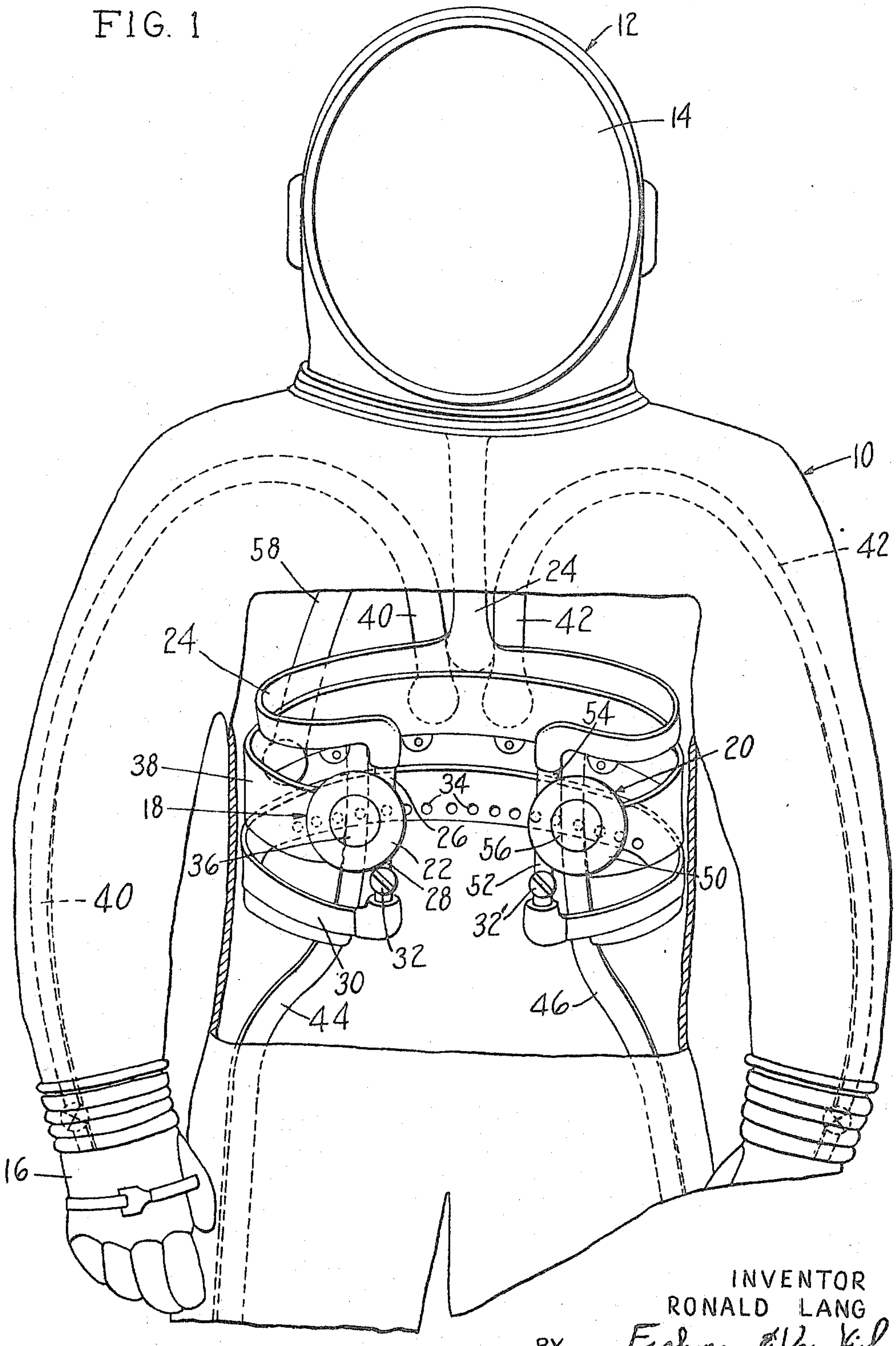
Jan. 6, 1970 R. LANG 3,487,765

PROTECTIVE GARMENT VENTILATION SYSTEM

Filed Oct. 6, 1966 3 Sheets-Sheet 1

FIG. 1



INVENTOR
RONALD LANG
BY Fishman & Van Kirk
ATTORNEYS

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PROTECTIVE GARMENT VENTILATION SYSTEM

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FIG. 2

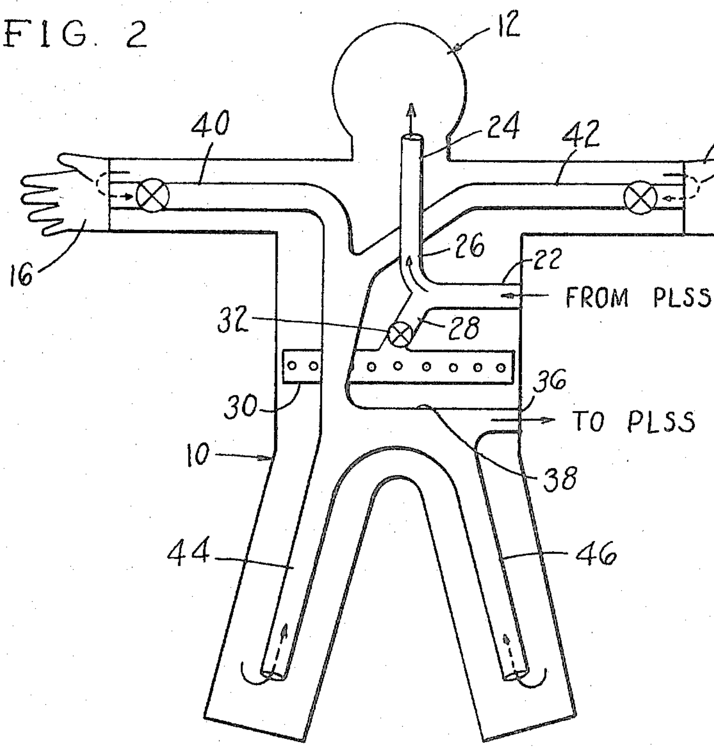
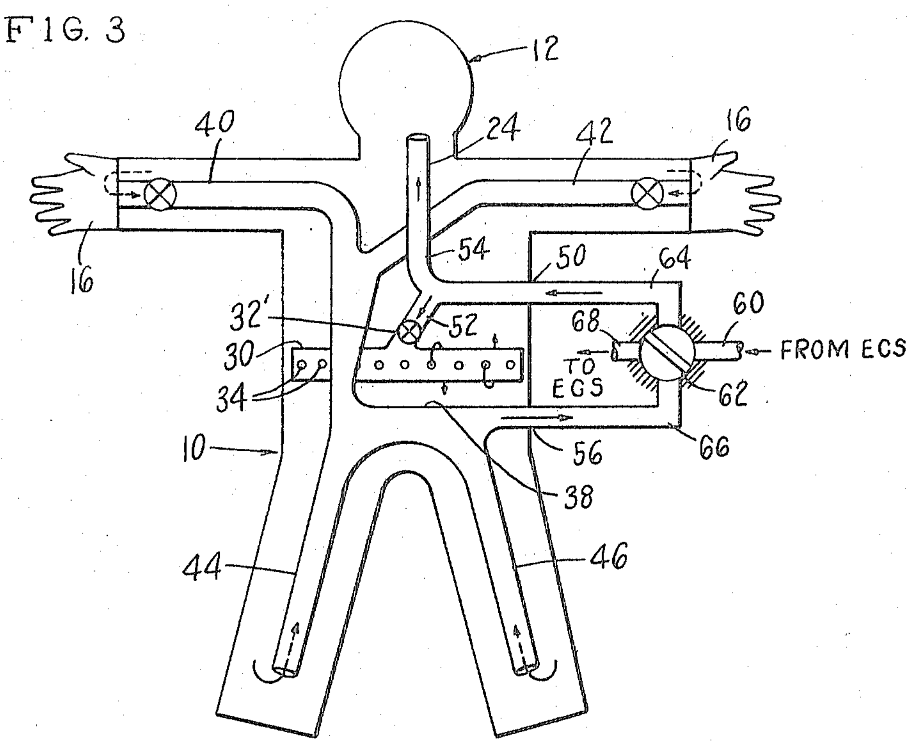


FIG. 3



PROTECTIVE GARMENT VENTILATION SYSTEM

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FIG. 4

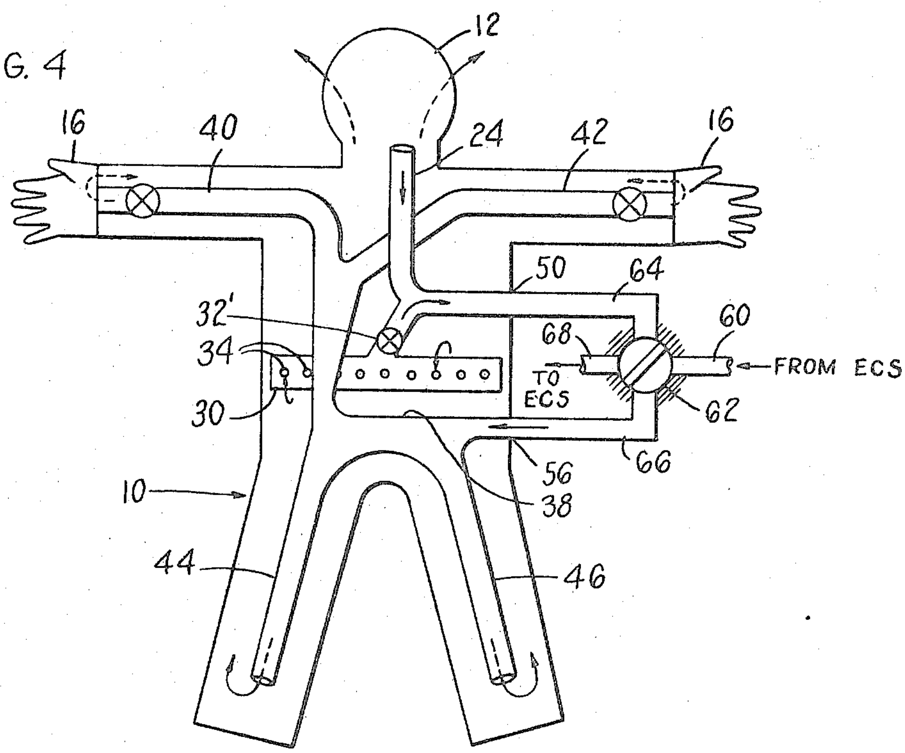
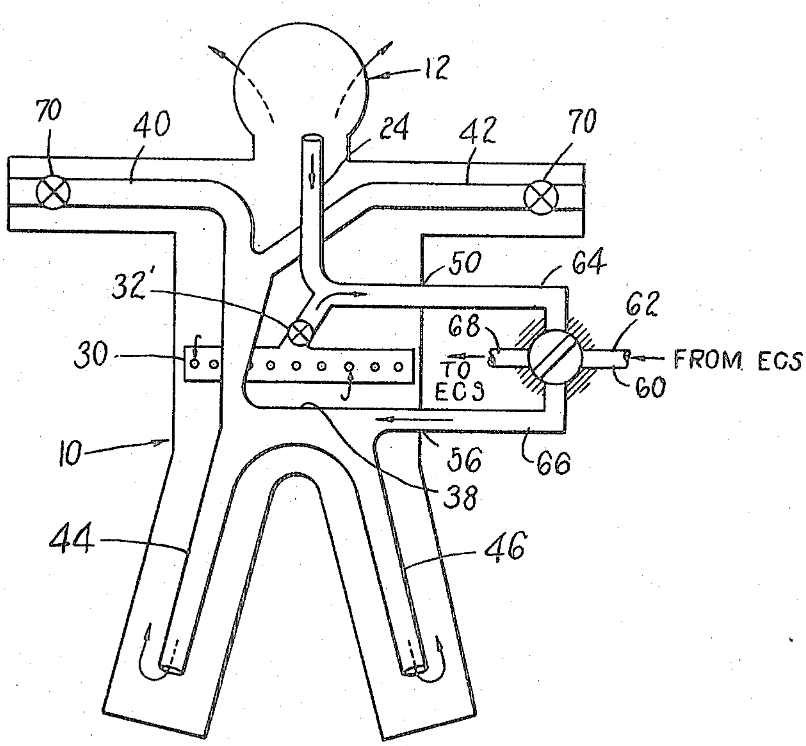


FIG. 5



3,487,765

PROTECTIVE GARMENT VENTILATION SYSTEM

Ronald Lang, Manchester, Conn., assignor to United Aircraft Corporation, East Hartford, Conn., a corporation of Delaware

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U.S. Cl. 98—1 11 Claims

ABSTRACT OF THE DISCLOSURE

A method of and apparatus for ventilating a protective garment wherein the direction of flow of a ventilating and purging gas within portions of the garment may be reversed in order to compensate for changes in environment and activity of the wearer, the present method and apparatus also contemplating the establishment of a condition wherein the entire flow of ventilating gas is first directed to a helmet associated with the garment.

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 Stat. 435; 42 U.S.C. 2457).

The present invention relates to garments which are intended to protect the wearer thereof from a hostile environment. More particularly, the present invention is directed to ventilating such garments so as to maintain a comfortable and non-toxic atmosphere therein. Accordingly, the general objects of the present invention are to provide new and improved methods and apparatus of such character.

While not limited thereto in its utility, the present invention is particularly suitable for incorporation in pressure suits. Accordingly, the discussion to follow will be centered upon use of the present invention as part of a space suit system. While not necessarily unique thereto, the problems associated with ventilating a protective suit designed for use in space are aggravated by the extremes of the environment to which the garment is subjected. That is, depending upon whether the wearer of the suit is engaged in intra- or extra-vehicular activity, the ventilation and purging requirements for the garment vary drastically. This is true whether the garment be liquid cooled, as are second generation space suit systems, or air cooled, as are the early systems such as those worn by Gemini astronauts.

The life support system for the protective garment, be it a portable back pack system or the orbital vehicle's environmental control system (ECS) which is connected to the garment by an umbilical, performs the functions of oxygen supply, suit pressurization, contaminate control and humidity control. In the case of a gas cooled garment, the support system must also provide for maintenance of the proper garment internal temperature. In a system with gas cooling, thermal control is accomplished principally by evaporative cooling of the body to a circulating oxygen stream with a small portion of heat removed by utilizing the sensible capacity of the gas stream. It is, of course, desired that the system remove the total sensible sweat loss as well as the insensible water loss (latent respiration plus water lost through skin diffusion). In short, if compatible with size and power requirements, it is desirable to select a volumetric flow rate for the circulating oxygen stream sufficient to maintain the subject at a "no sweat" condition or, at the very least, to achieve thermal equilibruim while simulta-

neously thoroughly purging the helmet area of carbon dioxide.

Present generation space suit systems, whether gaseous or liquid cooled, split the purging and ventilating gas flow entering the garment into a plurality of paths. Typically, the injected oxygen stream will be split between five flow paths; the arms, the legs and the helmet. Accordingly, with an oxygen supply of twelve cubic feet per minute, as is provided by the Gemini and Apollo vehicle ECS's, a volume of approximately five cubic feet per minute (40% of the total flow) is supplied to the helmet. As has been clearly shown by the visor fogging problems encountered during the extra-vehicular experiments performed during the Gemini program of the United States, this limited flow is insufficient to prevent visor fogging and to absorb sweat loss moisture in the helmet area.

When the subject has returned to his orbital vehicle, and opened his visor or removed his helmet, while garment ventilation is still needed, the requirements have changed with the conditions. That is, with the subject in a hospitable environment, it is unnecessary to directly deliver an oxygen stream to the head area since, with the helmet removed or visor open, the gas would be lost (merely added to the internal vehicle environment). Thus, for maximum efficiency it is desired that the flow path or paths for the ventilating and purging gas be capable of alteration in accordance with the environmental condition. That is, it is desirable to vary the path of flow of the oxygen stream within the garment in accordance with whether the visor is open or closed (or helmet on or off as dictated by the pressurization of the vehicle cabin). Further, the ventilation and purging requirements vary between the situation when the subject is merely sitting in an unpressurized vehicle (as will be a command pilot) and when the subject is engaged in extra-vehicular activity (as will be the pilot simultaneously). Under the former condition the peak metabolic loads imposed on the subject are much less than the 500 kcal. per hour which may be encountered during extra-vehicular activity. In other words, during extra-vehicular activity it is mandatory that the helmet area be CO_2 purged and dehumidified and, due to the high metabolic loads, this may be accomplished only by maintaining a high rate of oxygen flow. These conditions are, of course, not encountered while sitting in an unpressurized cabin and thus it is desirable to direct some of the flow which is used for helmet purging during extra-vehicular activity to the purpose of maintaining torso and extremity comfort during intravehicular activity with the visor closed.

In making the transition between the three above described environmental conditions; extra-vehicular activity, intra-vehicular activity with visor closed and intra-vehicular activity with visor open; it is mandatory that the controls that must be manipulated by the subject be easy to adjust since the adjustment procedure will normally be accomplished with gloves in place. It is also desirable that the number of controls which must be manipulated be held at a minimum.

The present invention overcomes the above-discussed problems and disadvantages of prior art protective garment ventilation systems by providing a novel method of garment ventilation and apparatus for performing that method. The apparatus of the present invention is characterized by its ease of use. The method of the present invention has three basic operative modes. Under a first mode of operation, the stream of ventilating and purging gas is directed in a first direction along a plurality of predetermined flow paths so as to provide ventilation of the torso and extremities, excluding the helmet area, of the protective garment. During a second mode of operation, the direction of flow of the pressurized ventilating gas along the predetermined paths is reversed and the helmet as well as the troso and extremities of the garment are ventilated. In a third mode of operation, the entire ventilating gas stream is directed to the helmet area to provide CO_2 purging and visor defrosting and thereafter this flow traverses the remainder of the garment to provide ventilation thereof. Transition between the first and second modes of operation is accomplished by switching a single two-position valve and transition from the second to third mode of operation is accomplished by properly adjusting second and third two-position valves.

It is therefore an object of the present invention to provide for the ventilation of a portective garment.

It is another object of the present invention to provide a ventilation system for a protective garment which has a plurality of modes of operation to suit varying operational conditions.

It is also an object of the present invention to provide a multi-mode ventilation system for a protective garment in which the transition from one mode of operation to another may be accomplished easily and surely.

It is yet another object of the present invention to accomplished adequate helmet ventilation and purging to prevent visor fogging in a protective garment when the subject is experiencing high metabolic loads.

It is still another object of the present invention to reverse the direction of flow of ventilating and purging gas through a protective garment in accordance with the change in the environment in which the garment is worn.

These and other objects of the present invention will become readily apparent to those skilled in the art by reference to the accompanying drawing wherein like reference numerals refer to like elements in the various figures and in which:

FIGURE 1 is a front view, partially broken away, which shows a first embodiment of the protective garment ventilation system of the present invention.

FIGURE 2 is a schematic showing of the flow paths of the ventilating gas in the embodiment of FIGURE 1 in a first operative mode.

FIGURE 3 is a schematic showing the flow paths of the ventilating gas in the embodiment of FIGURE 1 in a second operative mode.

FIGURE 4 is a schematic showing of the flow paths of the ventilating gas in the embodiment of FIGURE 1 under a third operative mode.

FIGURE 5 is a schematic showing the flow paths of the ventilating gas in the embodiment of the present invention shown in FIGURE 1 under the operative mode of FIGURE 4 but with gloves removed.

Before discussing the drawing, the characteristics of an optimum ventilation distribution system for a space suit will be outlined. As hereinafter employed, intra-vehicular operation is defined as suit ventilation from the ECS (environmental control system) of the space vehicle while extra-vehicular operation is defined as suit ventilation from the PLSS (Portable Life Support System) or EMU (Extra-vehicular Mobility Unit). In the embodiment to be described, the ventilation distribution system, including the suit, was designed to have a system pressure drop for intra-vehicular operation of 4.7 inches of water (including the suit half of the connectors) with an inlet flow of 12 cubic feet per minute at 3.5 p.s.i.a. and 70° F. For extra-vehicular (PLSS) operation, since liquid cooling of the suit is preferably employed, a flow rate of ventilating gas, usually oxygen, necessary to provide maximum moisture absorption capability (approximately 6 cubic feet per minute) was the controlling parameter rather than pressure drop. The ventilation system is functional with either or both the vehicle ECS and PLSS connected to the suit. During intra-vehicular operation with gas cooling and the helmet visor closed, sufficient flow (approximately 6 c.f.m. which is one-half the volume of gas delivered to the suit) is supplied to the helmet for effective CO_2 purging and visor defogging. Also during intra-vehicular operation, with the visor open and with gloves either on or off, sufficient flow is provided for cooling of the torso and extremities. During extra-vehicular operation, the ventilation flow is capable of absorbing the moisture associated with respiration and a nominal 140 cc. per hour of eccrine perspiration and this flow is directed to the helmet in such a manner that visor fogging may not occur. The system employs a gas connector concept which does not depend on indexing as a prerequisite for affecting a connection. Also, parallel connection of the vehicle ECS and the PLSS to the suit is possible during checkout of the PLSS prior to vehicle egress.

Referring now to FIGURE 1, the upper portions of a space suit **10** including the removable helmet **12** and its visor **14** are shown. Suit **10** will typically be comprised of several layers of aluminized Mylar. This material provides a highly effective radiation barrier in a vacuum environment. Visor **14** is of a transparent material having several layers of optical coating thereon which provide for temperature control, minimum heat leak and attenuation of eye damaging radiation. Removable gloves, such as shown at **16**, are associated with the suit. With gloves **16** in place, depending upon the mode of operation, the ventilating gas may be directed into the gloves so as to remove perspiration from the palms of the subject.

As shown in FIGURE 1, the inner and outer layers of the suit have been partially cut away to reveal a portion of the ventilation distribution system. Connection to the suit internal distribution system is made via a pair of multiple oxygen connectors **18** and **20**. Connectors **18** and **20** may be of the coaxial type which define inner and outer conduits for the flow of the ventilating and purging gas. The multiple oxygen connectors mate with the PLSS or space vehicle ECS multiple oxygen connections to form single connections with two passages, supply and return. The multiple connectors include mechanical check valves which open when the connection is made. Thus, when hoses are not plugged into connectors **18** and **20**, the connectors are sealed against leakage to or from the suit distribution system by means of spring loaded, poppet type valves. Alternatively, each of multiple connectors **18** and **20** may be replaced by two single conduit type connectors each of which has a spring operated disconnect valve therein. In this alternate approach, it is necessary for the subject to work with twice as many umbilical (hose) connections. However, this may be preferable in view of the considerable economic savings realized when using four standard single connectors as opposed to employing a pair of multiple connectors as shown.

Considering first connector **18**, the point at which the gas supply conduit from the PLSS is attached, the outer portion **22** of the connector communicates with the helmet supply vent **24** via conduit **26**. The outer portion of **22** of connector **18** also communicates, via a conduit **28**, with a torso supply vent **30**. Interposed in conduit **28**, for the purposes to be described below, is a value **32** which has an on and off position. Torso supply vent **30** is provided with a plurality of apertures **34** through which the ventilating gas may escape into the main body of the suit **10**. The internally disposed portion **36** of connector **18** communicates with a system return vent member **38** from which extend arm return vents **40** and **42** and leg return vents **44** and **46**. The arm return vents **40** and **42**, respectively, terminate at the left and right gloves **16** and, depending upon the mode of operation, either discharge oxygen over the palms of the subject's hands or provide a return path for oxygen which flows internally from the suit **10** to gloves **16**. Leg return vents **44** and **46**, respectively, terminate at the left and right feet of garment **10** and, like the arm return vents, either deliver oxygen to or return oxygen from the feet depending upon the mode of operation.

The outer portion **50** of connection **20** communicates with torso supply vent **30** via conduit **52** and helmet supply vent **24** via conduit **54**. Conduit **52** has interposed therein an on-off valve **32'** which serves the same function as valve **32**. The inner portion **56** of coaxial connector **20** communicates with the system return vent **38** and thus with arm return vents **40** and **42** and leg return vents **44** and **46**.

While not shown in FIGURE 1, each of arm return vents **40** and **42** includes a high flow shut off valve which is integral with the wrist disconnect. These valves may be spring operated poppet type valves which, when a glove **16** is removed, seal off the arm return vents. The ventilation distribution system also includes an emergency oxygen supply vent **58** which routes emergency oxygen from the ECS directly to the helmet.

Referring now to FIGURE 2, the distribution system of FIGURE 1 is shown schematically as adjusted for extra-vehicular activity. As previously noted, in the case of extra-vehicular activity, it is desired to provide maximum ventilation flow to helmet **12** so as to insure adequate CO_2 purging (the subject will be moving about and breathing hard), to prevent visor fogging and to insure removal of perspiration which might otherwise interfere with the subject's vision. For extra-vehicular activity, an umbilical cable from the vehicle's ECS or a connection to a portable life support system (PLSS) is inserted in connector **18** (the coaxial portions **22** and **36** of which are shown separated in FIGURE 2 for convenience). Under these conditions, the outer portion **22** of connector **18** serves as the inlet for the ventilating gas while the outer portion **36** of connector **18** serves as the return for the gas to a moisture and CO_2 removal unit. In a closed system which recirculates breathing oxygen, it is necessary to remove those contaminates which, if recirculated, would endanger the subject. Contaminate control systems are known in the art, do not constitute part of the present invention and thus will not be described in detail herein. Suffice it to say that carbon dioxide may be absorbed by passing the CO_2 ladden oxygen stream through a lithium hydroxide bed where the CO_2 reacts with the LiOH to produce lithium carbonate and water. Excess water is removed from the oxygen stream by a water separator.

After being connected to the PLSS oxygen supply and before venturing outside the friendly environment of the vehicle, the subject turns valves **32** and **32'** to the closed position. This insures that the entire oxygen stream supplied to suit **10** is delivered via helmet supply vent **24** to helmet **12**. The supply vent arrangement in helmet **12** is not shown in the drawing. However, the oxygen delivered to the helmet is discharged downwardly over the visor to provide a defrosting action. It should be noted that the internal visor temperature is maintained above the local dew point of the oxygen stream by utilizing selective optical coatings within a multiple visor system. The oxygen discharged into helmet **12** from vent **24** flows downwardly over the torso and to the ends of the extremities. The oxygen stream is thus collected at the gloves **16** and returned via arm return vents **40** and **42** to system return vent **38**. The oxygen flowing downwardly from helmet **12** is also returned from the legs of suit **10** via leg return vents **44** and **46** to system return vent **38**. From system return vent **38**, the now contaminated oxygen stream returns via center portion **36** of conduit **18** to the decontamination system portion of the PLSS.

For intra-vehicular activity with the visor of helmet **12** closed and gloves **16** on, as would be the case before or after vehicle egress, the degree of helmet purging required for extra-vehicular activity is not necessary. Accordingly, as may be seen from FIGURE 3, when the subject is, for example, seated in an unpressurized space vehicle, and reconnected to the vehicle ECS via connector **20** (coaxial portions **50** and **56** of which are shown separated in FIGURES 3, 4 and 5 for convenience), values **32** and **32'** are switched back to the open position thereby allowing a 50–50 split of vehicle ECS oxygen flow. Thus, oxygen supplied from the vehicle ECS via the outer portion **60** of a coaxial conduit passes through a two-position valve or flow director **62** and thence to the outer portion **50** of connector **20** via conduit portion **64**. Since valve **32'** is now open, the oxygen delivered to the ventivation distribution system is split between conduits **52** and **54** of suit **10**. Approximately one-half of the flow is thus delivered to helmet **12** from conduit **54** via helmet supply vent **24**. The other half of the flow is delivered to torso supply vent **30** via conduit **52** and valve **32'** and exits into the interior of the suit through apertures **34** in torso supply vent **30**. The oxygen delivered into the suit through apertures **34** in torso supply vent **30** and by flowing downwardly from helmet **12** around the neck is returned to the vehicle ECS via arm return vents **40** and **42** and leg return vents **44** and **46** in the same manner as during extra-vehicular activity. Thus, the contaminated oxygen stream collected at gloves **16** and in the vicinity of the feet is returned to the system return vent **38** and passes out of the suit through the inner portion **56** of connector **20**. The gas stream exiting the suit returns to the decontaminating section of the ECS via a conduit portion **66**, valve **62** and conduit portion **68**. As will be obvious, conduit portions **64** and **66** are coaxial as are conduit portions **60** and **68**.

It is worthy of note that, in the FIGURE 3 mode of operation, the coaxial oxygen supply and return conduits may be simultaneously connected to both of connectors **18** and **20**. This, of course, insures that there will be no time during which the subject is disconnected from an oxygen supply as he changes from one operational mode to another. Also, the dual connectors **18** and **20** permit check out of the PLSS prior to vehicle egress.

With the hatches sealed and the cabin pressurized, the subject will generally desire to remove his helmet or at least open the visor. Opening the visor without changing the ventilation flow path would not provide adequate extremity cooling because the flow to the helmet, approximately half of that delivered to the suit **10**, would exhaust to the cabin through the open visor. Moreover, most of the flow to the torso through apertures **34** in torso supply vent **30** would pass up through the visor opening in preference to exiting via the vent system. Accordingly, as may be seen from FIGURE 4, cross over valve **62** is incorporated into the vehicle-to-suit umbilical to change the ventilation flow path whenever the visor is opened. As noted above, valve **62** is a two-position valve which reverses the direction of gas flow in conduit portions **64** and **66**. Referring back to FIGURE 3, in the visor closed intra-vehicular mode of operation, the oxygen stream is transmitted from conduit portion **60** to conduit portion **64** by valve **62**. The contaminated oxygen stream which has diffused through the suit from the points of injection within the helmet and from the torso supply vent **30** pass outwardly through arm return vents **40** and **42** and leg return vents **44** and **46** to the ECS via conduit portion **66** and, through the action of valve **62**, conduit portion **68**. In the intra-vehicular operational mode with visor open as depicted in FIGURE 4, with valve **62** switched to its second position, the fresh oxygen stream from the ECS is deflected via valve **62** into inner portion **56** of connector **18** via conduit portion **66**. The oxygen stream is divided in suit **10** between arm vents **40** and **42** and leg vents **44** and **46**. The fresh oxygen is thus discharged at the hands and feet of the subject and thence diffuses through the suit **10** to torso vent **30** which now acts as a return vent and delivers the contaminated stream back to the ECS via the outer portion **50** of connector **18**, conduit portion **64** and conduit portion **68**. Some of the contaminated oxygen supplied to the suit through arm vents **40** and **42** passes into helmet **12** and into the cabin through the open visor. Similarly, some of the contaminated oxygen passing into the helmet is returned to the ECS via helmet vent **24**. Thus, it may be seen that during intra-vehicular operation, when conditions permit opening of the helmet visor or removal of the helmet, the resetting of a single two-position flow control valve will reverse the direction of flow of oxygen through the suit, provide adequate dehumidification of the torso and minimize loss of the oxygen ventilation stream into the cabin. During intra-vehicular operation with the visor open, as with the visor closed mode depicted in FIGURE 3, valve **32'** is maintained in the open position.

FIGURE 5 depicts the intra-vehicular operational mode with the helmet visor open and the gloves off. The ventilation flow path when the gloves are removed is the same as that for intra-vehicular operation with the visor open and gloves on as illustrated by FIGURE 4 except that the mechanical check valves **70** incorporated in the glove disconnects are closed when the gloves are removed. thus, in this mode of operation, the entire suit inlet flow is supplied via leg vents **44** and **46**.

As noted above, the present invention is particularly well suited for venting of space suits. However, the present invention has utility in many instances where it is desirable to provide protection from a hostile atmosphere while simultaneously permitting complete mobility of the subject. Thus, the present invention may find utility in the cleaning or flushing of the interior of large tanks used to store noxious or poisonous gases, working with poisonous aromatic fuels, work in areas contaminated by radioactive dust or gases, work in closed buildings and spaces where there is heat, lack of oxygen and/or noxious fumes, working within enclosed spaces filled with an inert gas, operation of vehicles within the earth's gravitational field but in hostile environments, and many other cases.

Accordingly, while the preferred embodiment has been disclosed and described, it is to be understood that various modifications and substitutions may be made thereto without departing from the spirit and scope of this invention. For example, while connection of the ventilating gas supply to the protective garment has been shown as being made through multiple connectors, it is to be expressly understood that separate supply and return connectors could instead be employed if desired. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

What is claimed is:

1. A method of ventilating a protective garment comprising the steps of:
- delivering gas to the garment from an external source;
- splitting the gas delivered to the garment into a plurality of flow paths to thereby direct the gas through the garment via a predetermined routing during a first mode of operation to entrap water vapor and carbon dioxide; and
- reversing the direction of gas flow along said plurality of flow paths under a second mode of opeartion.

2. The method of claim **1** wherein the garment includes a helmet and the step of splitting the reversed gas flow comprises:
- dividing the flow between the main body portion of the garment and the helmet portion.

3. The method of claim **2** further comprising the step of:
- directing all of the reverse flowing gas delivered to the garment to the helmet in a third mode of operation.

4. The method of claim **1** wherein the protective garment includes glove and foot portions and wherein the step of directing the gas comprises:
- splitting the gas supplied to the garment and delivering the split gas flow directly to the gloves and foot portions;
- allowing the gas to flow internally of the garment from the gloves and foot portions; and
- removing at least a portion of the circulated gas from the garment in the torso region of the garment.

5. The method of claim **4** wherein the protective garment includes a helmet and the step of reversing the direction of gas flow comprises:
- splitting the gas supplied to the garment and delivering the split gas flow directly to the helmet and torso regions of the garment;
- allowing the gas to flow internally of the garment from the helment and torso region to the gloves and foot portions; and
- removing the circulated gas from the gloves and foot portions of the garment and delivering it outside the garment.

6. The method of claim **4** wherein the protective garment includes a helmet and the step of reversing the direction of gas flow comprises:
- delivering all the gas supplied to the garment directly to the helmet;
- allowing the gas to flow internally of the garment from the helmet to the gloves and foot portions; and
- removing the circulated gas from the gloves and foot portions of the garment and delivering it outside the garment.

7. A ventilation system for a protective garment; said garment having foot portions, gloves and a helmet; said ventilation system comprising:
- first connector means communicating between the interior and exterior of the garment;
- second connector means communicating between the interior and exterior of the garment;
- a plurality of first conduit means interior of the garment communicating between said first connector means and the gloves and foot portions;
- a plurality of second conduit means interior of the garment communicating between said second connector means and the helmet and torso regions of the garment;
- means for delivering gas to said first connector means whereby the gas thus delivered circulates through the interior of the garment after being discharged from said plurality of first conduit means in the gloves and foot portions of the garment;
- means for receiving at least some of the gas circulated through the interior of the garment, said receiving means being connected to said second connector means, the circulated gas returning to said second connector means via at least one of said plurality of second conduit means; and
- means connected to said delivering and receiving means for reversing the direction of gas flow through said first and second connector means whereby the gas may be delivered through said second connector means and will circulate through the garment after being discharged from said second plurality of conduit means.

8. The apparatus of claim **7** wherein the gloves are removable and said ventilation system further comprises:
- first and second wrist disconnect switches positioned in first and second of said plurality of first conduit means, said disconnect switches preventing discharge of gas from said first and second of said first conduit means when the gloves are removed.

9. The apparatus of claim **7** further comprising:
- valve means, said valve means being positioned in one of said plurality of second conduit means between said second connector means and the torso region of the garment, turning of said valve means to the closed position causing all of the gas delivered to the garment through said second connector means to be supplied directly to the helmet.

10. The apparatus of claim **9** wherein the gloves are removable and said ventilation system further comprises:
- first and second wrist disconnect switches positioned in first and second of said plurality of first conduit means, said disconnect switches preventing discharge of gas from said first and second of said first conduit means when the gloves are removed.

11. The apparatus of claim 10 further comprising:

third connector means for communicating between said plurality of first conduit means and a delivering means;

fourth connector means for communicating between said plurality of second conduit means and a receiving means, said third and fourth connector means enabling simultaneous connection of the garment to two gas supplies.

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U.S. Cl. X.R.

62—259; 165—46