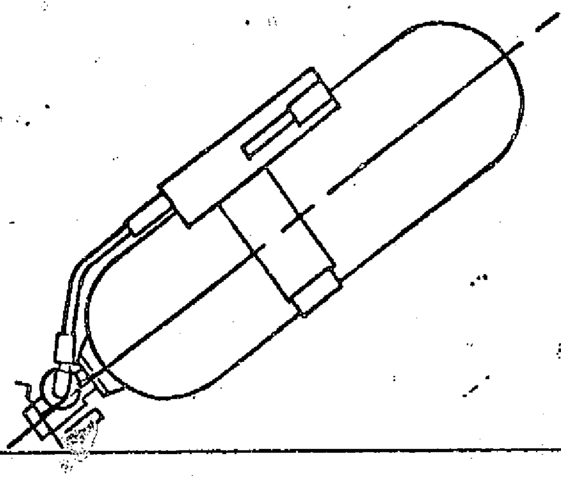
All testing was performed within the limits of the referenced specification.

Post Drop Tests revealed the following results:

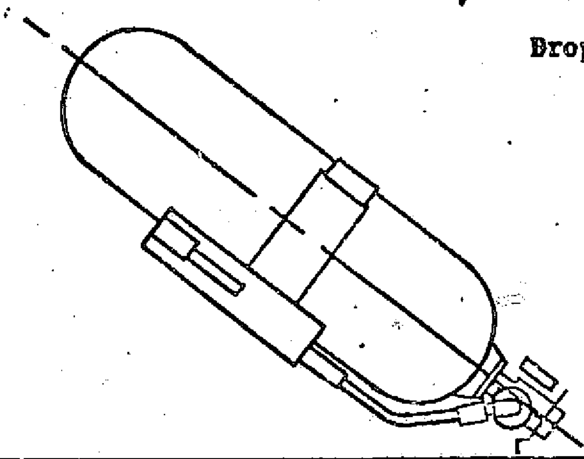
Post Drop Number	Post Drop Results
1	(a) Gauge shield bent (b) Gauge bent (c) Gauge glass popped out
2	(a) Bottle Retainer Tab bent straight
3	(a) Cylinder Valve broke off
4	(a) High pressure connection broke off at the cylinder valve
5	(a) Bottle strap popped open
6	(a) Left shoulder and left waste straps cut (b) Breathing regulator dented (c) Pressure Reducer cover open (d) Five screws of pressure reducer sheared off (e) Dents in pressure reducer (Dented by Bottle strap) (f) Bottle has cuts in it from bottle strap and pressure reducer

At the conclusion of the six (6) drops the unit was still pressurized to 4500 PSIG.

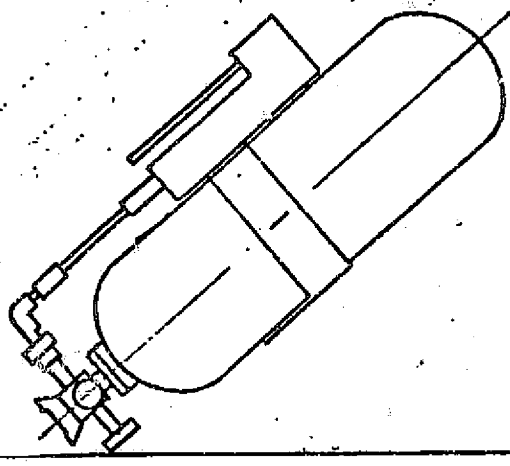
Drop 1



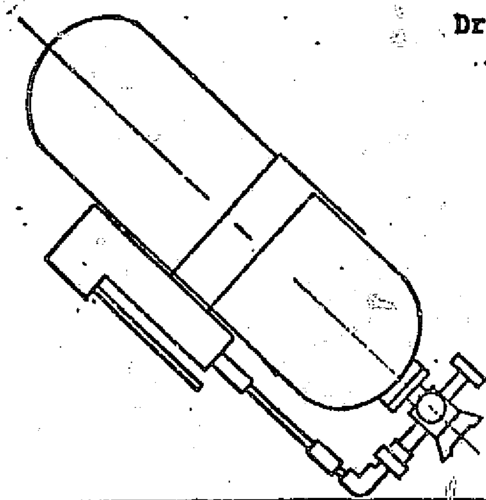
Drop 2



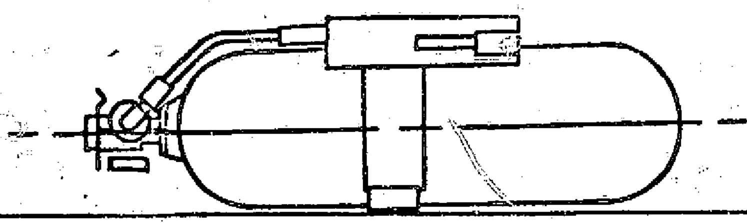
Drop 3



Drop 4



Drop 5



Drop 6

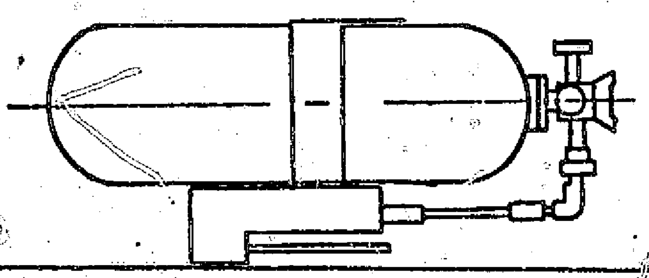


FIGURE 1

C-4

1

DAYTON T. BROWN INC.

Testing Laboratories Division

CHURCH STREET, BOHEMIA, L.I., N.Y. 11716

AREA CODE 516 LT 9-6300

TEST REPORT No. DTB04R73-2100

DAYTON T. BROWN, INC. JOB No. 400293-00-000

CUSTOMER

SCOTT AVIATION
225 ERIE STREET
LANCASTER, NEW YORK

SUBJECT

DROP TEST PROGRAM PERFORMED ON
ONE (1) FIREMAN'S BREATHING SYSTEM

SERIAL NUMBER: 36

ATTENTION: Mr. Harig

THIS REPORT CONTAINS: Three (3) Pages and One (1) Enclosure.

PREPARED BY	For W. Pellenz E. J. Brown
PROJECT ENGINEER	P. B. McNally P. B. McNally
Donald E. Schaefer Department Manager	D. E. Schaefer
DATE	26 December 1973

THE DATA CONTAINED IN THIS REPORT WAS OBTAINED BY TESTING IN COMPLIANCE WITH THE APPLICABLE TEST SPECIFICATION AS NOTED

TABLE OF CONTENTS

ADMINISTRATIVE INFORMATION:

Customer: Scott Aviation
Lancaster, New York

Test Item Description: One (1) Fireman's Breathing System

Part Number(s): None

Serial Number(s): 36

Date(s) Received: 13 December 1973

Date(s) Shipped: 13 December 1973

Customer Representative(s) Present During Portions of Test:

Name	Affiliation
Mr. Paul Bement	Scott Aviation

GENERAL TEST INFORMATION

The test item was nonoperating during this test.

The test item successfully completed all phases of testing. Anomalies noted during testing are detailed in the respective test enclosure.

Test data pertinent to this test program will remain on file at Dayton T. Brown, Inc., for ninety (90) days.

REFERENCES:

(a) Customer Purchase Order Number 48185C

(b) Dayton T. Brown, Inc. Job Number 400293-00-000

(c) Government Contract Number Not Applicable

(d) Test Specification Drop: Scott Test Procedure TP ER-1027

TEST PROGRAM SUMMARY:

TEST	REPORT ENCLOSURE	TEST ITEM DESCRIPTION	DATE STARTED	DATE COMPLETED	REMARKS
Drop r	1	Fireman's Breathing System	13 Dec 73	13 Dec 73	See Report Enclosure

ENCLOSURE 1

DROP TEST AND RESULTS

TEST REQUIREMENTS

Drop testing in accordance with Scott Aviation Test Procedure TP ER-1027.

TEST PROCEDURE

A Pretest Visual Inspection was performed.

With the unit pressurized to 4500 psig, the unit was dropped from a height of six (6) feet onto a flat concrete surface, one (1) drop per orientation noted by Figure 1 of this Enclosure.

A Post Test Visual Inspection of the test item was performed.

TEST RESULTS

A Pretest Visual Inspection of the test item revealed several cuts in harness assembly.

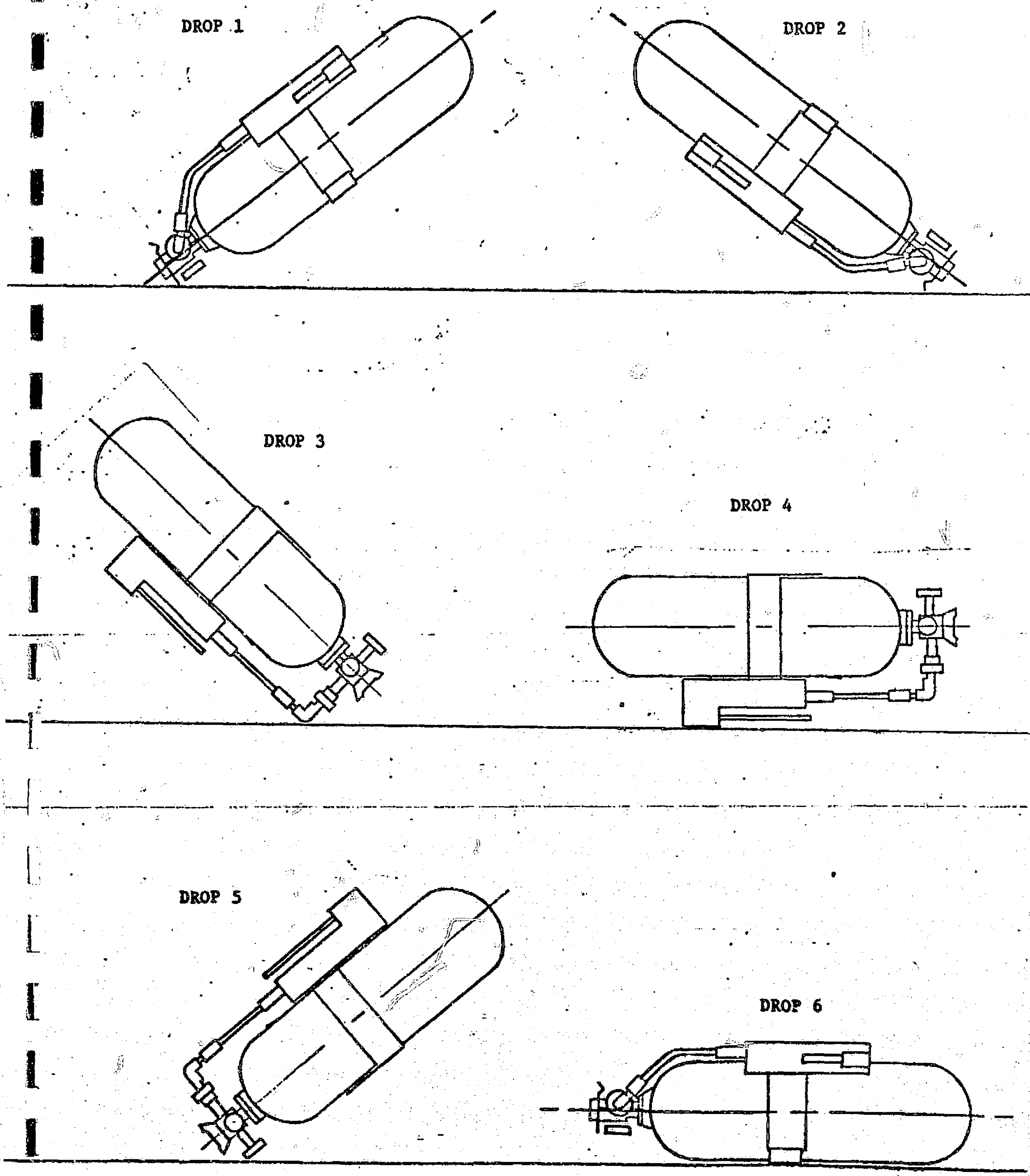
All testing was performed within the limits of the referenced specification.

Post Drop Tests revealed the following results:

Post Drop Number	Post Drop Results
1	(a) Gauge lens came off (b) Gauge shield bent down onto gauge (c) Gauge body bent at top
2	(a) Breathing regulator destroyed (b) Supply Hose to breathing regulator Broken off at regualtor, partial loss of air
3	(a) No further damage
4	(a) Bottle strap opened (b) Bottle strap no longer capable of holding bottle tight against back pack. (c) Low pressure hose connector on bottle regulator bent. (d) Two (2) indents in pressure regulator (dented by bottle strap)
5	(a) Cylinder valve handle broken
6	(a) Bottle strap popped open (b) Cylinder handle came off (c) Gauge face fell out.

In addition to above anomalies, scuff marks in various areas of the bottle surfaces were noted. At the conclusion of the six (6) Drops, the unit was still pressurized, but lower than 4500 PSIG.

Figure 1



DAYTON T. BROWN INC

TEST EQUIPMENT

TEST DROP

*	ITEM	MANUFACTURER	MODEL	S/N	ACCURACY
X	Quick Release	Dayton T. Brown, Inc.	---	---	----
X	Tape Measure	Lufkin	100 ft.	D.T.B. 68-359	± 1/8"

* X Indicates equipment used.

Test equipment utilized for the program reported herein was within its assigned interval of calibration. Details are on file at Dayton T. Brown, Inc. and will be made available upon request.

EXHIBIT V

ORIGINAL PAGE IS
OF POOR QUALITY

Item No.	Item	Manufacturer	Model	S/N	Accuracy
1	Flowmeter	Brooks	10-1110-10	F-214	± 2%
2	Flowmeter	Fisher-Porter	0-50 cc	F-204	± 2%
3	Pressure Gage	U. S. Gauge	0-3000 psi	G-218	± 2%
4	Pressure Gage	U. S. Gauge	0-5000 psi	G-224	± 2%
5	Pressure Gage	U. S. Gauge	0-5000 psi	G-212	± 2%
6	Pressure Gage	Sprague Eng'rg.	0-15000 psi	-	± 5%
7	Pressure Gage	U. S. Gauge	0-10,000 psi	G-221	± 5%
8	Pressure Gage	U. S. Gauge	0-600 psi	G-217	± 2%
9	Water Column	F. W. Dwyer	-2 to 20 inches/water	0063	± .02 in. H
10	Environmental Chamber	Tenny Engineering	TTUFR 100350	-	-
11	Temperature/Humidity Controller	Bristol Co.	TF-2T500FFF S4-43B	65A, 10, 606	± 5°F
12	Program Controller	Bristol Co.	253A500G1	65A, 10, 606	± 5°F
13	Salt Spray Chamber	Singleton Co.	B	-	-
14	Oscillograph Recorder	Brush	R-1152-60	0044	Transfer
15	Pressure Transducer	Strathan	PM5TCD	1449	Transfer
16	Pressure Transducer	Stratham	PM5TCD	1460	Transfer
17	Graduated Cylinder	Pyrex	3075	-	± .1 ML
18	Stop Watch	Meylan	204B	SW-51	± .2 sec.
19	Weight Scale	Detecto	-	P6512	± 1 oz.
20	Oscilloscope	Data Instruments, Inc.	555	1698209	± 1 MS
21	Sound Level Meter	H. H. Scott, Inc.	412	163921	± 1 DB

APPENDIX D

ACCEPTANCE TEST PROCEDURE

FIREFIGHTER'S BREATHING SYSTEM

ER 1031

225 ERIE STREET
LANCASTER, N.Y. 14086
TEL. 716 683-5100
TELEX 91-394

Engineering Report No. ER-1031

Acceptance Test Procedure for the Firefighter's Breathing System

NASA Contract No. NAS9-13177

Dated: 11 June 1973

Prepared by: P. R. Bement
P. R. Bement
Test Engineer

Approved by: J. L. Sullivan
J. L. Sullivan
Engineering Manager - Commercial Products

NI3-4067 10/72

TABLE OF CONTENTS

1.0 INTRODUCTION

This procedure describes a series of functional tests to be performed on each Firefighter's Breathing System prior to development testing and customer delivery.

The overall objective of this series is to verify that each FBS is physically and functionally correct following completion of manufacture.

2.0 APPLICABLE DOCUMENTS

NASA Specification FBS-SP-001, Revision 2, dated November 3, 1971.

Titled: "Performance, Design and Cost Requirements for a Compressed Air Demand-type Fireman's Breathing System"

Compressed Gas Association Commodity Specification for Air, Number G-7.1

3.0 GENERAL

3.1 Test Medium

The breathing gas used will be pure, dry breathing air conforming to the requirements of the Compressed Gas Association Commodity Specification for Air, G-7.1, Type I (Grade D or higher quality).

3.2 Environmental Conditions

Unless otherwise specified, the ambient conditions for conducting the operational tests herein will be as follows:

(1) Temperature: $77^{\circ} \pm 18^{\circ}F$

(2) Relative Humidity: 90 percent or less

(3) Barometric Pressure: Local standard (28 to 32 inches of Hg)

3.3 Order of Tests

Unless otherwise specified, all tests will be performed in the order presented herein.

3.4 Test Instrumentation

3.4.1 Accuracy

The accuracy of instruments and test equipment used to control or minitor test parameters specified herein shall:

(a) Conform to laboratory standards whose calibration is traceable to the prime standards at the U. S. Bureau of Standards.

(b) Have an accuracy of at least one-tenth the tolerance for the test article variable to be measured.

3.4.2 Calibration and Certification

Prior to starting any test, test engineering shall review the instrumentation to ascertain that:

(a) Calibration and certification have been accomplished and are valid.

(b) The calibration time period will not elapse during a test of long duration. If this possibility exists, the applicable instrument will be replaced by one with a more recent calibration date.

(c) Equipment, such as strip chart recorders, have been checked for proper operation and accuracy prior to starting the test. These instruments shall also be checked periodically during testing to ensure that drift has not exceeded the specified tolerance.

4.0 PROCEDURE

4.1 System Weight

Weigh the FBS and record the total, both with and without cylinder.

4.2 Stored Leakage (Cylinder Valve/Cylinder Assembly)

(1) Charge a cylinder and valve assembly to 4500 psig and immerse in a water bath (Figure 1).

(2) Collect the gas emitted from the assembly over a 24-hour period. This amount cannot exceed a rate of 0.5 scc/hour.

4.3 Operating Leakage

(1) With the cylinder of the FBS charged to 4500 psig, open the cylinder valve allowing the system to pressurize.

(2) Using Leak-Tek or an equivalent leakage indicator, check each component of the FBS for leakage. No leakage is allowed.

4.4 Dynamic Flow Requirements

(1) Install the FBS with a fully charged cylinder in the test setup shown in Figure 2. Record a description of the test instrumentation.

(2) Adjust the breathing machine (Scott P/N 22850) to obtain a peak flow of 257 LPM NTPD at approximately 34 cycles/minute.

(3) Open the cylinder valve and start the breathing machine. Continue to operate the breathing machine for a period of one (1) minute. During this period, record the following data:

(a) Continuously record inhalation and exhalation mask pressures.

(b) Continuously record mask flow rates.

(4) Bleed the cylinder pressure down to 950 psig.

(5) Open the cylinder valve and start the breathing machine. Continue to operate the breathing machine until cylinder pressure reaches 100 psig. During this period, record the following data:

(a) Continuously record inhalation and exhalation mask pressures.

(b) Continuously record mask flow rates.

(c) Record the pressure at which the low pressure warning actuates.

(6) Recharge the cylinder to 4500 psig.

(7) Adjust the speed of the breathing machine to obtain a peak flow of 476 LPM NTPD.

(8) Open the cylinder valve and start the breathing machine. Continue to operate the breathing machine for a period of one (1) minute. During this period, record the following data:

(a) Continuously record inhalation and exhalation mask pressures.

(b) Continuously record mask flow rates.

(9) Bleed the cylinder pressure down to 950 psig.

(10) Open the cylinder valve and start the breathing machine. Continue to operate the breathing machine until cylinder pressure reaches 570 psig. During this period, record the following data:

(a) Continuously record inhalation and exhalation mask pressures.

(b) Continuously record mask flow rates.

(c) Record the pressure at which the low pressure alarm actuates.

4.5 Purge Flow

(1) Install the FBS with the cylinder charged to 300 psig in the test setup shown in Figure 3.

(2) Open the purge valve fully which will cause a slight positive pressure in the mask.

(3) Slowly open the needle valve until the mask pressure is zero. Record the resulting flow shown on the flowmeter.

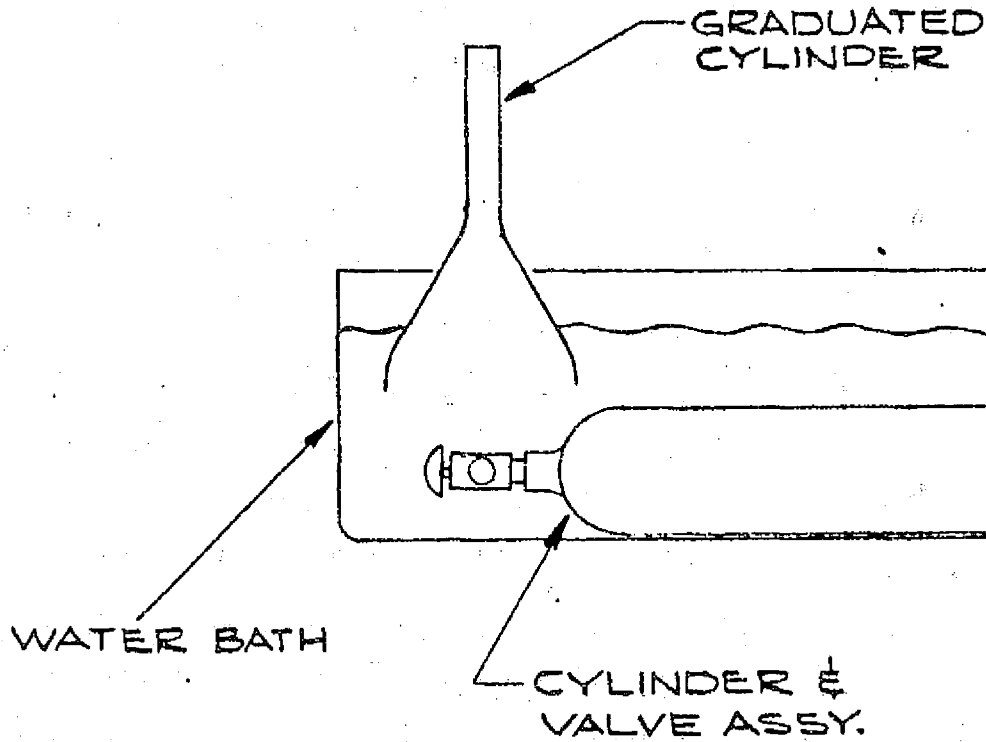


FIGURE 1

Para. 4.2 Stored Leakage

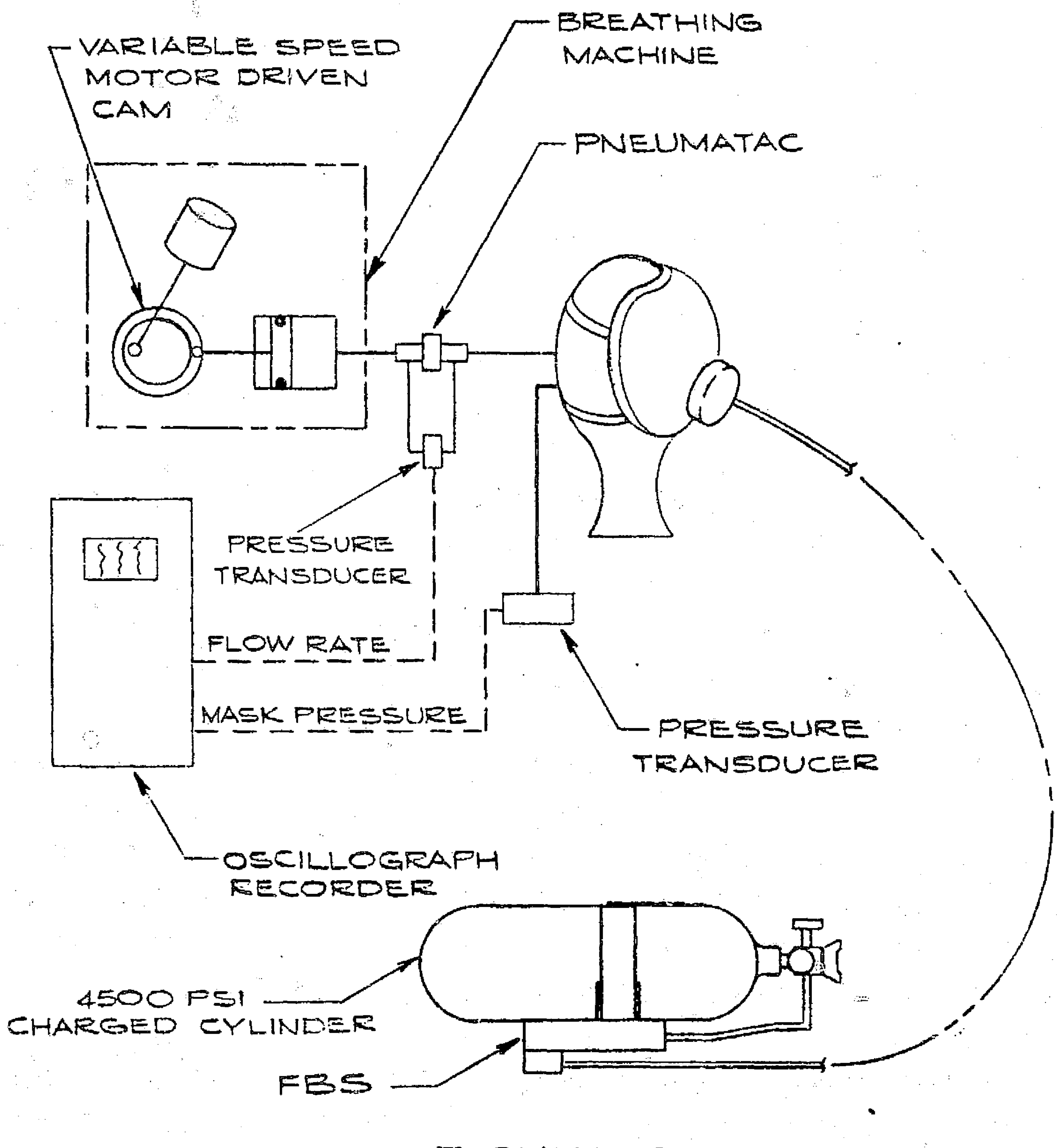


FIGURE 2

Para. 4.4 Dynamic Flow Requirements

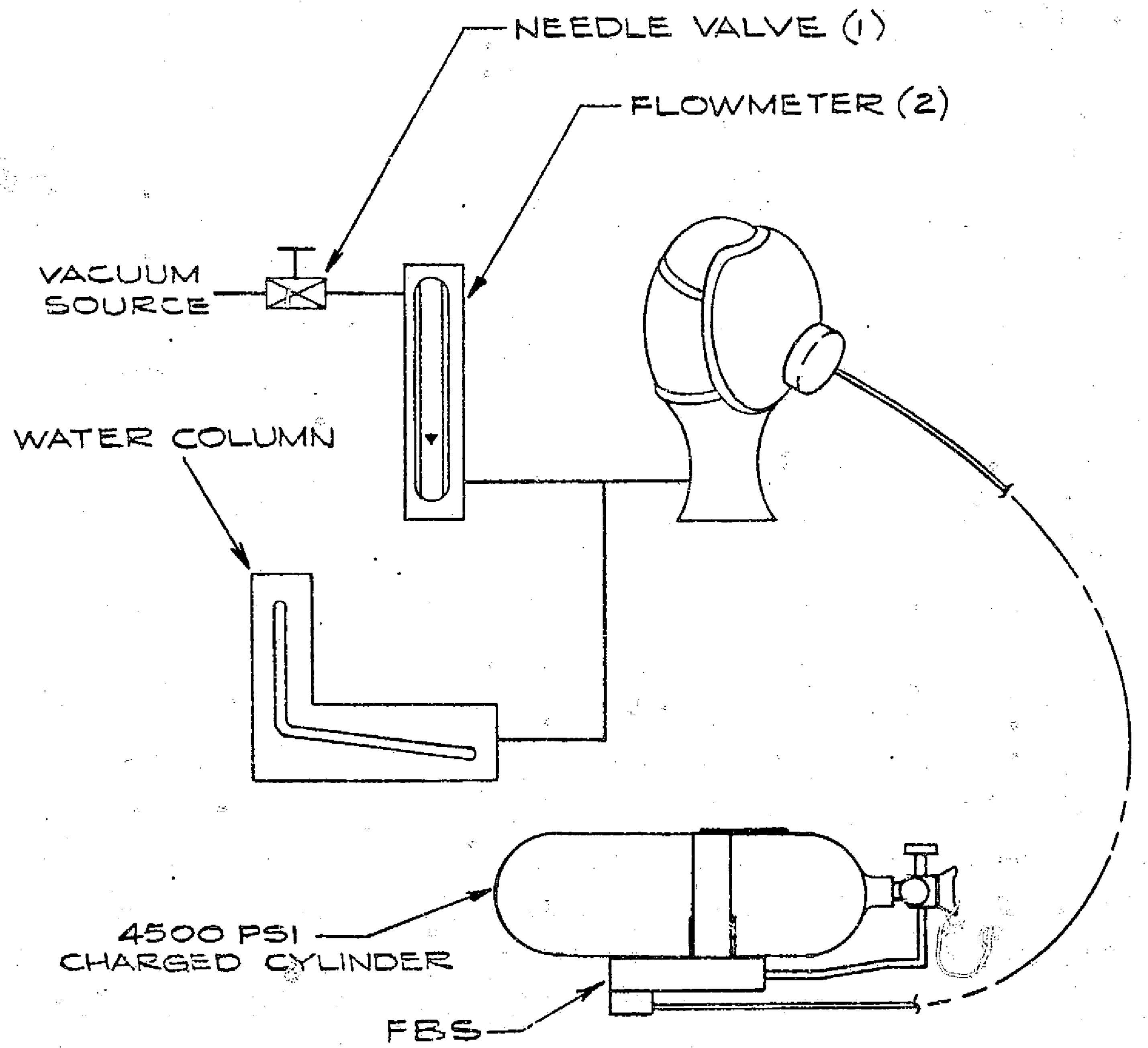


FIGURE 3

Para. 4.5 Purge Flow Test

APPENDIX A

Data Sheets

DATA SHEET # 1

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________________ Barometric Pressure ______________

TEST: SYSTEM WEIGHT

Paragraph: 4.1

Total weight without cylinder ______________________
(10 lb. maximum)

Total weight with cylinder ______________________

Test Equipment:

Tested by: ______________________

Verified by: ______________________

DATA SHEET # 2

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ______________

TEST: STORED LEAKAGE (CYLINDER VALVE/CYLINDER ASSEMBLY)

Paragraph: 4.2

Total leakage ______________ cc/24-hr.

Leakage Rate ______________ cc/hr.

Test Equipment:

Tested by: ______________________

Verified by: ______________________

DATA SHEET # 3

P/N ____________________
S/N ____________________
Date ____________________
Temperature ______________ Barometric Pressure ______________

TEST: OPERATING LEAKAGE

Paragraph: 4.3

Parameter	Required	Actual
Step (2) System Leakage	No leakage	

Tested by: ____________________

Verified by: ____________________

DATA SHEET # 4

P/N ________________
S/N ________________
Date ________________
Temperature ________________ Barometric Pressure ________________

TEST: DYNAMIC FLOW REQUIREMENTS

Paragraph: 4.4

Parameter	Required	Actual
Step (3) Peak Inhalation Pressure	-1.25 inches water max.	
Step (3) Peak Exhalation Pressure	+2.0 inches water max.	
Step (5) Peak Inhalation Pressure	-1.25 inches water max.	
Step (5) Peak Exhalation Pressure	+2.0 inches water max.	
Step (5) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	
Step (8) Peak Inhalation Pressure	-2.0 inches water max.	
Step (8) Peak Exhalation Pressure	+4.0 inches water max.	

Parameter	Required	Actual
Step (10) Peak Inhalation Pressure	-2.0 inches water max.	
Step (10) Peak Exhalation Pressure	+4.0 inches water max.	
Step (10) Low Pressure Alarm Actuation Pressure	880 to 830 PSIG	

Test Equipment:

Tested by: ____________________

Verified by: ____________________

DATA SHEET # 5

P/N ______________________
S/N ______________________
Date ______________________
Temperature ______________ Barometric Pressure ____________

TEST: PURGE FLOW

Paragraph: 4.5

Purge flow @ 100 psi cylinder pressure

______________ LPM NTPD
(125 LPM minimum)

Test Equipment:

Tested by: ______________________

Verified by: ______________________

APPENDIX E

QUALIFICATION TEST REPORT FOR

IMPROVED DEMAND REGULATOR COVER OF

FIREFIGHTER'S BREATHING SYSTEM

ER 1074

Engineering Report No. 1074

Qualification Test Report
for the
Improved Demand Regulator Cover
of the Firefighter's Breathing System

NASA Contract No. NAS 9-13177
Task Order 006

Dated: October 14, 1975

Prepared by: ______________________
P. R. Bement
Supervisor Technical Services

Approved by: ______________________
J. E. Nelson
Project Engineer

Approved by: ______________________
J. L. Sullivan
Manager - Engineering
Health/Safety Products

TABLE OF CONTENTS

1.0 ABSTRACT

This report presents the results of the Qualification Test Series performed on the improved demand regulator cover of the Firefighter's Breathing System. The series was intended to verify that design improvements made to the cover of the demand regulator comply with the required functional and environmental parameters and qualify it for use in the field evaluation program.

2.0 GENERAL

2.1 Item Tested

The item tested was an FBS with the improved demand regulator cover installed.

2.2 Applicable Documents

Scott Aviation Engineering Report No. ER 1055 "Qualification Test Procedure for the Improved Demand Regulator Cover of the Firefighter's Breathing System" dated 31 October 1974.

3.0 TEST PROGRAM

3.1 Procedure

All tests were performed in accordance with Scott Aviation Qualification Test Procedure No. ER 1055. This procedure appears in Exhibit II of this report.

3.2 Data

The data sheet appears in Exhibit I.

3.3 Test Performance

All tests were performed at Scott Aviation, Lancaster, New York except for low temperature operation which was performed at a nearby vendor facility.

4.0 TEST RESULTS

4.1 Exhalation Flow Characteristics

The demand regulator was subjected to the exhalation valve flow characteristics test as specified in paragraph 3.1 of ER 1055. All mask pressures were within the allowable ranges at each flow.

4.2 Exhalation Valve Leakage

The demand regulator was subjected to the exhalation valve leakage test as specified in paragraph 3.2 of ER 1055. The leakage rate was less than the maximum allowable of 5 cc/min.

4.3 Low Temperature Operation

The FBS was subjected to the low temperature operation test as specified in paragraph 3.3 of ER 1055. No frosting or increase in exhalation resistance was noted.

4.4 Contamination Resistance

The FBS was subjected to the contamination resistance test as specified in paragraph 3.4 of ER 1055. The contamination did not cause any abnormal exhalation valve leakage and a post test inspection showed that no contamination had entered inside the cover. Additionally, the 6 inch pencil was not able to disrupt the operation of the demand regulator.

4.5 Impact Resistance

The demand regulator was subjected to the impact resistance test as specified in paragraph 3.5 of ER 1055. The cover suffered superficial damage in the form of various dents and scratches during 5 of the drops. However, the drop directly onto the screw holding the cover to the regulator caused a hole to be punctured in the side of the regulator body thereby allowing gross leakage to occur. The screw was fitted with a rubber grommet around its head and the test repeated. Only superficial damage occurred with no increase in leakage noted.

TEST RECORD | ER 1055

Press. Red. S/N 19

Demand Reg. S/N Unknown

Para. 3.1 **EXHALATION FLOW**

Flow	Pressure Inches of Water	Limits Inches of Water
Crack (50 cc/min)	0.1	+0.5 max.
257 LPM, NTPD	1.3	+2.0 max.
476 LPM, NTPD	2.6	+4.0 max.

Para. 3.2 **EXHALATION VALVE LEAKAGE**

Draft Inches of Water	Flow cc/min	Limits cc/min
-0.5	1.9	5.0 max.
-2.0	2.6	5.0 max.

Para. 3.3 **LOW TEMPERATURE OPERATION**

COMMENTS: No frosting or increased exhalation resistance noted.

Para. 3.4 **CONTAMINATION RESISTANCE**

Exhalation Valve Leakage

Draft Inches of Water	Flow cc/min	Limits cc/min
-0.5	1.8	5.0 max.
-2.0	2.8	5.0 max.

COMMENTS: No contamination noted inside cover. Pencil did not disrupt regulator function.

Para. 3.5 **IMPACT RESISTANCE**

COMMENTS: Dents & scratches on cover on 5 drops. Remaining drop on screw punctured a hole in regulator body. Test repeated with grommet under screw head. No major dammage noted.

EXHALATION FLOW

Flow	Pressure Inches of Water	Limits Inches of Water
Crack (50 cc/min)	0.2	+0.5 max.
257 LPM, NTPD	1.4	+2.0 max.
476 LPM, NTPD	2.6	+4.0 max.

EXHALATION VALVE LEAKAGE

Draft Inches of Water	Flow cc/min	Limits cc/min
-0.5	1.9	5.0 max.
-2.0	2.7	5.0 max.

ENGINEERING REPORT NO. ER 1055

QUALIFICATION TEST PROCEDURE
FOR THE
IMPROVED DEMAND REGULATOR COVER
OF THE FIREFIGHTER'S BREATHING SYSTEM

NASA CONTRACT NO. NAS9-13177
TASK ORDER 006

DATED: 31 OCTOBER 1974

Prepared by: P.R. Bement

P. R. Bement, Supervisor
Technical Services

Approved by: J.E. Nelson

J. Nelson
Project Engineer

Approved by: J.L. Sullivan

J. L. Sullivan
Manager-Engineering
Health/Safety Products

TABLE OF CONTENTS

1.0 INTRODUCTION

This procedure describes a series of functional and environmental tests to be performed on the Firefighter's Breathing System. The series is intended to verify that design improvements made to the cover of the demand regulator comply with the required functional and environmental parameters and qualify it for use in the field evaluation program.

2.0 GENERAL

2.1 Environmental Conditions

Unless otherwise specified, the ambient conditions for conducting the operational tests herein will be as follows:

(1) Temperature: 77 ± 18° F

(2) Relative Humidity: 90 percent or less

(3) Barometric Pressure: Local standard (28 to 32 inches of Hg)

2.2 Test Article

Tests are to be conducted on an FBS whose demand regulator has been fitted with the improved cover.

2.3 Order of Tests

Unless otherwise specified, tests are to be conducted in the order presented herein.

3.0 SPECIFIED TESTS

3.1 Exhalation Flow Characteristics

3.1.1 Perform the exhalation valve flow tests by applying flows through the demand regulator of 50 cc/min. (cracking), 257 and 476 LPM, NTPD and noting and recording the resulting positive pressures.

3.2 Exhalation Valve Leakage

3.2.1 Disconnect the low pressure hose from the pressure reducer and cap the hose. Slowly draw successive negative pressures of -0.5 and -2.0 inches of water while noting and recording the resulting flow through a low range flow meter. This flow is the exhalation valve leakage.

3.3 Low Temperature Operation

3.3.1 Place the FBS with a fully charged 40 cubic foot cylinder on a subject and start up in the normal manner. Have the subject enter a chamber which is at 20 ± 5 F° and remain inside until the cylinder is depleted. During the test period alternate 1-minute periods of exercise and rest are required with the exercise period consisting of stepping onto and off a box 8.5 inches high at a rate of 30 cycles per minute. Note whether the improved demand regulator cover traps moisture causing a frost build-up with resulting increased exhalation resistance.

3.4 Contamination Resistance

3.4.1 Place the FBS with a fully charged cylinder on a subject wearing a turnout coat and helmet and startup in the normal manner. Sprinkle one pound of a mixture of dirt, sand, and ashes down on the subject from approximately two feet over his helmet. Following this, place the subject directly in the flow of a large electric fan. Sprinkle one pound of a mixture of dirt, sand, and ashes into the air stream of the fan so that it strikes the subject in the mask area. While standing in the contaminated air stream the subject should rotate slowly so that contamination impinges on all areas of the regulator.

Following this exposure, attempt to disrupt the operation of the regulator by inserting a standard wooden pencil of 6 inches in length into the exhalation opening in the cover. Note results.

Upon completion of the contamination exposure, remove the demand regulator from the FBS and perform the exhalation valve leakage test as defined in Paragraph 3.2. After testing for leakage, remove the cover from the demand regulator and check for signs of contamination.

3.5 <u>Impact Resistance</u>

3.5.1 Disconnect the demand regulator from the FBS. Drop the demand regulator six times from a height of 6 feet onto a concrete surface. Each drop should be of different orientation, but in each case, the cover should be the primary target of impact. Inspect for damage after each drop and record. Following the six drops, perform the exhalation flow characteristics test of paragraph 3.1 and the exhalation valve leakage test of paragraph 3.2.

APPENDIX

Press. Red. S/N ____________

Demand Reg. S/N ____________

TEST RECORD ER 1055

Para. 3.1 EXHALATION FLOW

Flow	Pressure Inches of Water	Limits Inches of Water
Crack (50 cc/min)		+0.5 max.
257 LPM, NTPD		+2.0 max.
476 LPM, NTPD		+4.0 max.

Para. 3.2 EXHALATION VALVE LEAKAGE

Draft Inches of Water	Flow cc/min	Limits cc/min
-0.5		5.0 max.
-2.0		5.0 max.

Para. 3.3 LOW TEMPERATURE OPERATION

COMMENTS: ____

Para. 3.4 CONTAMINATION RESISTANCE

Exhalation Valve Leakage

Draft Inches of Water	Flow cc/min	Limits cc/min
-0.5		5.0 max.
-2.0		5.0 max.

COMMENTS: ____

Para. 3.5 IMPACT RESISTANCE

COMMENTS: ____

EXHALATION FLOW

Flow	Pressure Inches of Water	Limits Inches of Water
Crack (50 cc/min)		+0.5 max.
257 LPM, NTPD		+2.0 max.
476 LPM, NTPD		+4.0 max.

EXHALATION VALVE LEAKAGE

Draft Inches of Water	Flow cc/min	Limits cc/min
-0.5		5.0 max.
-2.0		5.0 max.

APPENDIX F

INVESTIGATION AND CORRECTION OF PRESSURE

REDUCER SQUEAL ON

FIREFIGHTER'S BREATHING SYSTEM

ER 1073

SCOTT
AVIATION

INVESTIGATION AND CORRECTION OF PRESSURE REDUCER SQUEAL ON THE FIREFIGHTER'S BREATHING SYSTEM

ENGINEERING REPORT

No. 1073

NASA CONTRACT NAS 9-13177

Dated October 9, 1975

Prepared by:

J. L. Sullivan
Manager of Engineering
Health & Safety Products

Approved by:

R. R. Cyr
Director of Engineering

SCOTT AVIATION
225 ERIE STREET
LANCASTER, NEW YORK 14086
TEL.: 716 683-5100
TELEX: 091-394

ENG-4008 12/67

Summary

A squeal in the pressure reducer of the FBS, was discovered, as an itermittent condition, during the early phases of the field evaluation program. It was normally confused with the audible warning device of the system. The problem was diagnosed as resonant cavity amplification of a specific frequency of the random noise generated at the valve seat of the pressure reducer. It was resolved by insertion of a pin of suitable size into the resonant cavity (upper part of the piston), in order to create a mixed boundary condition to upset the resonance.

Introduction

During the early phases of the field evaluation program, an intermittent squeal in the pressure reducer was detected in several systems. The squeal was particularly troublesome for the user since the frequency was very close to that of the warning device and it was usually accepted as the warning tone.

The intermittent nature of the squeal made diagnosis of the problem difficult and led to apparent "fixes" that subsequently proved ineffective. In retrospect it was possible that a "buzz" that was originally detected in the first developmental pressure reducers was the forerunner of the subsequently defined "squeal problem". The "buzz" of the developmental units was apparently corrected by modification of check valves located between the primary and back-up pressure reducers.

Analysis

Analysis was begun by measurement of the frequency of the squeal. It was found to be essentially a pure tone at 3000 Hz., which was very close to the warning whistle tone of 3100 Hz.

The source of the squeal was positively established as the pressure reducer, rather than check valve or transfer valves, by the construction of a single function pressure reducer (figure 1) that exhibited the same intermittent squeal problem as the complete pressure reducer assembly. It was found that the squeal was most repeatedly generated with a new valve and seat with the regulator at a high ambient temperature.

Considering the spring supported system as a simple spring-mass system the natural frequency is established as follows:

$$\omega_n = \sqrt{\frac{K}{M}} \quad \text{------------------} \quad (1)$$

$$f_n = \frac{\omega_n}{2} \quad \text{------------------} \quad (2)$$

$$f_n = \frac{1}{2\pi}\sqrt{\frac{K}{M}} \quad \text{----------------} \quad (3)$$

Where f_n = natural frequency in Hz.

K = spring rate in lbs/ft.

M = mass in slugs

The piston weighed 13.8 grams which translates to 9.45 X 10^{-4} slugs.

The spring rate was 69 lbs/in.

Substituting in (3)

$$f_m = \frac{1}{2\pi}\sqrt{\frac{69\text{x}12}{9.45\text{x}10^{-4}}} = 149 \text{ Hz.}$$

This frequency was significantly lower than the measured frequency of the squeal.

A second spring with a higher rate was substituted in the pressure reducer. The second spring had a rate of 290 lbs/in. which resulted in a natural frequency of 305 Hz. However, the squeal was observed again at the same frequency. It appeared improbable that squeal was a result of simple longitudinal harmonic vibration of the piston.

Lateral vibration of the piston stem was considered a possibility. The guiding of the piston stem was improved with no effect. Subsequently, friction damping in the form of T.F.E. plugs that squeezed the stem proved equally inefffective. Consequently, lateral vibration of the stem was eliminated as a probable cause of the squeal.

A higher frequency longitudinal vibration resulting from the high spring rate of non-sliding o-rings was investigated by replacement of the o-rings with lower friction quad ring seals and also with a spring loaded T.F.E. seal. Neither modification permanently changed the characteristics of the squeal.

Consideration of the "organ pipe" effect on the central bore of the piston proved significant. The fundamental frequency of an open pipe $f = V/2L$ and for a closed pipe $f_c = V/4L$[1].

Where f = frequency in H_z

V = velocity of sound in air in ft/sec.

L - length of the pipe in ft.

For air at 60^oF $V = 1118$ ft/sec.[2] The length of the pipe from the valve seat is approximately 1.1 inches.

i.e. $L = \frac{1.1}{12} = .092$ ft.

therefore $f_o = \frac{V}{2x.092} = 6016\ H_z$

Similarly $f_c = \frac{V}{4x.092} = 3036\ H_z$

The values for the closed pipe is sufficiently close to the measured frequency of the squeal to suggest that the problem had been identified.

In order to prove the theory and to remedy the problem, several modifications were attempted. First, a spring was inserted in bore of the piston, but that proved ineffective. Next, the cover of the regulator was modified as in figure 2 so a screw could be inserted to penetrate into the bore of the piston, without touching the piston itself. By insertion and removal of the screw it proved possible to repeatedly eliminate the squeal. The theory had been proven and one possible remedy found.

The insertion of a screw through the cover was not considered a good final remedy, since that design created a possible leakage path from the pressure reducer. Subsequently, it was found that a Kel-F 81 pin inserted in the outlet end of the piston (figure 3) repeatedly silenced the squeal. The pin created a mixed boundary condition at the outlet of the resonant cavity with the pin promoting "closed pipe" resonance at approximately 3000 H_z. and the space around it

(1) Sears, Mechanics, Heat and Sound. pp. 498-500
Addison-Wesley Press Inc., Cambridge Mass. 1950
(2) Jeans, Science and Music
Dover Publications, New York 1965

promoting "open pipe" resonance at approximately 6000 Hz. The net effect was total elimination of the squeal.

Subsequent qualification testing as reported in ER 1064 "Delta Qualification Test Report of the Pressure Reducer Sonic Alternator for the Firefighter's Breathing System" and Field Evaluation experience proved the effectiveness of the modification.

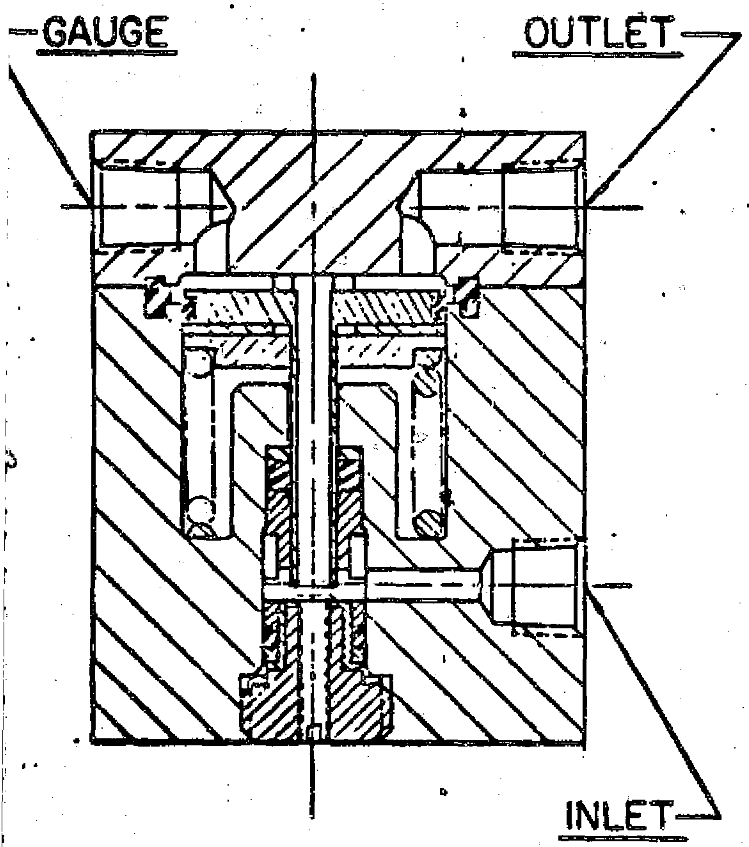


FIG. 1

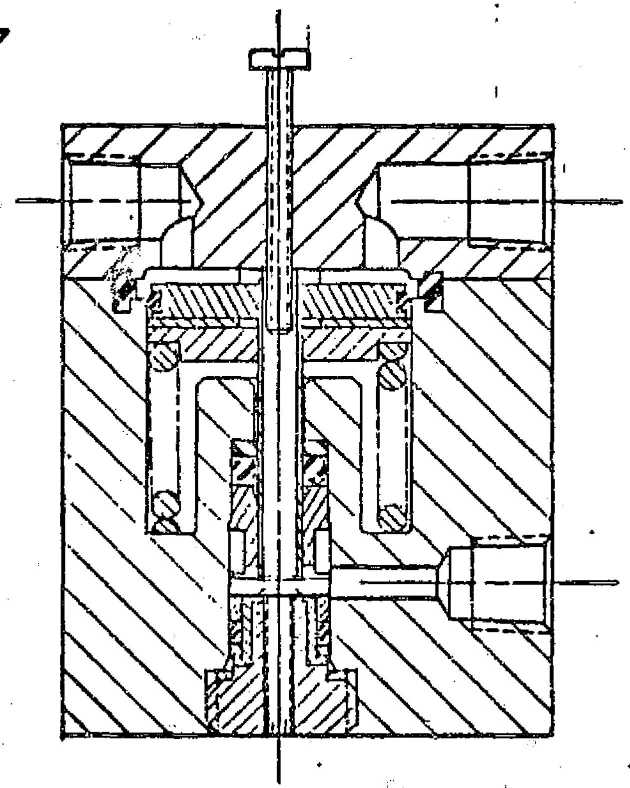


FIG. 2

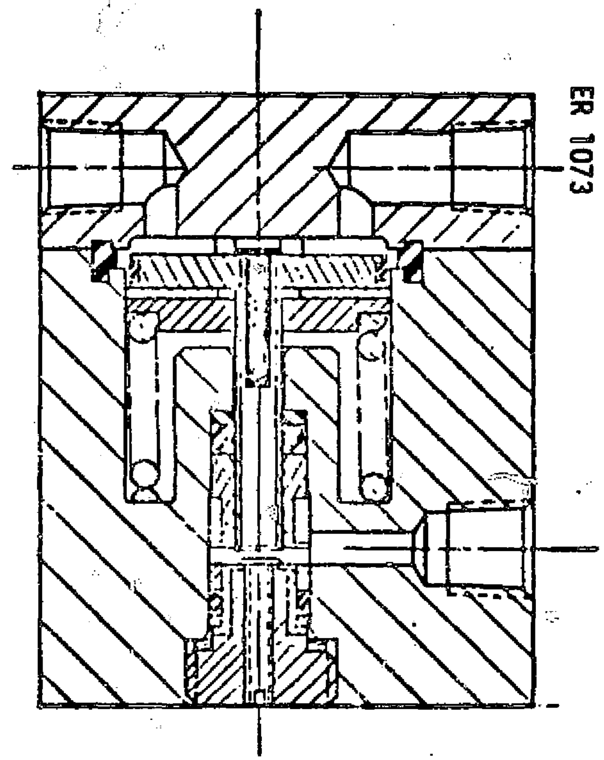


FIG. 3

APPENDIX G

DELTA QUALIFICATION TEST OF PRESSURE REDUCER

SONIC ATTENUATOR

FIREFIGHTER'S BREATHING SYSTEM

ER 1064

Engineering Report No. ER 1064

Delta Qualification Test Report Of The Pressure Reducer Sonic Attenuator For The Firefighter's Breathing System

NASA Contract No. NAS 9-13177

Task Order 009

Dated: 21 March, 1975

Prepared By: P. R. Bement

P. R. Bement
Supervisor Technical Services

Approved By: E. A. Giorgini

E. A. Giorgini
Project Engineer

Approved By: J. L. Sullivan

J. L. Sullivan
Manager of Engineering
Health/Safety Products

TABLE OF CONTENTS

1.0 ABSTRACT

This report presents the results of the Delta Qualification Test Series performed on the pressure reducer sonic attenuator for the Firefighter's Breathing System. The series of functional and environmental tests was intended to verify that the sonic attenuator eliminated the "squeal" from the pressure reducer while not compromising its function in any manner.

2.0 GENERAL

2.1 Item Tested

All tests were conducted using a test block machined to simulate the primary section of the pressure reducer P/N 27237. The test unit was assembled with parts from the present configuration with the addition of the sonic attenuator P/N 27429. The cover of the test block was modified with an access port and sealing plug to allow removal of the sonic attenuator.

2.2 Applicable Documents

Scott Aviation Engineering Report No. ER 1062 "Delta Qualification Test Procedure of the pressure reducer sonic attenuator for the Firefighter's Breathing System" dated 30th of January 1975.

3.0 TEST PROGRAM

3.1 Procedure

All tests were performed in accordance with Scott Aviation Delta Qualification Test Procedure No. ER 1062. This procedure appears in Exhibit II of this report.

3.2 Data

All data sheets appear in Exhibit I.

3.3 Test Performance

All tests were performed at Scott Aviation, Lancaster, New York.

4.0 TEST RESULTS

4.1 Physical Characteristics

The sonic attenuator was subjected to the physical characteristics inspection as specified in Paragraph 3.1 of ER 1062. The part satisfied the diminsions specified on the drawing and had a good general appearance.

4.2 Flow Test

The sonic attenuator assembled into the test block was subjected to the flow test as specified in Paragraph 3.2 of ER 1062. The test block satisfied the flow requirements and a post test inspection of the sonic attenuator show no change in physical characteristics.

4.3 High Temperature/Backpressure

The sonic attenuator assembled into the test block was subjected to the high temperature/backpressure test as specified in Paragraph 3.3 of ER 1062. Post test inspection showed that the sonic attenuator had not lodged in the hole in the center of the regulator piston. Visual inspection of the physical characteristics showed no defects or changes.

4.4 Life Cycle

The sonic attenuator assembled into the test block was subjected to the life cycle test as specified in Paragraph 3.4 of ER 1062. Flow tests and physical characteristics inspections at the 0, 20, 50 and 100,000 cycle intervals showed no resulting changes.

5.0 CONCLUSION

The test results show that the addition of the sonic attenuator eliminates any "squeal" from the operation of the pressure reducer without effecting its ability to function.

It can be concluded that the addition of the sonic attenuator meets the intent of the NASA specification and is both safe and suitable for its intended use.

DATA SHEET 1062

Para. 3.1 Physical Characteristics

Length .496 in. Head Dia. .144 in.

Pin Dia. .105 in. Head Thk. .012 in.

Weight .1527 grams

General Appearance ____________

Para 3.2 Flow Test

Inlet (PSI)	Flow (LPM)	Draft (in. H_2O)	Allowable (in. H_2O)
1200	390	-.62	-2.0

Para. 3.3 High Temp/Backpressure

Visual Inspection pin free in center of piston, dropped out when sealing plug removed

Length .495 in. Head Dia. .144 in.

Pin Dia. .105 in. Head Thk. .012 in.

Weight .1527 grams

Para. 3.4 Life Cycle

0 Cycles

Length .496 in. Head Dia. .144 in.

Pin Dia. .105 in. Head Thk. .012 in.

Weight .1527 grams

Inlet (PSI)	Flow (LPM)	Draft (in. H_2O)	Allowable (in. H_2O)
1200	390	-.65	-2.0

20,000 Cycles

Length .496 in. Head Dia. .144 in.

Pin Dia. .105 in. Head Thk. .012 in.

Weight .1526 grams

Inlet (PSI)	Flow (LPM)	Draft (in. H_2O)	Allowable (in. H_2O)
1200	390	-.91	-2.0

50,000 Cycles

Length .495 in. Head Dia. .144 in.

Pin Dia. .105 in. Head Thk. .012 in.

Weight .1526 grams

Inlet (PSI)	Flow (LPM)	Draft (in. H_2O)	Allowable (in. H_2O)
1200	390	-.84	-2.0

100,000 Cycles

Length .495 in. Head Dia. .144 in.

Pin Dia. .105 in. Head Thk. .012 in.

Weight .1526 grams

Inlet (PSI)	Flow (LPM)	Draft (in. H_2O)	Allowable (in. H_2O)
1200	390	-.72	-2.0

Engineering Report No. ER 1062

DELTA QUALIFICATION TEST PROCEDURE
OF THE
PRESSURE REDUCER SONIC ATTENUATOR
FOR THE
FIREFIGHTER'S BREATHING SYSTEM

NASA CONTRACT NO. NAS9-13177

DATED: 26 FEBRUARY, 1975

Prepared By: P. R. B[illegible]

P. R. Bement
Supervisor, Technical Services

Approved By: E. Giorgini

E. Giorgini
Project Engineer

Approved By: J. L. Sullivan

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Manager of Engineering
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1.0 INTRODUCTION

This procedure presents a series of qualification tests to be performed on the pressure reducer for the Fire-fighter's Breathing System.

The tests are intended to verify that the addition of the sonic attenuator eliminates the "squeal" from the function of the pressure reducer. Additionally, the test series is intended to verify that pressure reducer performance will continue to comply with the required functional and environmental parameters and qualify it for use during the Field Evaluation Program.

2.0 GENERAL

2.1 TEST MEDIUM

The gas used will be pure, dry breathing air conforming to the requirements of the Compressed Gas Association Commodity Specification for Air, G-7.1, Type I (Grade D or higher quality.)

2.2 ENVIRONMENTAL CONDITIONS

Unless otherwise specified, the ambient conditions for conducting the operational tests herein will be as follows:

(1) Temperature: $77 \pm 18°F$

(2) Relative Humidity: 90 percent or less

(3) Barometric Pressure: Local standard (28 to 32 inches of Hg)

2.3 TEST ARTICLE

All tests will be conducted using a test block machined to simulate the primary section of the pressure reducer P/N 27237. The test unit will be assembled with parts from the present configuration such as piston, spring, seat, etc., with the addition of the sonic attenuator P/N 27249. The cover of the test block will be modified with an access port and sealing plug to allow removal of the sonic attenuator.

2.4 ORDER OF TESTS

Unless otherwise specified, all tests will be performed in the order presented herein.

2.5 PASS/FAIL CRITERIA

The following criteria must be satisfied during the course of testing.

1) The unit must meet the flow requirements.

2) The sonic attenuator must be free from excessive wear or deformation.

3) The regulator must not emit any "squeal."

4) The sonic attenuator must be constrained by the cover of the test block and freely positioned within the flow port at the large diameter end of the piston.

3.0 SPECIFIED TESTS

3.1 PHYSICAL CHARACTERISTICS OF THE SONIC ATTENUATOR

Before beginning any tests determine the following characteristics of the sonic attenuator.

1) Overall length, pin diameter, head diameter and head thickness.

2) Weight

3) General appearance.

3.2 FLOW TEST

Apply pressure to the inlet of the test block which has a demand regulator attached. Draw flow at the inlet pressure indicated on the data sheet and record the resulting draft. Following the flow test, remove the sonic attenuator from the test block and repeat the measurements of paragraph 3.1.

3.3 HIGH TEMPERATURE/BACKPRESSURE

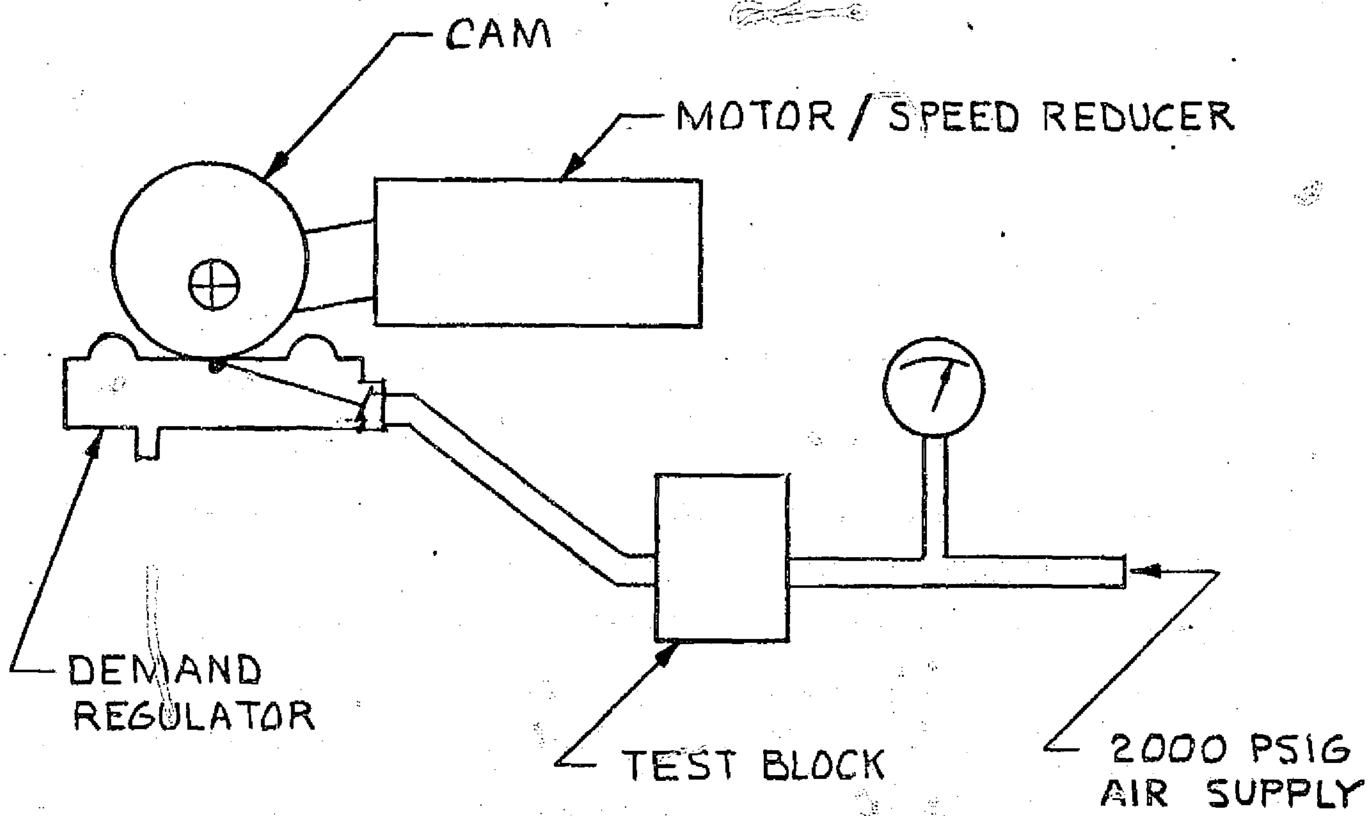
Place the test block in an environmental chamber for a minimum of 16 hours at a temperature of 165°F. Following this exposure, remove the block from the chamber and apply a pressure of 500 PSI to the inlet. Backpressure the low pressure port to 150 PSIG, remove supply pressure and maintain the 150 PSIG backpressure. After thirty minutes exposure to the above conditions vent all pressure and visually inspect to determine that the sonic attenuator is not lodged in the hole in the center of the piston. If the sonic attenuator is lodged in the hole, attach a demand regulator to the test block, apply 500 PSIG to the inlet and take 10 normal breaths. Again visually inspect and note results.

Following the above tests remove the sonic attenuator from the test block and repeat the measurements of Paragraph 3.1.

3.4 LIFE CYCLE

Install the test block in the test setup shown in Figure I. Adjust the cam controlling the demand regulator to draw a peak flow of 150 LPM with 2000 PSIG applied to the inlet test block. Adjust the speed of the motor to 30 RPM.

Using the system explained above cycle the test block until a total of 100,000 simulated breathing cycles have been obtained. Perform the flow test of Paragraph 3.2 and then the physical paragraph characteristics of 3.1 at the 0, 20, 50 and 100 thousand cycle intervals during the life cycle.



LIFE CYCLE

FIGURE 1

ITEM NO.	ITEM	MANUFACTURER	MODEL	S/N	ACCURACY
1	Flowmeter	Brooks	10-1110-10	F-214	± 2%
2	Pressure Gage	U. S. Gauge	0-3000 psi	G-218	± 2%
3	Water Column	F. W. Dwyer	-2 to 20 inches/water	0063	± .02 in. H_2O
4	Environmental Chamber	Tenny Engineering	TTUFR 100350		
5	Temperature/Humidity Controller	Bristol Company	TF-2T500FFF S4-43B	65A,10 606	± 5°F
6	Program Controller	Bristol Company	253A500G1	65A,10	± 5°F
7	Stop Watch	Meylan	204B	SW-51	± .2 sec.
8	Analytical Balance	Chemical Rubber Co.		1Q3042	± 0.1 Mg
9	Vernier Clipers	Helios	0-6	V-23	± .001

APPENDIX H

DELTA QUALIFICATION TEST REPORT FOR MODIFIED

FIREFIGHTER'S BREATHING SYSTEM

ER 1056

ENGINEERING REPORT NO. ER 1056

DELTA QUALIFICATION TEST REPORT FOR THE MODIFIED FIREFIGHTER'S BREATHING SYSTEM

NASA CONTRACT NAS9-13177
TASK ORDER 007
DATED: 31 OCTOBER 74

Prepared By: P. R. Bement

P. R. Bement, Supervisor
Technical Services

Approved By: E. Giorgini

E. Giorgini
Project Engineer

Approved By: J. L. Sullivan

J. L. Sullivan
Manager of Engineering
Health/Safety Products

TABLE OF CONTENTS

1.0 ABSTRACT

This report presents the results of the Delta Qualification Test Series performed on the Modified Firefighter's Breathing System (FBS), Scott Part Number 27275. The series of functional and environmental tests was intended to verify that design improvements made in the FBS comply with required parameters and qualify it for use in the field evaluation program.

The unit successfully passed the tests, although some problems were experienced during life cycling. These were not considered significant since they occurred after 70% of the test was completed and a user would not have detected the problem. Normal maintenance would have returned the unit to proper regulated pressure tolerances.

It can be concluded that the modified configuration of the FBS meets the intent of the NASA specification and is both safe and suitable for its intended use.

2.0 GENERAL

2.1 Items Tested

Partial Firefighter's Breathing System - Scott P/N 27275, Rev. B, consisting of pressure reducers P/N 27237, Rev. B, S/N's 6 and 7 and breathing regulators P/N 27235, Rev. B S/N's 1 and 8.

2.2 Applicable Documents

Scott Aviation Engineering Report No. ER 1054 "Delta Acceptance Test Procedure for the Modified Firefighter's Breathing System" dated 4 October 1974.

Scott Aviation Engineering Report No. ER 1053.
"Delta Acceptance Test Procedure for the Firefighter's Breathing System" dated 16 September 1974.

3.0 TEST PROGRAM

3.1 Procedure

All tests were performed in accordance with Scott Aviation Delta Acceptance Test Procedure No. ER 1053 and Delta Qualification Test Procedure No. ER 1054. These procedures appear in Exhibits II & III of this report.

3.2 Data

All data sheets appear in Exhibit I.

3.3 Test Performance

All tests were performed at Scott Aviation, Lancaster, New York.

4.0 TEST RESULTS

4.1 Specified Tests

4.1.1 Low Temperature Operation

The FBS (Pressure Reducer #7 and Demand Regulator #8) was subjected to the low temperature operation test as defined by paragraph 3.1 of ER 1054. The unit successfully met all requirements. A leak of 10 cc/min was detected in the backup seat retainer while at -40°F low temperature. When the unit was returned to room ambient conditions, the leak rate reduced to 0.5 cc/min.

4.1.2 High Temperature Operation

The FBS (Pressure Reducer #7 and Demand Regulator #8) was subjected to the high temperature operation test as defined by paragraph 3.2 of ER 1054. The unit successfully met all requirements. During breathdown at 165 F a noise was emitted from the primary spring/piston assembly when inlet pressure was decreasing from approximately 4000 to 3000 psi and then it disappeared. This did not affect unit performance.

4.1.3 Life Cycling

The FBS (Pressure Reducer #6 and Demand Regulator #1) was subjected to the life cycling test as defined by paragraph 3.3 of ER 1054. The performance test at the completion of 3500 total cycles showed that the lockup pressure of the backup regulator in the pressure reducer had climbed to 155 psi (150 psi maximum allowed) and the relief valve had cracked as evidenced by bubble leakage. When the unit was rechecked 16 hours later, the backup pressure crept to 153 psi with no leakage apparent. This situation was relayed to NASA and the decision was made to continue testing rather than perform maintenance on the unit.

After 5000 total cycles, the primary lockup pressure was 102 psi (100 psi maximum allowed) and the backup lockup pressure was 153.5 psi (150 psi maximum allowed). All other parameters were found to be within required tolerances.

The high lockup pressures encountered were not considered significant since routine maintenance procedures would have corrected this problem and functional performance was not degraded.

4.1.4 High Pressure Exposure

The FBS (Pressure Reducer #7 and Demand Regulator #8) was subjected to the high pressure exposure test as defined by paragraph 3.4 of ER 1054. After 72 hours of exposure to 4500 psig, the unit successfully met all requirements. Leakage was detected at the vent of the low pressure turn-on (1.3 cc/min) and at the vent of the transfer valve (less than bubble leakage $1X10^{-3}$ scc/sec).

4.2 SPECIAL TEST

4.2.1 High Pressure Exposure at High Temperature

The FBS (Pressure Reducer #7 and Demand Regulator #8) was subjected to the high pressure exposure at high temperature as defined by Paragraph 4.1 of ER 1054. Following 16 hours of exposure to 4500 psi inlet and 165°F, the unit was tested and it successfully met all requirements. A leakage of 1.6 cc/min was detected at the vent of the low cylinder turn-on, and the diaphragm of the demand regulator fluttered somewhat during the high flow conditions of breathdown using the breathing machine. It should be noted that during both normal and heavy subjective breathing, no fluttering occurred. Neither of these conditions effected the performance of the FBS.

5.0 CONCLUSION

The problems encountered during testing were analyzed as follows:

Leakage - All leakages encountered were well below the allowable outward leakage of 20 cc/min and, therefore, not considered detrimental to unit performance.

High Lockup - Lockup pressures exceeding the maximum allowed were experienced only after 3500 simulated usage cycles. This situation could have been corrected by maintenance procedures and, therefore, does not signal a design problem. Additionally, it should be noted that a user would not have detected these conditions without the use of pressure gages to measure interstage pressures.

It can be concluded that the modified configuration of the FBS meets the intent of the NASA specification and is both safe and suitable for its intended use.

[redacted] TEST RECORD [redacted] ER 1053 E. E. Eidencer SA 38

Figure 2

Date: 10-1-74

[redacted]ress. [redacted] S/N 7

System S/N

[redacted]d Reg. S/N [redacted]

AFTER PROOF PRESS. 6750 PSI FOR 5 MIN.

FUNCTIONAL TESTS

1. Turn on and breathe. Did whistle sound? YES
2. Continue breathing. Did whistle stop after several breaths? YES
3. Engage press-to-test and continue breathing. Did warning whistle sound? YES
4. Release press-to-test and continue breathing. Did warning whistle stop after several breaths? YES
5. Comments:
6. Perform an external leakage test. None allowed. NONE
7. Turn cylinder valve off and slowly breathe trapped system pressure down. Did warning whistle sound? YES
8. Comments

PERFORMANCE TESTS

1. Initial Turn On 4300 psi. Supply Pressure
   - a) 1 breaths required to transfer to primary (6 breaths max.)
   - b) 88 psi primary pressure
   - c) Did whistle sound momentarily prior to transfer to primary? YES
   - d) Did whistle fully cease after several breaths? YES
   - e) Turn cylinder off and breathe system down. Did whistle come on for low pressure warning? YES
   - f) Comments:
2. Interstage Pressure (Normal Breathing)

Inhalation	Exhalation	Lockup After 3 Minutes
78 psi	92 psi (95 max)	92 psi (100 max) primary @4300 ± 200 psi
120 psi	130 psi (120-140)	131 psi (150 max) backup @4300 ± 200 psi
72 psi	85 psi (95 max)	86 psi (100 max) primary @1200 ± 200 psi
114 psi	124 psi (120-140)	124 psi (150 max) backup @800 $^{+0}_{-50}$ psi

Comments:

3. Press-To-Test & Transfer
   - a) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 4300 ± 200 psi. (3 breaths max.)
   - b) Release P. T. T. 1 breaths required to transfer to primary pressure schedule at 4300 ± 200 psi (6 breaths max.)
   - c) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 1200 ± 200 psi (3 breaths max.).
   - d) Release P. T. T. 1 breaths required to transfer to primary at 1200 ± 200 psi (6 breaths max).
   - e) Repeat P.T.T. and release several times and check for repeated transfer and return from primary to backup and back to primary.
   - f) Comments: OK. AT 1200 AND 4300 PSI
4. Demand Regulator Inward Leakage (Exhalation Valve)

Draft Inches of Water	Flow cc/Min.	Limits cc/Min.
-0.5	1.4	5.0
-2.0	2.2	5.0

5. Flow Draft

Flow	Primary 4300 ± 200 psi	Primary 1200 ± 200 psi	Backup 1200 ± 200 psi	Backup 570 psi	Backup 100 psi	Limits in H_2O
Cracking(50 cc/min)		0.41	0.46			-0.1 to -0.5
178 LPM, NTPD					0.8	-2.0 max.
257 LPM, NTPD	0.9	0.8	1.1			-1.25 max.
390 LPM, NTPD	1.0	0.8				-2.0 max.
476 LPM, NTPD			1.0	1.2		-2.0 max.

*Interstage Pressure shall be 90 psig min.

Comments:

6. Low Cylinder Pressure Turn-On: 860 (865 ± 35 psi)

   Comments:
7. Whistle Alarm Dynamic Full On/Full Off

   Dynamic Full on 109 PSIG (100-110 PSI)
   Dynamic Full off 85 PSIG (80-90 PSI)
8. Purge Flow

Inlet Pressure PSIG	Flow LPM, NTPD	Limits LPM, NTPD
300	15[illegible]	125 to 200 LPM

9. Exhalation Flow

Flow	Pressure Inches of Water	Limits Inches of Water
Crack(50 cc/min)	0.08	+0.5 max.
257 LPM, NTPD	1.3	+2.0 max.
476 LPM, NTPD	2.6	+4.0 max.

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[redacted] TEST RECORD ER 1053 [redacted]

Figure 2

T.E. Clainier

Date: 10-4-14 System S/N ______

[redacted]ress[redacted]. S/[redacted] 7 [redacted] [redacted]nd R[redacted]N [redacted] 2 [redacted]

SI 18

AFTER 12HR SOAK AT -40°F BROUGHT BACK TO ROOM TEMP.

FUNCTIONAL TESTS

1. Turn on and breathe. Did whistle sound? YES
2. Continue breathing. Did whistle stop after several breaths? YES
3. Engage press-to-test and continue breathing. Did warning whistle sound? YES
4. Release press-to-test and continue breathing. Did warning whistle stop after several breaths? YES
5. Comments: ______
6. Perform an external leakage test. None allowed.
   ~~O-RING IN OUTLET DISCONNECT~~ O.K.
   BACKUP SEAT RETAINER LEAKED 0.5 cc/MIN
7. Turn cylinder valve off and slowly breathe trapped system pressure down. Did warning whistle sound? YES
8. Comments ______

PERFORMANCE TESTS

1. Initial Turn On 4300 psi. Supply Pressure
   a) 1 breaths required to transfer to primary (6 breaths max.)
   b) 87 psi primary pressure
   c) Did whistle sound momentarily prior to transfer to primary? YES
   d) Did whistle fully cease after several breaths? YES
   e) Turn cylinder off and breathe system down. Did whistle come on for low pressure warning? YES
   f) Comments: ______

2. Interstage Pressure (Normal Breathing)

Inhalation	Exhalation	Lockup After 3 Minutes
76 psi	86 psi (95 max)	87.5 psi (100 max) primary @4300 ± 200 psi
119 psi	127 psi (120-140)	127 psi (150 max) backup @4300 ± 200 psi
68 psi	79 psi (95 max)	80.5 psi (100 max) primary @1200 ± 200 psi
114 psi	120 psi (120-140)	119 psi (150 max) backup @800 $^{+0}_{-50}$ psi

Comments: ______

3. Press-To-Test & Transfer
   a) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 4300 ± 200 psi. (3 breaths max.)
   b) Release P. T. T. 1 breaths required to transfer to primary pressure schedule at 4300 ± 200 psi (6 breaths max.)
   c) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 1200 ± 200 psi (3 breaths max.).
   d) Release P. T. T. 2 breaths required to transfer to primary at 1200 ± 200 psi (6 breaths max).
   e) Repeat P.T.T. and release several times and check for repeated transfer and return from primary to backup and back to primary.
   f) Comments: ______

4. Demand Regulator Inward Leakage (Exhalation Valve)

Draft Inches of Water	Flow cc/Min.	Limits cc/Min.
-0.5	1.6	5.0
-2.0	3.8	5.0

5. Plow Draft

Flow	Primary ~~4300~~ ± 200 psi	Primary 1200 ± 200 psi	Backup 1200 ± 200 psi	Backup 570 psi	Backup 100 psi	Limits in H_2O
Cracking(50 cc/min)		0.46	0.40			-0.1 to -0.5
178 LPM, NTPD					0.92	-2.0 max.
257 LPM, NTPD	0.90	0.80	1.06			-1.25 max.
390 LPM, NTPD	0.72	1.00				-2.0 max.
476 LPM, NTPD			1.12	1.10		-2.0 max.

*Interstage Pressure shall be 90 psig min.

Comments: ______

6. Low Cylinder Pressure Turn-On: 835 (865 ± 35 psi)

   Comments: ______

7. Whistle Alarm Dynamic Full On/Full Off

   Dynamic Full on 101 PSIG (100-110 PSI)
   Dynamic Full off 84 PSIG (80-90 PSI)

8. Purge Flow

Inlet Pressure PSIG	Flow LPM, NTPD	Limits LPM, NTPD
300	150	125 to 200 LPM

9. Exhalation Flow 300 1.02 IN.H2O 106 PSIG. 178 LPM 90 PSI MIN

Flow	Pressure Inches of Water	Limits Inches of Water
Crack(50 cc/min)	0.08	+0.5 max.
257 LPM, NTPD	1.10	+2.0 max.
476 LPM, NTPD	2.80	+4.0 max.

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POST HIGH TEMP SOAK

[redacted] TEST RECORD [redacted] ER 1053 [redacted]

Figure 2

E. C. Pelletier

SA 38

Date: 10-3-84 System S/N ______

[redacted]

FUNCTIONAL TESTS

1. Turn on and breathe. Did whistle sound? YES
2. Continue breathing. Did whistle stop after several breaths? YES
3. Engage press-to-test and continue breathing. Did warning whistle sound? YES
4. Release press-to-test and continue breathing. Did warning whistle stop after several breaths? YES
5. Comments: ______
6. Perform an external leakage test. None allowed.
   NO LEAKAGE
7. Turn cylinder valve off and slowly breathe trapped system pressure down. Did warning whistle sound? YES
8. Comments
   DURING BREATHDOWN NOISE WAS NOTED FROM THE SPRING/PISTON OF PRIMARY

PERFORMANCE TESTS

1. Initial Turn On 4300 psi. Supply Pressure
   a) 1 breaths required to transfer to primary (6 breaths max.)
   b) 92 psi primary pressure
   c) Did whistle sound momentarily prior to transfer to primary? YES
   d) Did whistle fully cease after several breaths? YES
   e) Turn cylinder off and breathe system down. Did whistle come on for low pressure warning? YES
   f) Comments: DURING PERFORMANCE TEST NOISE WAS NOTED FROM SPRING/PISTON OF PRIMARY
2. Interstage Pressure (Normal Breathing)

Inhalation	Exhalation	Lockup After 3 Minutes
80 psi	90 psi (95 max)	97 psi (100 max) primary @4300 ± 200 psi
122 psi	129 psi (120-140)	129 psi (150 max) backup @4300 ± 200 psi
70 psi	79 psi (95 max)	81 psi (100 max) primary @1200 ± 200 psi
114 psi	124 psi (120-140)	126 psi (150 max) backup @800 $^{+0}_{-50}$ psi

Comments: ______

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3. Press-To-Test & Transfer
   a) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 4300 ± 200 psi. (3 breaths max.)
   b) Release P. T. T. 1 breaths required to transfer to primary pressure schedule at 4300 ± 200 psi (6 breaths max.)
   c) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 1200 ± 200 psi (3 breaths max.).
   d) Release P. T. T. 2 breaths required to transfer to primary at 1200 ± 200 psi (6 breaths max).
   e) Repeat P.T.T. and release several times and check for repeated transfer and return from primary to backup and back to primary.
   f) Comments: ______
4. Demand Regulator Inward Leakage (Exhalation Valve)

Draft Inches of Water	Flow cc/Min.	Limits cc/Min.
-0.5	2.0	5.0
-2.0	1.9	5.0

5. Flow Draft

Flow	Primary 4300 ± 200 psi	Primary 1200 ± 200 psi	Backup 1200 ± 200 psi	Backup 570 psi	Backup 100 psi	Limits in H_2O
Cracking (50 cc/min)		.08	.08			-0.1 to -0.5
178 LPM, NTPD					0.82	-2.0 max.
257 LPM, NTPD	0.8	0.86	1.14			-1.25 max.
390 LPM, NTPD	0.8	0.8				-2.0 max.
476 LPM, NTPD			1.18	1.3		-2.0 max.*

*Interstage Pressure shall be 90 psig min.

Comments: ______

6. Low Cylinder Pressure Turn-On: 850 (865 ± 35 psi)

   Comments: ______
7. Whistle Alarm Dynamic Full On/Full Off

   Dynamic Full on 106 PSIG (100-110 PSI)
   Dynamic Full off 87 PSIG (80-90 PSI)
8. Purge Flow

Inlet Pressure PSIG	Flow LPM, NTPD	Limits LPM, NTPD
300	155	125 to 200 LPM

9. Exhalation Flow 300 1.0 IN H_2O 106 PSI 178 LPM 90 PSI MIN.

Flow	Pressure Inches of Water	Limits Inches of Water
Crack (50 cc/min)	0.10	+0.5 max.
257 LPM, NTPD	1.4	+2.0 max.
476 LPM, NTPD	2.7	+4.0 max.

[redacted] TEST RECORD ER 1053 [redacted]

Figure 2

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Date: 10-8-74 System S/N ______

Pres[redacted]d. S[redacted] 7[redacted] [redacted]nd R[redacted]/N [redacted]

AFTER 72HR HI PRESS. EXPOSURE

CTIONAL TESTS

Turn on and breathe. Did whistle sound? YES

Continue breathing. Did whistle stop after several breaths? YES

Engage press-to-test and continue breathing. Did warning whistle sound? YES

Release press-to-test and continue breathing. Did warning whistle stop after several breaths? YES

Comments:

Perform an external leakage test. None allowed.
1.3 CC/MIN LOW CYLINDER VENT LEAKAGE
SMALL LEAKAGE OUT TRANSFER VALVE VENT COULD NOT MEASURE

Turn cylinder valve off and slowly breathe trapped system pressure down. Did warning whistle sound? YES

Comments

FORMANCE TESTS

Initial Turn On 4300 psi. Supply Pressure

a) 1 breaths required to transfer to primary (6 breaths max.)

b) 88 psi primary pressure

c) Did whistle sound momentarily prior to transfer to primary? YES

d) Did whistle fully cease after several breaths? YES

e) Turn cylinder off and breathe system down. Did whistle come on for low pressure warning? YES

f) Comments:

Interstage Pressure (Normal Breathing)

Inhalation	Exhalation	Lockup After 3 Minutes
76 psi	88 psi (95 max)	88 psi (100 max) primary @4300 ± 200 psi
121 psi	130 psi (120-140)	130 psi (150 max) backup @4300 ± 200 psi
68 psi	80 psi (95 max)	80 psi (100 max) primary @1200 ± 200 psi
112 psi	124 psi (120-140)	122 psi (150 max) backup @800 +0/-50 psi

Comments:

3. Press-To-Test & Transfer

a) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 4300 ± 200 psi. (3 breaths max.)

b) Release P. T. T. 1 breaths required to transfer to primary pressure schedule at 4300 ± 200 psi (6 breaths max.)

c) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 1200 ± 200 psi (3 breaths max.).

d) Release P. T. T. 2 breaths required to transfer to primary at 1200 ± 200 psi (6 breaths max).

e) Repeat P.T.T. and release several times and check for repeated transfer and return from primary to backup and back to primary.

f) Comments:

4. Demand Regulator Inward Leakage (Exhalation Valve)

Draft Inches of Water	Flow cc/Min.	Limits cc/Min.
-0.5	3.5	5.0
-2.0	3.8	5.0

5. Flow Draft

Flow	Primary 4300 ± 200 psi	Primary 1200 ± 200 psi	Backup 1200 ± 200 psi	Backup 570 psi	Backup 100 psi	Limits in H_2O
Cracking(50 cc/min)		0.44	0.46			-0.1 to -0.5
178 LPM, NTPD					0.90	-2.0 max.
257 LPM, NTPD	0.80	0.78	1.20			-1.25 max.
390 LPM, NTPD	0.80	0.80				-2.0 max.
476 LPM, NTPD			1.27	1.10		-2.0 max.*

*Interstage Pressure shall be 90 psig min.

Comments:

6. Low Cylinder Pressure Turn-On: 840 (865 ± 35 psi)

Comments:

7. Whistle Alarm Dynamic Full On/Full Off

Dynamic Full on 105 PSIG (100-110 PSI)
Dynamic Full off 85 PSIG (80-90 PSI)

8. Purge Flow

Inlet Pressure PSIG	Flow LPM, NTPD	Limits LPM, NTPD
300	150	125 to 200 LPM

9. Exhalation Flow 300 0.78 IN. H_2O 116 PSI 178 LPM 90 PSI MIN.

Flow	Pressure Inches of Water	Limits Inches of Water
Crack (50 cc/min)	0.10	+0.5 max.
257 LPM, NTPD	1.30	+2.0 max.
476 LPM, NTPD	2.50	+4.0 max.

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TEST RECORD ER 1053 [redacted] Date: 10-10-14 System S/N

[redacted] Pros[redacted]. S[redacted] [redacted]nd R[redacted]/N [redacted]

Figure 2 E.E. [illegible] SA 38

FUNCTIONAL TESTS

1. Turn on and breathe. Did whistle sound? YES
2. Continue breathing. Did whistle stop after several breaths? YES
3. Engage press-to-test and continue breathing. Did warning whistle sound? YES
4. Release press-to-test and continue breathing. Did warning whistle stop after several breaths? YES
5. Comments:
6. Perform an external leakage test. None allowed.
   1.6 CC/MIN LOW CYLINDER TRANSFER VENT LEAKAGE
7. Turn cylinder valve off and slowly breathe trapped system pressure down. Did warning whistle sound? YES
8. Comments
   DURING BREATH DOWN DIAPHRAGM FLUTTERED PERIODICALLY

PERFORMANCE TESTS

1. Initial Turn On 4300 psi. Supply Pressure
   a) 1 breaths required to transfer to primary (6 breaths max.)
   b) 98 psi primary pressure
   c) Did whistle sound momentarily prior to transfer to primary? YES
   d) Did whistle fully cease after several breaths? YES
   e) Turn cylinder off and breathe system down. Did whistle come on for low pressure warning? YES
   f) Comments:
2. Interstage Pressure (Normal Breathing)

Inhalation	Exhalation	Lockup After 3 Minutes
78 psi	90 psi (95 max)	98.5 psi (100 max) primary @4300 ± 200 psi
122 psi	130 psi (120-140)	130 psi (150 max) backup @4300 ± 200 psi
70 psi	80 psi (95 max)	87 psi (100 max) primary @1200 ± 200 psi
112 psi	122 psi (120-140)	124 psi (150 max) backup @800 $^{+0}_{-50}$ psi

Comments:

HIGH TEMP/PRESS EXPOSURE AT 165°F FOR 16 HRS.

3. Press-To-Test & Transfer
   a) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 4300 ± 200 psi. (3 breaths max.)
   b) Release P. T. T. 1 breaths required to transfer to primary pressure schedule at 4300 ± 200 psi (6 breaths max.)
   c) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 1200 ± 200 psi (3 breaths max.).
   d) Release P. T. T. 2 breaths required to transfer to primary at 1200 ± 200 psi (6 breaths max).
   e) Repeat P.T.T. and release several times and check for repeated transfer and return from primary to backup and back to primary.
   f) Comments:
4. Demand Regulator Inward Leakage (Exhalation Valve)

Draft Inches of Water	Flow cc/Min.	Limits cc/Min.
-0.5	1.20	5.0
-2.0	1.95	5.0

5. Flow Draft

Flow	Primary 4300 ± 200 psi	Primary 1200 ± 200 psi	Backup 1200 ± 200 psi	Backup 570 psi	Backup 100 psi	Limits in H_2O
Cracking (50 cc/min)		0.38	0.38			-0.1 to -0.5
178 LPM, NTPD					0.95	-2.0 max.
257 LPM, NTPD	0.90	0.96	1.10			-1.25 max.
390 LPM, NTPD	0.75	0.96				-2.0 max.
476 LPM, NTPD			1.20	1.10		-2.0 max.

*Interstage Pressure shall be 90 psig min.

Comments: DIAPHRAGM FLUTTERED AT 476 LPM

6. Low Cylinder Pressure Turn-On: 835 (865 ± 35 psi)
   Comments:
7. Whistle Alarm Dynamic Full On/Full Off
   Dynamic Full on 105 PSIG (100-110 PSI)
   Dynamic Full off 86 PSIG (80-90 PSI)
8. Purge Flow

Inlet Pressure PSIG	Flow LPM, NTPD	Limits LPM, NTPD
300	150	125 to 200 LPM

300 0.96 IN. H_2O 113 PSIG 178 LPM 90 PSI MIN.

9. Exhalation Flow

Flow	Pressure Inches of Water	Limits Inches of Water
Crack (50 cc/min)	0.08	+0.5 max.
257 LPM, NTPD	1.30	+2.0 max.
476 LPM, NTPD	2.60	+4.0 max.

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[redacted] TEST RECORD ER 1053 [redacted]

Figure 2

[illegible] SA 38

Date: 9/30/74 System S/N

Press. Red. S/N [redacted] 6 [redacted] Demand Reg. S/N [redacted]

AFTER PROOF PRESS. 6750 PSIG FOR 5MIN.

FUNCTIONAL TESTS

1. Turn on and breathe. Did whistle sound? YES
2. Continue breathing. Did whistle stop after several breaths? YES
3. Engage press-to-test and continue breathing. Did warning whistle sound? YES
4. Release press-to-test and continue breathing. Did warning whistle stop after several breaths? YES
5. Comments:
6. Perform an external leakage test. None allowed.

   NONE
7. Turn cylinder valve off and slowly breathe trapped system pressure down. Did warning whistle sound? YES
8. Comments

PERFORMANCE TESTS

1. Initial Turn On 4300 psi. Supply Pressure
   - a) 1 breaths required to transfer to primary (6 breaths max.)
   - b) 88 psi primary pressure
   - c) Did whistle sound momentarily prior to transfer to primary? YES
   - d) Did whistle fully cease after several breaths? YES
   - e) Turn cylinder off and breathe system down. Did whistle come on for low pressure warning? YES
   - f) Comments:
2. Interstage Pressure (Normal Breathing)

Inhalation	Exhalation	Lockup After 3 Minutes
75 psi	88 psi (95 max)	87 psi (100 max) primary @4300 ± 200 psi
124 psi	134 psi (120-140)	134.5 psi (150 max) backup @4300 ± 200 psi
70 psi	81 psi (95 max)	82 psi (100 max) primary @1200 ± 200 psi
122 psi	133 psi (120-140)	134 psi (150 max) backup @800 $^{+0}_{-50}$ psi

Comments:

3. Press-To-Test & Transfer
   - a) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 4300 ± 200 psi. (3 breaths max.)
   - b) Release P. T. T. 1 breaths required to transfer to primary pressure schedule at 4300 ± 200 psi (6 breaths max.)
   - c) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 1200 ± 200 psi (3 breaths max.).
   - d) Release P. T. T. 2 breaths required to transfer to primary at 1200 ± 200 psi (6 breaths max).
   - e) Repeat P.T.T. and release several times and check for repeated transfer and return from primary to backup and back to primary.
   - f) Comments: OK 4300 & 1200 PSI REPEATED
4. Demand Regulator Inward Leakage (Exhalation Valve)

Draft Inches of Water	Flow cc/Min.	Limits cc/Min.
-0.5	0.30	5.0
-2.0	0.50	5.0

5. Flow Draft

Flow	Primary 4300 ± 200 psi	Primary 1200 ± 200 psi	Backup 1200 ± 200 psi	Backup 570 psi	Backup 100 psi	Limits in H_2O
Cracking(50 cc/min)		.38	.46			-0.1 to -0.5
178 LPM, NTPD					0.4	-2.0 max.
257 LPM, NTPD	0.6	0.6	0.8			-1.25 max.
390	0.8	0.7				-2.0 max.
4[illegible] LPM, NTPD			1.0*	1.0		-2.0 max.

*Interstage Pressure shall be 90 psig min.

Comments:

6. Low Cylinder Pressure Turn-On: 875 (865 ± 35 psi)

   Comments:
7. Whistle Alarm Dynamic Full On/Full Off

   Dynamic Full on 105 PSIG (100-110 PSI)

   Dynamic Full off 54 PSIG (80-90 PSI)
8. Purge Flow

Inlet Pressure PSIG	Flow LPM, NTPD	Limits LPM, NTPD
300	150	125 to 200 LPM

9. Exhalation Flow

Flow	Pressure Inches of Water	Limits Inches of Water
Crack(50 cc/min)	0.08	+0.5 max.
257 LPM, NTPD	1.3	+2.0 max.
476 LPM, NTPD	2.6	+4.0 max.

TEST RECORD [redacted] ER 1053 [redacted]

Figure 2

E.E. Eidenier

SA 38

Date: 10-2-74 System S/N ____

Pres[redacted] S/N [redacted] Demand Reg. S/N [redacted]

AFTER 500 CYCLES

FUNCTIONAL TESTS

1. Turn on and breathe. Did whistle sound? YES
2. Continue breathing. Did whistle stop after several breaths? YES
3. Engage press-to-test and continue breathing. Did warning whistle sound? YES
4. Release press-to-test and continue breathing. Did warning whistle stop after several breaths? YES
5. Comments:

LESS THAN 0.5 cc/m LEAKAGE

6. Perform an external leakage test. None allowed.

BACK UP LEAKS (EXTERNAL SEAT) 02 cc/M HASTING MASS FLOW METER
LEAK THRU AMBIENT HOLE LOW CYLINDER ACTUATOR

7. Turn cylinder valve off and slowly breathe trapped system pressure down. Did warning whistle sound? YES
8. Comments

PERFORMANCE TESTS

1. Initial Turn On 4300 psi. Supply Pressure
   a) 1 breaths required to transfer to primary (6 breaths max.)
   b) 88 psi primary pressure
   c) Did whistle sound momentarily prior to transfer to primary? YES
   d) Did whistle fully cease after several breaths? YES.
   e) Turn cylinder off and breathe system down. Did whistle come on for low pressure warning? YES
   f) Comments:
2. Interstage Pressure (Normal Breathing)

Inhalation	Exhalation	Lockup After 3 Minutes
78 psi	89 psi (95 max)	90 psi (100 max) primary @4300 ± 200 psi
125 psi	134 psi (120-140)	146 psi (150 max) backup @4300 ± 200 psi
70 psi	81 psi (95 max)	82 psi (100 max) primary @1200 ± 200 psi
122 psi	129 psi (120-140)	130 psi (150 max) backup @800 $^{+0}_{-50}$ psi

Comments:

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3. Press-To-Test & Transfer
   a) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 4300 ± 200 psi. (3 breaths max.)
   b) Release P. T. T. 1 breaths required to transfer to primary pressure schedule at 4300 ± 200 psi (6 breaths max.)
   c) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 1200 ± 200 psi (3 breaths max.).
   d) Release P. T. T. 2 breaths required to transfer to primary at 1200 ± 200 psi (6 breaths max).
   e) Repeat P.T.T. and release several times and check for repeated transfer and return from primary to backup and back to primary.
   f) Comments:
4. Demand Regulator Inward Leakage (Exhalation Valve)

Draft Inches of Water	Flow cc/Min.	Limits cc/Min.
-0.5	.00	5.0
-2.0	0.04	5.0

5. Flow Draft

Flow	Primary 4300 ± 200 psi	Primary 1200 ± 200 psi	Backup 1200 ± 200 psi	Backup 570 psi	Backup 100 psi	Limits in H_2O
Cracking (50 cc/min)		0.3	0.4			-0.1 to -0.5
178 LPM, NTPD					0.5	-2.0 max.
257 LPM, NTPD	.5	.7	.8			-1.25 max.
390 LPM, NTPD	.7	.8				-2.0 max.
476 LPM, NTPD			.9*	1.1		-2.0 max.

*Interstage Pressure shall be 90 psig min.

Comments:

6. Low Cylinder Pressure Turn-On: 870 (865 ± 35 psi)

   Comments:

7. Whistle Alarm Dynamic Full On/Full Off

   Dynamic Full on 106 PSIG (100-110 PSI)
   Dynamic Full off 88 PSIG (80-90 PSI)

8. Purge Flow

Inlet Pressure PSIG	Flow LPM, NTPD	Limits LPM, NTPD
300 (114)	140	125 to 200 LPM

500 178 LPM MIN. * 90 MIN. INTER.

9. Exhalation Flow

Flow	Pressure Inches of Water	Limits Inches of Water
Crack (50 cc/min)	0.07	+0.5 max.
257 LPM, NTPD	1.3	+2.0 max.
476 LPM, NTPD	2.6	+4.0 max.

TEST RECORD ER 1053 Date: 10/4/74 System S/N ____

[redacted] Press[redacted]d. S[redacted] [redacted]nd R[redacted]/N [redacted]

Figure 2

SA 38

AFTER 1500 CYCLES

FUNCTIONAL TESTS

1. Turn on and breathe. Did whistle sound? YES
2. Continue breathing. Did whistle stop after several breaths? YES
3. Engage press-to-test and continue breathing. Did warning whistle sound? YES
4. Release press-to-test and continue breathing. Did warning whistle stop after several breaths? YES
5. Comments:
6. Perform an external leakage test. None allowed.

   LOW CYLINDER VENT HOLE VERY SLIGHT LEAK COULD NOT BE MEASURED
7. Turn cylinder valve off and slowly breathe trapped system pressure down. Did warning whistle sound? YES
8. Comments

PERFORMANCE TESTS

1. Initial Turn On 4300 psi. Supply Pressure
   - a) 1 breaths required to transfer to primary (6 breaths max.)
   - b) 88 psi primary pressure
   - c) Did whistle sound momentarily prior to transfer to primary? YES
   - d) Did whistle fully cease after several breaths? YES
   - e) Turn cylinder off and breathe system down. Did whistle come on for low pressure warning? YES
   - f) Comments:
2. Interstage Pressure (Normal Breathing)

Inhalation	Exhalation	Lockup After 3 Minutes
78 psi	89 psi (95 max)	91.5 psi (100 max) primary @4300 ± 200 psi
125 psi	134 psi (120-140)	144 psi (150 max) backup @4300 ± 200 psi
73 psi	80 psi (95 max)	86.5 psi (100 max) primary @1200 ± 200 psi
122 psi	130 psi (120-140)	134 psi (150 max) backup @800 $^{+0}_{-50}$ psi

Comments:

3. Press-To-Test & Transfer
   - a) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 4300 ± 200 psi. (3 breaths max.)
   - b) Release P. T. T. 2 breaths required to transfer to primary pressure schedule at 4300 ± 200 psi (6 breaths max.)
   - c) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 1200 ± 200 psi (3 breaths max.).
   - d) Release P. T. T. 3 breaths required to transfer to primary at 1200 ± 200 psi (6 breaths max).
   - e) Repeat P.T.T. and release several times and check for repeated transfer and return from primary to backup and back to primary.
   - f) Comments:
4. Demand Regulator Inward Leakage (Exhalation Valve)

Draft Inches of Water	Flow cc/Min.	Limits cc/Min.
-0.5	0.00	5.0
-2.0	0.20	5.0

5. Flow Draft

Flow	Primary 4300 ± 200 psi	Primary 1200 ± 200 psi	Backup 1200 ± 200 psi	Backup 570 psi	Backup 100 psi	Limits in H_2O
Cracking(50 cc/min)		0.30	0.44			-0.1 to -0.5
178 LPM, NTPD					0.04	-2.0 max.
257 LPM, NTPD	0.70	0.60	0.80			-1.25 max.
390 LPM, NTPD*	0.80	0.60				-2.0 max.
476 LPM, NTPD			1.0	1.0		-2.0 max.

*Interstage Pressure shall be 90 psig min.

Comments:

6. Low Cylinder Pressure Turn-On: 870 (865 ± 35 psi)

   Comments:
7. Whistle Alarm Dynamic Full On/Full Off

   Dynamic Full on 106 PSIG (100-110 PSI)
   Dynamic Full off 85 PSIG (80-90 PSI)
8. Purge Flow

Inlet Pressure PSIG	Flow LPM, NTPD	Limits LPM, NTPD
300	140	125 to 200 LPM

300 0.80 IN. H_2O 114 PSIG 178 LPM 90 PSI MIN.

9. Exhalation Flow

Flow	Pressure Inches of Water	Limits Inches of Water
Crack(50 cc/min)	0.10	+0.5 max.
257 LPM, NTPD	1.20	+2.0 max.
476 LPM, NTPD	2.50	+4.0 max.

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[redacted] TEST RECORD [redacted] ER 1053 [redacted]

Figure 2

E. C. Eidener

SA 38

Date: 10-7-74

System S/N ____

Pre[redacted]ed. [redacted] [redacted]and [redacted]S/N [redacted]

AFTER 2500 CYCLES

FUNCTIONAL TESTS

1. Turn on and breathe. Did whistle sound? YES
2. Continue breathing. Did whistle stop after several breaths? YES
3. Engage press-to-test and continue breathing. Did warning whistle sound? YES
4. Release press-to-test and continue breathing. Did warning whistle stop after several breaths? YES
5. Comments: ____
6. Perform an external leakage test. None allowed. ____
7. Turn cylinder valve off and slowly breathe trapped system pressure down. Did warning whistle sound? YES
8. Comments ____

PERFORMANCE TESTS

1. Initial Turn On 4300 psi. Supply Pressure
   - a) 2 breaths required to transfer to primary (6 breaths max.)
   - b) 90 psi primary pressure
   - c) Did whistle sound momentarily prior to transfer to primary? YES
   - d) Did whistle fully cease after several breaths? YES
   - e) Turn cylinder off and breathe system down. Did whistle come on for low pressure warning? YES
   - f) Comments: ____
2. Interstage Pressure (Normal Breathing)

Inhalation	Exhalation	Lockup After 3 Minutes
80 psi	89 psi (95 max)	44 psi (100 max) primary @4300 ± 300 psi
127 psi	137 psi (120-140)	139 psi (150 max) backup @4300 ± 200 psi
72 psi	82 psi (95 max)	88 psi (100 max) primary @1200 ± 200 psi
118 psi	130 psi (120-140)	134 psi (150 max) backup @800 $^{+0}_{-50}$ psi

Comments: ____

3. Press-To-Test & Transfer
   - a) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 4300 ± 200 psi. (3 breaths max.)
   - b) Release P. T. T. 2 breaths required to transfer to primary pressure schedule at 4300 ± 200 psi (6 breaths max.)
   - c) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 1200 ± 200 psi (3 breaths max.).
   - d) Release P. T. T. 3 TO 4 breaths required to transfer to primary at 1200 ± 200 psi (6 breaths max).
   - e) Repeat P.T.T. and release several times and check for repeated transfer and return from primary to backup and back to primary.
   - f) Comments: 3 TO 4 STRONG BREATHS REQUIRED TO TRANSFER TO PRIMARY
4. Demand Regulator Inward Leakage (Exhalation Valve)

Draft Inches of Water	Flow cc/Min.	Limits cc/Min.
-0.5	0.00	5.0
-2.0	0.02	5.0

5. Flow Draft

Flow	Primary 4300 ± 200 psi	Primary 1200 ± 200 psi	Backup 1200 ± 200 psi	Backup 570 psi	Backup 100 psi	Limits in H_2O
Cracking(50 cc/min)		0.44	0.46			-0.1 to -0.5
178 LPM, NTPD					0.70	-2.0 max.
257 LPM, NTPD	0.64	0.72	0.98			-1.25 max.
390 LPM, NTPD*	0.82	0.86				-2.0 max.
476 LPM, NTPD			1.24	1.20		-2.0 max.

*Interstage Pressure shall be 90 psig min.

Comments: ____

6. Low Cylinder Pressure Turn-On: 890 (865 ± 35 psi)

   Comments: ____
7. Whistle Alarm Dynamic Full On/Full Off

   Dynamic Full on 106 PSIG (100-110 PSI)
   Dynamic Full off 84 PSIG (80-90 PSI)
8. Purge Flow

Inlet Pressure PSIG	Flow LPM, NTPD	Limits LPM, NTPD
300	130	125 to 200 LPM

9. Exhalation Flow 3co 0.66 H_2O 114 PSIG 178LPM 90PSI MIN.

Flow	Pressure Inches of Water	Limits Inches of Water
Crack(50 cc/min)	.04	+0.5 max.
257 LPM, NTPD	1.20	+2.0 max.
476 LPM, NTPD	2.30	+4.0 max.

[redacted] TEST RECORD ER 1053
Figure 2
E. G. Palmer

SA 38

Date: 10-8-74 System S/N ______

[redacted]Pres[redacted]d. S[redacted] 6 [redacted] [redacted]nd R[redacted]/N [redacted]

AFTER 3500 CYCLES

FUNCTIONAL TESTS

1. Turn on and breathe. Did whistle sound? YES
2. Continue breathing. Did whistle stop after several breaths? YES
3. Engage press-to-test and continue breathing. Did warning whistle sound? YES
4. Release press-to-test and continue breathing. Did warning whistle stop after several breaths? YES
5. Comments: ______
6. Perform an external leakage test. None allowed.
   NONE
7. Turn cylinder valve off and slowly breathe trapped system pressure down. Did warning whistle sound? YES
8. Comments ______

PERFORMANCE TESTS

1. Initial Turn On 4300 psi. Supply Pressure
   a) 1 breaths required to transfer to primary (6 breaths max.)
   b) ~~99~~ 93 psi primary pressure
   c) Did whistle sound momentarily prior to transfer to primary? YES
   d) Did whistle fully cease after several breaths? YES
   e) Turn cylinder off and breathe system down. Did whistle come on for low pressure warning? YES
   f) Comments: ______
2. Interstage Pressure (Normal Breathing)

Inhalation	Exhalation	Lockup After 3 Minutes
~~85~~ 75 psi	~~84~~ 93 psi (95 max)	~~99~~ 93 psi (100 max) primary @4300 ± 200 psi
135 psi	146 psi (120-140)	125 psi (150 max) backup @4300 ± 200 psi
68 psi	75 psi (95 max)	81 psi (100 max) primary @1200 ± 200 psi
122 psi	134 psi (120-140)	138 psi (150 max) backup @800 $^{+0}_{-50}$ psi

Comments:
DEEP BREATH 105
SHALLOW BREATH 99 } at Start while Cold
AFTER ROOM TEMP. LOCK UP 93 PSIG.

3. Press-To-Test & Transfer
   a) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 4300 ± 200 psi. (3 breaths max.)
   b) Release P. T. T. 2 breaths required to transfer to primary pressure schedule at 4300 ± 200 psi (6 breaths max.)
   c) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 1200 ± 200 psi (3 breaths max.).
   d) Release P. T. T. 3 breaths required to transfer to primary at 1200 ± 200 psi (6 breaths max).
   e) Repeat P.T.T. and release several times and check for repeated transfer and return from primary to backup and back to primary.
   f) Comments: ______
4. Demand Regulator Inward Leakage (Exhalation Valve)

Draft Inches of Water	Flow cc/Min.	Limits cc/Min.
-0.5	0.08	5.0
-2.0	0.02	5.0

5. Flow Draft

Flow	Primary 4300 ± 200 psi	Primary 1200 ± 200 psi	Backup 1200 ± 200 psi	Backup 570 psi	Backup 100 psi	Limits in H_2O
Cracking(50 cc/min)		0.48	0.44			-0.1 to -0.5
178 LPM, NTPD					0.52	-2.0 max.
257 LPM, NTPD	0.70	0.70	0.88			-1.25 max.
390 LPM, NTPD	0.84	0.84				-2.0 max.
476 LPM, NTPD			1.16	1.1		-2.0 max.

*Interstage Pressure shall be 90 psig min.

Comments: ______

6. Low Cylinder Pressure Turn-On: 880 (865 ± 35 psi)
   Comments: ______
7. Whistle Alarm Dynamic Full On/Full Off
   Dynamic Full on 104 PSIG (100-110 PSI)
   Dynamic Full off 84 PSIG (80-90 PSI)
8. Purge Flow

Inlet Pressure PSIG	Flow LPM, NTPD	Limits LPM, NTPD
300	125	125 to 200 LPM

9. Exhalation Flow 300 0.60 IN.H2O 115 PSI 178LPM 90 PSI MIN

Flow	Pressure Inches of Water	Limits Inches of Water
Crack(50 cc/min)	0.20	+0.5 max.
257 LPM, NTPD	1.30	+2.0 max.
476 LPM, NTPD	2.30	+4.0 max.

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[redacted] TEST RECORD [redacted] ER 1053 [redacted]

Figure 2

P.E. Eidenier

SA 38

Date: 10-11-74 System S/N ______

[redacted] Pres[redacted]d. S[redacted] [redacted] nd R[redacted]/N [redacted]

AFTER 5000 CYCLES

FUNCTIONAL TESTS

1. Turn on and breathe. Did whistle sound? YES
2. Continue breathing. Did whistle stop after several breaths? YES
3. Engage press-to-test and continue breathing. Did warning whistle sound? YES
4. Release press-to-test and continue breathing. Did warning whistle stop after several breaths? YES
5. Comments:
6. Perform an external leakage test. None allowed.

   NONE
7. Turn cylinder valve off and slowly breathe trapped system pressure down. Did warning whistle sound? YES
8. Comments

PERFORMANCE TESTS

1. Initial Turn On 4300 psi. Supply Pressure
   a) 1 breaths required to transfer to primary (6 breaths max.)
   b) 95 psi primary pressure
   c) Did whistle sound momentarily prior to transfer to primary? YES
   d) Did whistle fully cease after several breaths? YES
   e) Turn cylinder off and breathe system down. Did whistle come on for low pressure warning? YES
   f) Comments:
2. Interstage Pressure (Normal Breathing)

Inhalation	Exhalation	Lockup After 3 Minutes
83 psi	92 psi (95 max)	102 psi (100 max) primary @4300 ± 200 psi
124 psi	135 psi (120-140)	135.5 psi (150 max) backup @4300 ± 200 psi
72 psi	84 psi (95 max)	96 psi (100 max) primary @1200 ± 200 psi
120 psi	132 psi (120-140)	139 psi (150 max) backup @800 $^{+0}_{-50}$ psi

Comments:

BACKUP AT 1MIN. 153 4300 PSIG RELIEF VALVE DID NOT CRACK

3. Press-To-Test & Transfer
   a) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 4300 ± 200 psi. (3 breaths max.)
   b) Release P. T. T. 2 breaths required to transfer to primary pressure schedule at 4300 ± 200 psi (6 breaths max.)
   c) Engage P. T. T. 1 breaths required to transfer to backup pressure schedule at 1200 ± 200 psi (3 breaths max.).
   d) Release P. T. T. 2 breaths required to transfer to primary at 1200 ± 200 psi (6 breaths max).
   e) Repeat P.T.T. and release several times and check for repeated transfer and return from primary to backup and back to primary.
   f) Comments:
4. Demand Regulator Inward Leakage (Exhalation Valve)

Draft Inches of Water	Flow cc/Min.	Limits cc/Min.
-0.5	1.25	5.0
-2.0	0.25	5.0

5. Flow Draft

Flow	Primary 4300 ± 200 psi	Primary 1200 ± 200 psi	Backup 1200 ± 200 psi	Backup 570 psi	Backup 100 psi	Limits in H_2O
Cracking(50 cc/min)		0.32	0.34			-0.1 to -0.5
178 LPM, NTPD					0.56	-2.0 max.
257 LPM, NTPD	0.66	0.66	0.90			-1.25 max.
390 LPM, NTPD*	0.84	0.82				-2.0 max.
476 LPM, NTPD			1.16	1.14		-2.0 max.

*Interstage Pressure shall be 90 psig min.

Comments:

6. Low Cylinder Pressure Turn-On: 880 (865 ± 35 psi)

   Comments:
7. Whistle Alarm Dynamic Full On/Full Off

   Dynamic Full on 104 PSIG (100-110 PSI)
   Dynamic Full off 86 PSIG (80-90 PSI)
8. Purge Flow

Inlet Pressure PSIG	Flow LPM, NTPD	Limits LPM, NTPD
300	110	125 to 200 LPM

9. Exhalation Flow 300 0.76 IN.H_2O 114 PSIG 178LPM 90 PSI MIN.

Flow	Pressure Inches of Water	Limits Inches of Water
Crack(50 cc/min)	0.06	+0.5 max.
257 LPM, NTPD	1.30	+2.0 max.
476 LPM, NTPD	2.60	+4.0 max.

Engineering Report No. ER 1054

DELTA
QUALIFICATION TEST PROCEDURE
FOR THE
MODIFIED FIREFIGHTER'S BREATHING SYSTEM

NASA CONTRACT NAS9-13177

Dated: 4 OCTOBER 1974

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Cognizant NASA Representative

TABLE OF CONTENTS

1.0 INTRODUCTION

This procedure describes a series of functional and environmental tests to be performed on the Modified Firefighter's Breathing System (FBS) Scott Part Number 27275.

The tests are intended to verify that design improvements made in the FBS comply with the required functional and environmental parameters and qualify it for use in the field evaluation program. These tests are limited to those which are necessary to prove basic compliance and augment the tests reported in the Development Test Report ER 1041 Dated 21 February 1974 and the Supplemental Test Report ER 1051 Dated 10 August 1974.

2.0 GENERAL

2.1 Test Medium

The breathing gas used will be pure, dry breathing air conforming to the requirements of the Compressed Gas Association Commodity Specification for Air, G-7.1, Type I (Grade D or higher quality).

2.2 Environmental Conditions

Unless otherwise specified, the ambient conditions for conducting the operational tests herein will be as follows:

(1) Temperature: 77 $\pm$ 18° F

(2) Relative Humidity: 90 percent or less

(3) Barometric Pressure: Local standard (28 to 32 inches of Hg)

2.3 Test Articles

Tests are to be conducted on two units to be randomly selected from the first group which has their pressure reducers and breathing regulators retrofitted as defined by drawings 27237 Rev. B and 27235 Rev. B.

2.4 Order of Tests

Prior to qualification testing, all test articles shall be acceptance tested in accordance with Delta Acceptance Test Procedure ER 1053.

No particular sequence of tests will be followed except that one test unit will be subjected to life cycle testing as defined in Paragraph 3.3 and the second qualification unit will be subjected to all other tests.

3.0 SPECIFIED TESTS

3.1 Low Temperature Operation

3.1.1 Place a partial FBS in an environmental chamber and subject to the low temperature tests as follows:

3.1.1.1 The partial FBS shall consist of a high pressure hose, pressure reducer, demand regulator and high pressure cylinder and valve. The components shall be interconnected, the purge valve and cylinder valve in the "off" position and the cylinder charged to 4300 to 4500 psig.

3.1.2 Lower the chamber temperature to -40 F $\pm$ 5 F for a period of twelve (12) hours minimum.

3.1.3 Upon completion of the 12-hour exposure and while the system remains in the cold chamber, open the cylinder valve and perform the "functional tests" defined in paragraph 5.1 and breath down test defined in paragraph 5.3 of this procedure.

3.1.5 Upon completion of the "functional tests" and breathdown test, the system to room temperature and perform the "performance tests" defined in Paragraph 5.2.

3.2 High Temperature Operation

3.2.1 Place a partial FBS in an environmental chamber and subject to the high temperature tests defined in 3.2.2 to 3.2.6.

3.2.1.1 The partial FBS shall consist of a high pressure hose, pressure reducer, demand regulator and high pressure cylinder and valve. The components shall be interconnected, and the purge valve and cylinder valve in the "off" position and the cylinder charged to 3700 psi. The assembly shall then be placed in the temperature chamber.

3.2.2 Raise the temperature of the chamber to 120°F ± 5°F and hold for 6 hours minimum.

3.2.3 Raise the temperature of the chamber to 154°F ± 5°F within a time period of one (1) hour and then hold for an additional four (4) hours.

3.2.4 Lower the internal chamber temperature to 120°F ± 5°F within a time period of one (1) hour.

3.2.5 Repeat Steps 3.2.2 through 3.2.4 two additional times making a total of three 12-hour cycles.

3.2.6 Adjust the temperature of the chamber to 165 F ± 5 F and hold for a period of 8 hours minimum.

3.2.7 Upon completion of the 8-hour exposure and while the system remains in the hot chamber, open the cylinder and perform the "functional tests" and breathdown tests defined in Paragraph 5.1 and 5.3.

3.2.8 Upon completion of the "functional tests" and breakdown test, turn the cylinder valve off, separate from the high pressure cylinder and return the system to room temperature and perform the "performance tests" defined in Paragraph 5.2.

3.3 Life Cycling Test

3.3.1 Install a partial FBS in the test setup as shown in Figure 1.

3.3.2 Actuate the valve device to open pressurizing the supply volume downstream of the cylinder valve to 4300 ± 200 psi. Actuate the valve device to close.

3.3.3 With needle valve (1) preset to flow 110 ± 10 1 lpm, open - then close - solenoid to simulate inhalation. Use sequence timer to open and close solenoid at a rate of 12 to 14 cycles per minute.

3.3.4 Allow the simulated inhalation at 12 to 14 cycles per minute until pressure in the supply volume is between 200 to 500 psig.

3.3.5 Repeat paragraphs 3.3.2 through 3.3.4 a total of 5000 times stopping after 500, 1500, 2500, 3500, and 5000 cycles to perform the "functional tests" and "performance tests" defined in paragraphs 5.2 and 5.3.

3.3.6 Maintenance is permitted during the life cycling test, if required. Any of the following factors, should they occur, will signal the need for system maintenance.

a) Failure of the warning signal to turn on.

b) Failure of the warning signal to turn off.

c) Inability to transfer from and to the primary regulator during the press-to-test mode.

d) Gross external leakage.

e) High lockup pressure on the backup system as evidenced by relief valve cracking.

f) Gross flow/draft deficiencies.

Any of the above or other unforeseen deficiencies will be discussed with NASA as they occur and prior to performance of maintenance.

3.4 <u>High Pressure Exposure Test</u>

3.4.1 Connect a partial FBS to a high pressure cylinder pressurized to 4300 to 4500. The cylinder valve shall be "open" and the purge valve of the demand regulator shall be in the off position.

3.4.2 Upon completion of 72 hours of high pressure exposure at a no-flow condition, perform the "functional tests" defined in paragraph 5.1 .

3.4.3 Upon completion of the "functional tests", turn the cylinder valve off, separate from the high pressure cylinder and perform the "performance tests" defined in Paragraph 5.2 .

4.0 <u>SPECIAL TESTS</u>

4.1 <u>High Pressure Exposure at High Temperature</u>

4.1.1 Following completion of high pressure exposure, paragraph 3.4, connect the partial FBS to a high pressure cylinder pressurized to 3700 psig. The cylinder valve shall be "open" and the purge valve of the demand regulator shall be in the "off" position.

4.1.2 Place the assembly in an environmental chamber at 165 F ± 5 F for a minimum of 16 hours.

4.1.3 While still at 165 F and in the temperature chamber, subject the FBS to the "functional test" defined in paragraph 5.1 and breathdown test defined in paragraph 5.3 of this procedure.

4.1.4 Upon completion of the "functional tests" breathdown tests, turn the cylinder valve off, separate from the high pressure cylinder and perform the "performance tests" defined in paragraph 5.2 .

4.1.5 Since this is not considered an operational condition, the "pass-fail criteria" shall be that no failure of the warning whistle to be initiated shall occur when performing the "functional tests" and that no decrease in the backup pressure schedule shall occur which could cause a failure of the warning whistle to be initiated when "performance tests" are made.

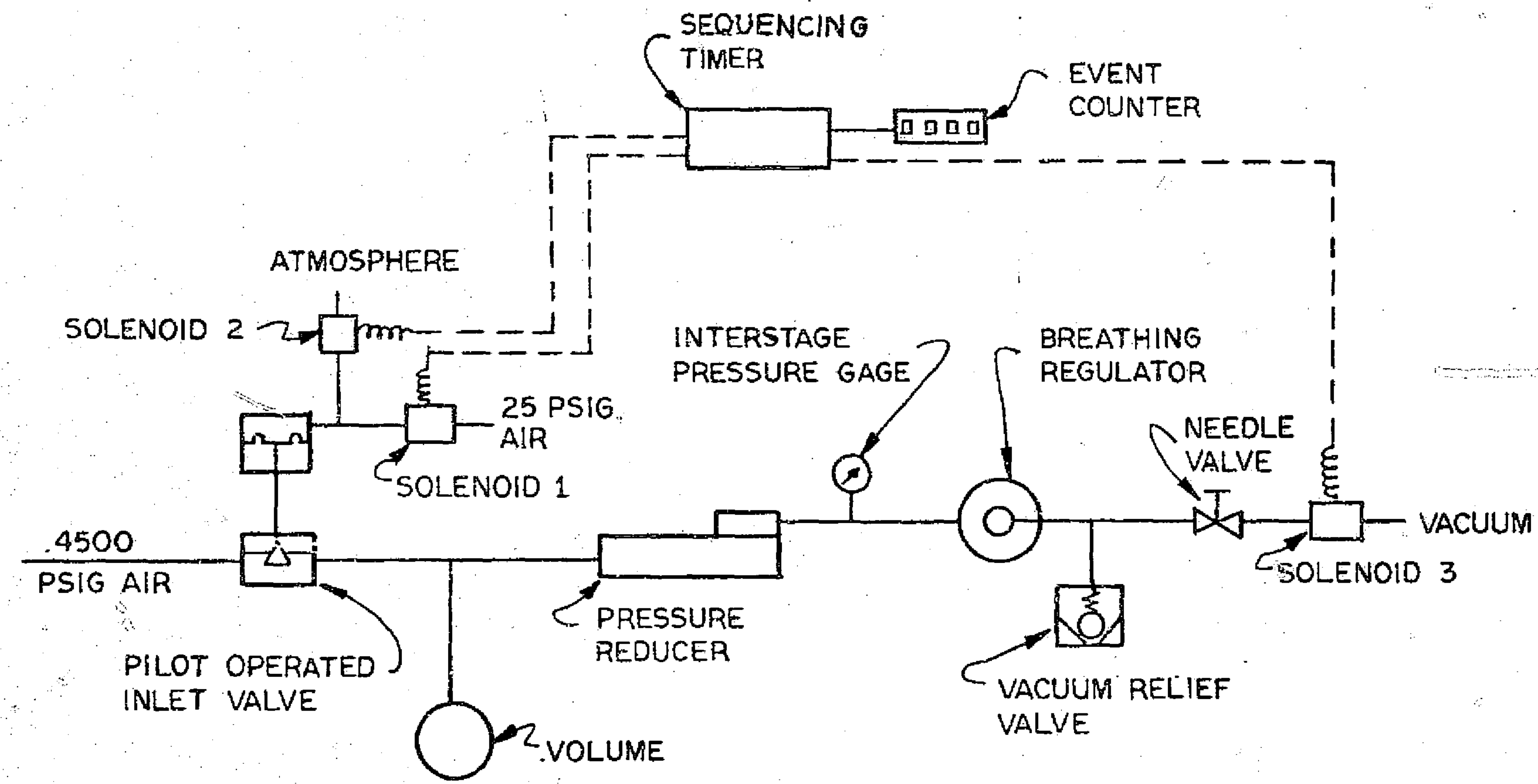
5.0 Test Data

5.1 Functional Tests as defined in paragraph 4.2 of Delta Acceptance Test Procedure ER 1053 shall be performed on the partial FBS while exposed to the conditions of each specified test. Record all data on the test record, figure 2 of ER 1053.

5.2 Performance Tests as defined in paragraph 4.3 of ER 1053 shall be performed on the partial FBS less the high pressure cylinder after completion of each specified test and when returned to standard conditions. The interstage pressures shall be monitored for all tests except primary flow-draft. Record all required values on the test record, Figure 2 of ER 1053.

5.3 Breathdown Test

This test is to be performed following the functional tests where specified and while the system is still exposed to the specified temperature. Turn the cylinder valve on and breath down the system to depletion. Verify that a low pressure warning tone is obtained at approximately 850 psig cylinder pressure and that the tone continues to sound until a cylinder pressure of approximately 300 psig is reached. Breath down may be accomplished manually or by a breathing machine.



SCHEMATIC LIFE CYCLE TEST

FIGURE 1

SEQUENCE
A) SOLENOID 1 OPENS ALLOWING PILOT OPERATED VALVE TO OPEN AND CHARGE SYSTEM TO 4500 PSIG.
B) SOLENOID 1 CLOSES AND SOLENOID 2 OPENS, CLOSING PILOT OPERATED VALVE.
C) SOLENOID 3 ALTERNATELY OPENS AND CLOSES ALLOWING FLOW TO BE DRAWN FROM THE SYSTEM UNTIL A PRESSURE OF 200 TO 500 PSIG IS REACHED.
D) THE FUEL CYCLE IS COMPLETED AND STEP A BEGINS AGAIN.

Engineering Report No. ER 1053

DELTA
ACCEPTANCE TEST PROCEDURE
FOR THE
FIREFIGHTER'S BREATHING SYSTEM

NASA CONTRACT NO. NAS9-13177

DATED: 16 SEPTEMBER 1974

Prepared By: P. R. Bement

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Manager of Engineering
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TABLE OF CONTENTS

1.0 INTRODUCTION

This procedure describes a series of functional and performance tests to be performed on each Firefighter's Breathing System prior to Delta qualification testing and customer delivery.

The overall objective of this series is to verify that each FBS is functionally correct following completion of design changes and installation of retrofit parts.

2.0 APPLICABLE DOCUMENTS

NASA Specification FBS-SP-001, Revision 2, dated November 3, 1971.

Titled: "Performance, Design and Cost Requirements for a Compressed Air Demand-type Fireman's Breathing System:

Compressed Gas Association Commodity Specification for Air, Number G-7.1

3.0 GENERAL

3.1 Test Medium

The breathing gas used will be pure, dry breathing air conforming to the requirements of the Compressed Gas Association Commodity Specification for Air, G-7.1, Type I (Grade D or higher quality).

3.2 Environmental Conditions

Unless otherwise specified, the ambient conditions for conducting the operational tests herein will be as follows:

(1) Temperature: $77 \pm 18^{\circ}F$

(2) Relative Humidity: 90 percent or less

(3) Barometric Pressure: Local standard (28 to 32 inches of Hg)

3.3 Order of Tests

Unless otherwise specified, all tests will be performed in the order presented herein.

3.4 Test Instrumentation

3.4.1 Accuracy

The accuracy of instruments and test equipment used to control or minitor test parameters specified herein shall:

(a) Conform to laboratory standards whose calibration is traceable to the prime standards at the U. S. Bureau of Standards.

(b) Have an accuracy of at least one-tenth the tolerance for the test article variable to be measured.

3.4.2 Calibration and Certification

Prior to starting any test, test engineering shall review the instrumentation to ascertain that:

(a) Calibration and certification have been accomplished and are valid.

(b) The calibration time period will not elapse during a test of long duration. If this possibility exists, the applicable instrument will be replaced by one with a more recent calibration date.

4.0 SPECIFIED TESTS

4.1 Proof Pressure Test

4.1.1 Subject a partial FBS to an inlet proof pressure of 6750 psi for a minimum of 5 minutes.

4.1.1.1 The partial FBS shall consist of a high pressure hose, pressure reducer and demand regulator. The components shall be interconnected and purge valve closed.

4.1.2 Gradually decrease the supply pressure from 6750 psi to 4500 psi and perform an external leakage check. Upon completion, gradually reduce the supply to vent the system.

4.1.3 Upon completion of the proof pressure test, perform the "functional tests" and the "performance tests" defined in Paragraphs 4.2 and 4.3.

4.2 FUNCTIONAL TESTS

4.2.1 Functional tests as defined below shall be performed on the partial FBS. Record all required comments on the test record, Figure 2.

4.2.1.1 Turn the cylinder valve "on" and take several breaths from the demand regulator.

4.2.1.2 Note if the whistle sounded on the first breath.

4.2.1.2.2 Note if the whistle stopped after several breaths.

4.2.1.3 Engage the press-to-test and take several breaths.

4.2.1.4 Note if transfer to the backup pressure schedule occurs as evidenced by the warning whistle.

4.2.1.5 Release press-to-test and take several breaths.

4.2.1.6 Note if transfer to the primary pressure schedule occurs, that the whistle stopped after several breaths.

4.2.1.7 Perform an external leakage test.

4.2.1.8 Turn the cylinder valve "off" and breathe through the demand regulator to breathe the residual trapped system pressure down.

4.2.1.9 Note if transfer to the backup pressure schedule occurs as evidenced by the warning whistle.

4.3 PERFORMANCE TESTS

4.3.1 Performance Tests as defined below shall be performed on the partial FBS less the high pressure cylinder. The interstage pressures shall be monitored for all tests except flow-draft. Record all required values on the test record, Figure 2.

4.3.1.1 Initial Turn On

4.3.1.2 Apply 4300 $\pm$ 200 psi note and record this supply pressure.

4.3.1.3 Breathe through the demand regulator, note how many breaths were required to transfer to the primary pressure schedule and note the primary pressure.

4.3.1.4 Note if whistle sounded momentarily prior to transfer to the primary.

4.3.1.5 Note if whistle fully ceases after several breaths.

4.3.1.6 Turn the cylinder valve "off' and breathe the system down. Note if the whistle came on for low pressure warning.

4.3.2 Interstage Pressure

4.3.2.1 Breathe normally through the demand regulator, note and record the high and low interstage pressures for the primary and backup pressure schedules for supply pressures of 4300 ± 200 psi and 1200 ± 200 psi.

4.3.2.2 Note and record the primary and backup pressures at lockup after three (3) minutes.

4.3.3 Press-To-Test and Transfer

4.3.3.1 Engage the press-to-test and breathe through the demand regulator, note and record the number of breaths required to transfer to and from primary to backup pressure schedules, at 4300 ± 200 psi and 1200 ± 200 psi supply pressure.

4.3.4 Demand Regulator Inward Leakage (Exhalation Valve)

4.3.4.1 Disconnect the low pressure hose from the pressure reducer and cap the hose. Slowly draw successive negative pressures of -0.5 and -2.0 inches of water while noting and recording the resulting flow through a low range flow meter. This flow is the leakage through the demand regulator (exhalation valve).

4.3.5 Flow Draft

4.3.5.1 Perform flow draft tests as specified on the test record at supply pressures of 4300 ± 200; 1200 ± 200, 570, and 100 psig. Note and record the draft required to obtain demand valve cracking (50 cc/min) and flows of 178, 257, 390, and 476 LPM, NTPD.

4.3.6 Low Cylinder Pressure Turn-On

4.3.6.1 Slowly decrease the inlet pressure and determine pressure at which transfer from the primary to the backup pressure schedule occurs. Note and record this low cylinder pressure turn-on.

4.3.7 <u>Whistle Alarm Dynamic Full-On/Full-Off</u>

4.3.7.1 Connect the breathing regulator to a separate regulated pressure source. Breathe thru the demand regulator starting with a supply pressure between 95 and 99 psi. Increase the inlet pressure in one PSIG increment and breathe three to four times at each pressure. While observing the pressure gage, record the pressure at which the whistle alarm is "full-on". This pressure should be the highest pressure observed on the gage. The dynamic "full-off" pressure should be determined by decreasing pressure and using similar methods as described above. Start with a pressure between 92-95 psi and note and record the lowest pressure observed during inhalation. (i.e. Droop Pressure)

4.3.8 <u>Purge Flow</u>

4.3.8.1 Apply 300 PSIG to the inlet of a partial FBS (Figure 1).

4.3.8.2 Open purge valve fully which will cause a slight positive pressure in the mask.

4.3.8.3 Slowly open the needle valve until the mask pressure is zero. Record the resulting flow on the flowmeter.

4.3.9 <u>Exhalation Flow</u>

4.3.9.1 Perform the exhalation valve flow tests by applying flows through the demand regulator of 50 cc/min (cracking), 257 and 476 LPM, NTPD and noting and recording the resulting positive pressures.

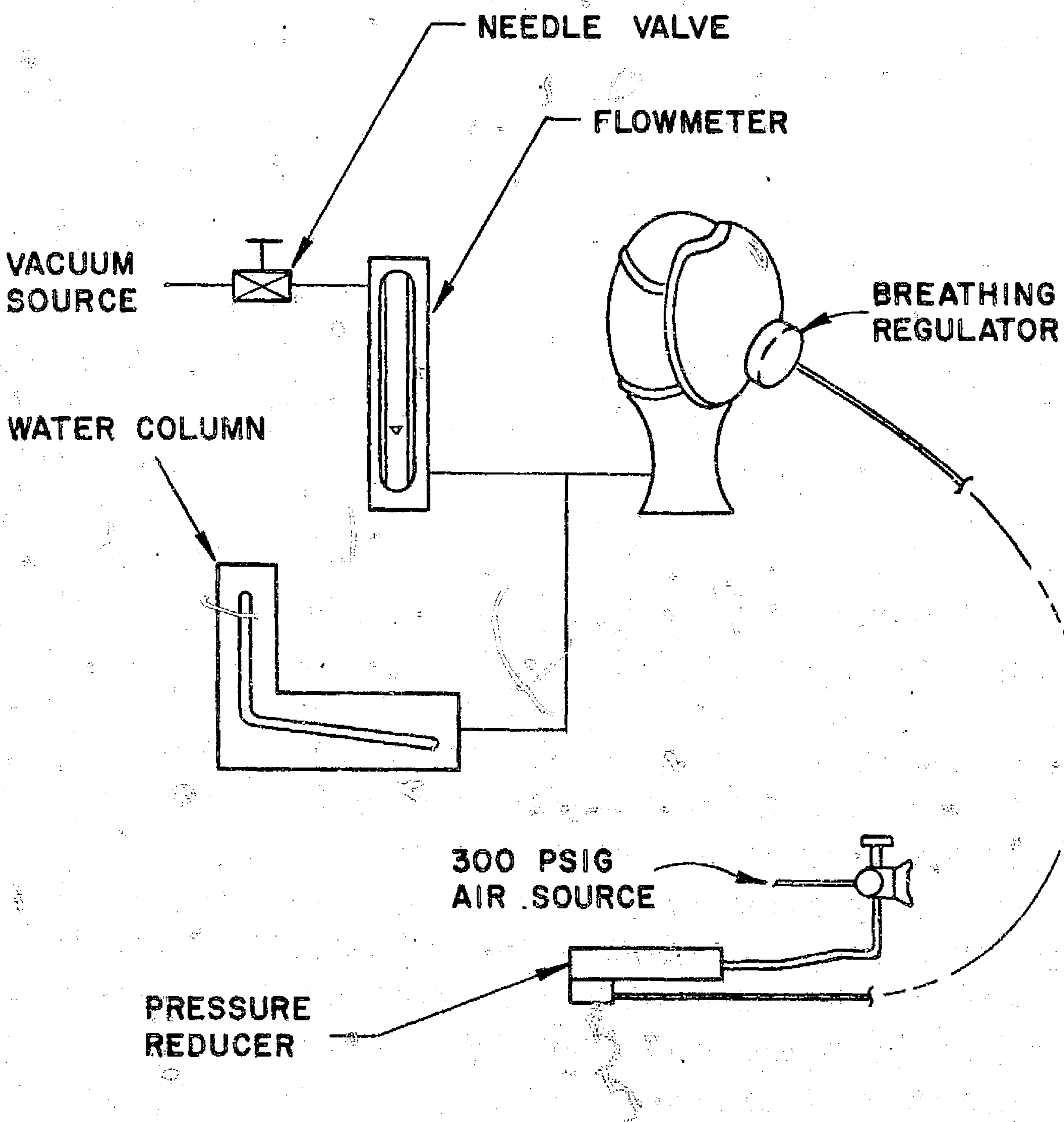
NEEDLE VALVE
FLOWMETER
VACUUM SOURCE
BREATHING REGULATOR
WATER COLUMN
300 PSIG AIR SOURCE
PRESSURE REDUCER

FIGURE I

[redacted]TION[redacted]STS[redacted]

1. Turn on and breathe. Did whistle sound? ____________

2. Continue breathing. Did whistle stop after several breaths? ________

3. Engage press-to-test and continue breathing. Did warning whistle sound? __________

4. Release press-to-test and continue breathing. Did warning whistle stop after several breaths? __________

5. Comments:

____

6. Perform an external leakage test. None allowed.

____

7. Turn cylinder valve off and slowly breathe trapped system pressure down. Did warning whistle sound? ________

8. Comments

____

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PERFORMANCE TESTS

1. Initial Turn On ________ psi. Supply Pressure

   a) __________ breaths required to transfer to primary (6 breaths max.)

   b) __________ psi primary pressure

   c) Did whistle sound momentarily prior to transfer to primary? ______

   d) Did whistle fully cease after several breaths? ________

   e) Turn cylinder off and breathe system down. Did whistle come on for low pressure warning? ________

   f) Comments: ______________________________

2. Interstage Pressure (Normal Breathing)

Inhalation	Exhalation	Lockup After 3 Minutes
_____psi	_____psi (95 max)	_____psi (100 max) primary @4300 ± 200 psi
_____psi	_____psi (120-140)	_____psi (150 max) backup @4300 ± 200 psi
_____psi	_____psi (95 max)	_____psi (100 max) primary @1200 ± 200 psi
_____psi	_____psi (120-140)	_____psi (150 max) backup @800 $^{+0}_{-50}$ psi

3. Mask Leakage

Draft (In. H_2O)	Flow (cc/min)	Limit (cc/min)
-1.0		20

4. Press-To-Test & Transfer

   a) Engage P.[redacted] breaths [redacted] to [redacted] backup pressure schedule at 4300 ± 200 psi. (3 breaths max.)

   b) Release P. T. T. ________ breaths required to transfer to primary pressure schedule at 4300 ± 200 psi (6 breaths max.)

   c) Engage P. T. T. ________ breaths required to transfer to backup pressure schedule at 1200 ± 200 psi. (3 breaths max.).

   d) Release P. T. T. ________ breaths required to transfer to primary at 1200 ± 200 psi (6 breaths max).

   e) Repeat P.T.T. and release several times and check for repeated transfer and return from primary to backup and back to primary.

   f) Comments: ______________________________

5. Demand Regulator Inward Leakage (Exhalation Valve)

Draft Inches of Water	Flow cc/Min.	Limits cc/Min.
-0.5		5.0
-2.0		5.0

6. Flow Draft

Flow	Primary 4300 ± 200 psi	Primary 1200 ± 200 psi	Backup 1200 ± 200 psi	Backup 570 psi	Backup 100 psi	Limits in H_2O
Cracking(50 cc/min)						-0.1 to -0.5
178 LPM, NTPD						-2.0 max.
257 LPM, NTPD						-1.25 max.
390 LPM, NTPD						-2.0 max.
476 LPM, NTPD			*			-2.0 max.

*Interstage Pressure shall be 90 psig min.

Comments: ______________________________

7. Low Cylinder Pressure Turn-On: ________ (865 ± 35 psi)

8. Whistle Alarm Dynamic Full On/Full Off

Dynamic Full on __________ PSIG (100-110 PSI)
Dynamic Full off __________ PSIG (80-90 PSI)

9. Purge & Back-up Flow

	Inlet Pressure PSIG	Draft (In. H_2O)	Flow LPM, NTPD	Limits LPM, NTPD
Purge @	300			125 to 200 LPM
Backup @	300			178 LPM, 90 PSI Interstage Minimum

10. Exhalation Flow

Flow	Pressure Inches of Water	Limits Inches of Water
Crack (50 cc/min)		+0.5 max.
257 LPM, NTPD		+2.0 max.
476 LPM, NTPD		+4.0 max.

TEST EQUIPMENT

Item No.	Item	Manufacturer	Model	S/N	Accuracy
1	Flowmeter	Brooks	10-1110-10	F-214	$\pm$ 2%
2	Flowmeter	Fisher-Porter	0-50 cc	F-204	$\pm$ 2%
3	Mass Flowmeter	Hastings-Raydist	0-10 cc	F-175	$\pm$ 2%
4	Pressure Gage	U. S. Gauge	0-3000 psi	G-218	$\pm$ 2%
5	Pressure Gage	U. S. Gauge	0-5000 psi	G-224	$\pm$ 2%
6	Pressure Gage	U. S. Gauge	0-5000 psi	G-212	$\pm$ 2%
7	Pressure Gage	U. S. Gauge	0-10,000 psi	G-221	$\pm$ 5%
8	Pressure Gage	U. S. Gauge	0-600 psi	G-217	$\pm$ 2%
9	Water Column	F. W. Dwyer	-2 to 20 inches/water	0063	$\pm$ .02 in. H_2O
10	Environmental Chamber	Tenny Engineering	TTUFR 100350		
11	Temperature/Humidity Controller	Bristol Company	TF-2T500FFF S4-43B	65A,10 606	$\pm$ 5°F
12	Program Controller	Bristol Company	253A500G1	65A,10 606	$\pm$ 5°F
13	Stop Watch	Meylan	204B	SW-51	$\pm$ .2 sec.