Nov. 2, 1971 M. C. CASE ET AL 3,616,818

CRUSH RESISTANT CONDUIT

Filed Dec. 9, 1968 2 Sheets-Sheet 1

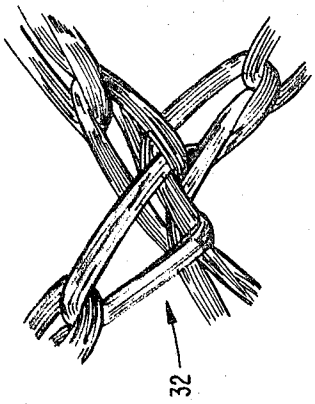


FIG. 2B

FIG. 1

FIG. 1A

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Filed Dec. 9, 1968 2 Sheets-Sheet 2

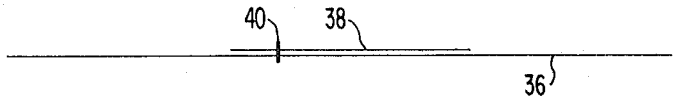


Fig. 2

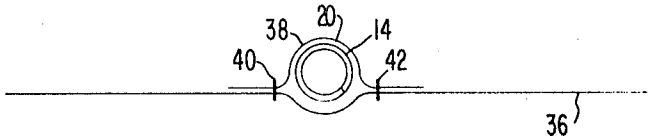


Fig. 3

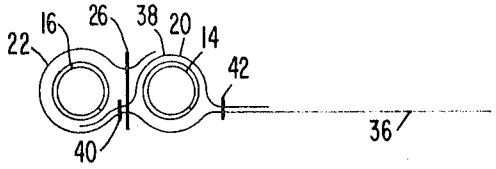


Fig. 4

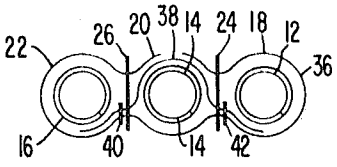


Fig. 5

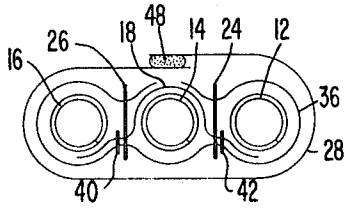


Fig. 6

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3,616,818

CRUSH RESISTANT CONDUIT

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Int. Cl. F16l 11/10
U.S. Cl. 138—129 13 Claims

ABSTRACT OF THE DISCLOSURE

Disclosed is a conduit or duct for feeding life support gas, such as oxygen, to or from portions of a spacesuit. The conduit comprises a plurality of side-by-side helical coils, each surrounded by a flexible open mesh sleeve. The sleeves are joined by longitudinal stitching and are secured to the coils by means of an adhesive. Surrounding the coils and sleeves is a flexible gas impermeable cover. The conduit or duct, while quite flexible, is extremely resistant to being crushed.

This invention relates to a gas conduit or duct and more particularly to a crush resistant conduit or duct that is also quite flexible. The duct is particularly adapted to pass life supporting gases, such as air or oxygen, through a spacesuit or the like and is especially designed for incorporation in the spacesuits worn by astronauts in the United States Apollo Program.

There is disclosed in assignee's United States patent applications Ser. Nos. 636,855 and 641,735, both filed May 8, 1967, novel ventilation systems for use in a spacesuit or similar garment. As disclosed in these applications, the ventilation system forms part of a pressure garment assembly which provides life support to the astronaut in a hostile environment. A life supporting gas, such as oxygen, is supplied to the pressure garment assembly and acts to provide a breathable atmosphere for the astronaut, pressurizes the interior of the garment, and also flows over the astronaut's body so as to remove wastes, such a moisture resulting from perspiration.

At the same time, the pressure garment assembly is provided with a system of corrugated joints and mechanical restraints to enhance the astronaut's mobility so that he may bend and flex various portions of his body with a minimum of effort so that he may perform designated tasks during a space mission. Thus, the conduits or ducts for supplying life supporting gas to the astronaut must not only be highly resistant to crushing so as to assure a constant supply of life sustaining gas, but also must be highly flexible to permit the astronaut to bend and readily move about. These crush resistant and flexible ducts are secured to the inner lining of the pressure garment assembly and pass over the astronaut's body to either supply life giving gas or to exhaust it from the interior of the spacesuit. These conduits extend generally from the extremities of the spacesuit to the center of the torso and pass across several joints, including the knees and elbows, where they are especially susceptible of being crushed and yet must exhibit a substantial amount of flexibility.

In the present invention, the crush resistant conduit takes the form of a plurality of coplanar helical coils or helical springs which are covered by an inner layer of gas permeable open mesh material, such as knitted nylon fabric, and an outer layer or cover of material impermeable to gas, such as neoprenecoated nylon. The coils resemble springs in that they are quite flexible and exhibit some resiliency and may be formed of metal, but are preferably made of solid nylon tubing that is heat set into the configuration of a helical coil. The inner layer or mesh is stitched between coils to form coil-surrounding sleeves which are bonded to the coil turns by an adhesive. This inner layer acts to maintain the coils in side-by-side relationship and prevents the coils from collapsing while at the same time permitting the conduits to readily flex and bend. The outer layer or cover renders the conduits gastight so that gas may flow through the conduits without escaping to the surrounding atmosphere.

It is therefore one object of the present invention to provide a novel crush resistant and flexible conduit or duct for the transmission of gases.

Another object of the present invention is to provide a crush resistant and flexible duct or conduit particularly suited for use in a spacesuit or the like to supply and/or remove life support gases from the interior of the suit.

Another object of the present invention is to provide an improved method for constructing a crush resistant and flexible conduit or duct.

Another object of the present invention is to provide an improved method of constructing a gas conduit or duct for use in spacesuits which permits simplified fabrication techniques.

Another object of the present invention is to provide a non-crushable or crush resistant conduit or duct incorporating a plurality of resilient and flexible springs or coils adapted to maintain the structural integrity of the conduit against collapse while at the same time permitting the conduit to offer little or no resistance to substantial bending or flexing. The conduit assures that the astronaut may readily move about and bend the various joints of the suit in which the conduit is incorporated without risking the possibility that gas flow through the conduit will momentarily be cut off by conduit collapse.

These and further objects and advantages of the present invention will become more apparent upon reference to the following specification, claims, and appended drawings, wherein:

FIG. 1 is a perspective view of a three-coil conduit or duct constructed in accordance with the present invention;

FIG. 1A is an enlarged view of the open mesh fabric overlying a portion of a coil turn;

FIG. 1B is a further enlargement showing the knitted nature of the fabric; and

FIGS. 2–6 illustrate various stages in the fabrication of the flexible crush resistant conduit or duct of FIG. 1.

Referring to the drawings, the novel conduit or duct of the present invention is generally indicated at **10** in FIG. 1 and comprises three springs or helical coils **12, 14,** and **16**. Surrounding the coils are three sleeves **18, 20,** and **22** of open construction so that they are permeable to gas. Sleeves **18, 20,** and **22** are integrally joined by two parallel longitudinal rows of stitching, indicated in FIG. 1 at **24** and **26**. Finally, the entire coil and sleeve assembly is enclosed in a gas impermeable outer layer or cover **28**.

Coils **12, 14,** and **16** are all of helical configuration and are formed of rigid tubing, either hollow or solid, such that the coils will readily bend and flex. The coils are preferably of identical construction with longitudinal axes which lie in a common plane. While the coils may be made of metal, such as stainless steel or the like, in the preferred embodiment the coils **12, 14** and **16** are formed of solid nylon tubing, i.e., extruded nylon that is heat set into the helical coil configuration shown.

Sleeves **18, 20,** and **22** may be formed of any flexible mesh-like material but in the preferred embodiment are formed from an open mesh or knitted nylon fabric. The size of the mesh is not critical and varies with the size of the conduit, in turn dependent upon the quantities of gas which the conduit **10** must handle. In the preferred embodiment, the openings, such as the opening indicated

at **30** in FIG. 1A between adjacent fibers, is of a diamond shape with dimensions approximately equal to the diameter of the tubing forming a turn of the coils. That is, the two mutually perpendicular dimensions *x* and *y* of the opening **30** through the mesh in the preferred embodiment are both on the order of the diameter A illustrated in FIG. 1. One of the interstices **32** is shown to an enlarged scale in FIG. 1B.

Sleeves **18**, **20**, and **22** are attached to each other by parallel rows **24** and **26** of nylon stitching. The coils and surrounding sleeves are then dipped in a suitable adhesive which adhesively secures the mesh sleeve to its respective coil at the areas of contact of the mesh fibers with the coil turns. The adhesive is cured either at elevated temperature or at room temperature as required so that it securely locks the sleeves to the coils. This adhesion, in conjunction with the stitching between sleeves, restrains the coils against displacement so that they always remain in side-by-side relation as illustrated and further prevents the coils from collapsing when they are bent or flexed. Finally, the assembled coils and interconnected sleeves are surrounded by the outer gas impervious cover **28**.

FIGS. 2–6 show a preferred method of fabricating a three-coil conduit in accordance with the present invention. In these figures, like parts bear like reference numerals.

Referring to FIG. 2, a flat sheet of mesh-like fabric **36**, having a width at least equal to the distance around the three coils when in the position illustrated in FIG. 1, is laid flat on a work surface (not shown). A second flat sheet **38** of the same mesh-like fabric, having a width approximately equal to the circumference of one coil, is then positioned substantially in the center of the larger sheet with one of its ends secured by stitching **40** to the larger sheet **36**.

Referring to FIG. 3, the center coil **14** is then positioned between the larger mesh sheet **36** and the smaller mesh sheet **38** and the other end of the smaller sheet is attached to the larger one as at **42**, thus securing the central coil **14** within the sleeve **20** formed by upper sheet **38** and the adjacent portion of lower sheet **36**.

Referring to FIG. 4, one of the other coils, such as outer coil **16**, is then positioned on one side of the inner coil **14** and the end of the larger sheet **36** on that side is folded around the outer coil and stitched back upon itself to form one longitudinal row of stitching **26** between sleeves **20** and **30**.

Referring now to FIG. 5, the other outer coil **12** is then positioned on the other side of the inner coil **14** and this end of the larger mesh sheet **36** is similarly rolled around that coil and stitched to itself to form the longitudinal row of stitching **24** between mesh sleeves **18** and **20**.

The coils and mesh fabric assembly is then dipped into an adhesive, such as a urethane adhesive sold under the trade name Estane presently manufactured and sold by the B. F. Goodrich Company, and after dipping the assembly is preferably cured at a suitable temperature in an oven. This dipping and curing forms beads at the contact areas of the mesh fibers with the coil turns which secures the mesh fibers to the coils at these areas. This securing or locking of the fabric sleeves to the coils or springs is believed to result from the fact that the adhesive wraps around the filaments of the mesh and contacts the adjacent surface areas of the coils upon which they abut so as to secure them together. That is, the mesh sleeves are tightly and firmly wrapped around the coils and it is believed that the adhesive does not necessarily penetrate the space between the mesh fibers and the coil surfaces at their areas of contact, but instead wraps around the filaments or fibers of the mesh and contacts the adjacent surfaces of the coils, i.e., those surfaces of the coil underlying the periphery of the mesh fibers to lock the mesh to the coils.

Finally, referring to FIG. 6, a gas impervious outer cover **28** is then wrapped around the coils and mesh with its overlapping ends secured by an adhesive **48**, such as a neoprene cement. Cover **28** is preferably formed of neoprene-coated nylon and is impervious to gas so as to provide the conduit with gas retention properties. The coils and surrounding mesh sleeves of the crush resistant conduit are pervious to gas, whereas the outer cover is not. This results in a conduit that is capable of distributing and carrying life support gases to and from selected points in a spacesuit, yet one which has ideal anti-crush and flexibility characteristics by virtue of the structural relationship between the coplanar coils and the mesh-like fabric inner layers or sleeves. An important feature of the construction resides in the adhesive locking action of the mesh fabric to the coils only at or adjacent to the areas of overlap between the mesh fibers and the coil surfaces which they contact. This construction prevents the coils from shifting or being compressed in either axial or transverse directions when subjected to external pressure since the mesh-like fabric is locked to the coils.

In the preferred embodiment, the conduit is illustrated as formed of three coils having an integral sleeve construction. It is apparent that conduits may be satisfactorily constructed with two or more coils and mesh sleeves, depending upon the quantities of gas to be handled by the conduit. Furthermore, although the sleeves in the preferred embodiment are illustrated as formed with an integral common mesh sheet **36**, the individual sleeves **18**, **20**, and **22** may be formed from separate sheets and joined by stitching such as the longitudinal rows of stitching **24** and **26**. In either case, the longitudinal stitching is used to hold and separate the coils irrespective of whether a multiple piece or a single piece sleeve construction is used. The common sheet **36** construction illustrated is preferred because it simplifies fabrication techniques, allows production line compensation for slight variations in the material dimensions and stitching characteristics, and permits more accurate inspection of the materials during various stages of fabrication.

It is apparent from the above that the present invention provides a conduit construction which insures the free flow of life support gas at all times while at the same time offering little resistance to bending or flexing. The combination of coplanar helical coils surrounded and locked in place by flexible open mesh sleeves permits flexibility and great freedom of movement to the suit wearer. The sleeves are sewn together and adhesively locked to the coils so that the coils will not collapse and will not move out of alignment with each other. Gas is retained by the flexible outer cover.

The conduits are of relatively inexpensive and simple construction and may be readily fabricated from available materials. Through the novel method of assembly described and shown in FIGS. 2–6, the conduits can be readily inspected at various stages of manufacture to insure accuracy and reliability, particularly necessary when the conduits are incorporated in a spacesuit and must be relied upon for the transport of life support gases.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. A crush resistant flexible conduit comprising a plurality of helical coils, a flexible gas permeable sleeve surrounding each of said coils, each sleeve being joined to an adjacent sleeve and to its respective coil, and a flexible gas impervious cover surrounding said coils and sleeves.

2. A conduit according to claim **1** wherein said coils have coplanar longitudinal axes such that they lie in side-by-side relationship.

3. A conduit according to claim 1 wherein said sleeves are joined longitudinally between said coils.

4. A conduit according to claim 1 wherein said sleeves are joined to the turns of said coils.

5. A crush resistant flexible conduit comprising a plurality of helical coils all having longitudinal axes lying in a common plane, an open mesh flexible sleeve surrounding each of said coils, adjacent sleeves being longitudinally joined between said coils, adhesive joining said sleeves to the turns of the coils, and a gas impervious flexible cover surrounding said coils and sleeves.

6. A conduit according to claim 5 comprising three coils of identical size and configuration.

7. A conduit according to claim 5 wherein said sleeves are joined by longitudinal stitching.

8. A conduit according to claim 5 wherein said sleeves are formed of a knitted fabric.

9. A conduit according to claim 5 wherein said cover comprises a rubber impregnated fabric.

10. A crush resistant flexible conduit comprising a plurality of helical coils all having longitudinal axes lying in a comon plane, a fabric open mesh sleeve surrounding each of said coils, adjacent sleeves being joined between said coils by a longitudinal row of stitching, adhesive at the areas of contact of said mesh fabric with said coils adhesively joining said sleeves to adjacent surfaces of said coils, and a gas impervious flexible cover surrounding said coils and sleeves.

11. A conduit according to claim 10 wherein said coils are plastic.

12. A conduit according to claim 11 wherein said coils are made of heat set nylon.

13. A conduit according to claim 10 wherein said coils and sleeves are made of nylon and are joined by urethane adhesive.

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HENRY S. JAUDON, Primary Examiner

U.S. Cl. X.R.

138—138, 111