

[54] **METHOD FOR FORMING CRUSH  
RESISTANT CONDUIT**

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[22] Filed: **May 1, 1970**

[21] Appl. No.: **33,889**

**Related U.S. Application Data**

[62] Division of Ser. No. 782,283, Dec. 9, 1968, Pat. No.  
3,616,818.

[52] U.S. Cl. ....156/144, 156/93, 156/292,  
161/47

[51] Int. Cl. ....F16I 11/10

[58] Field of Search ..161/47, 139, 93; 156/143, 144,  
156/292-294; 138/111, 129, 138

[56] **References Cited**  
**UNITED STATES PATENTS**

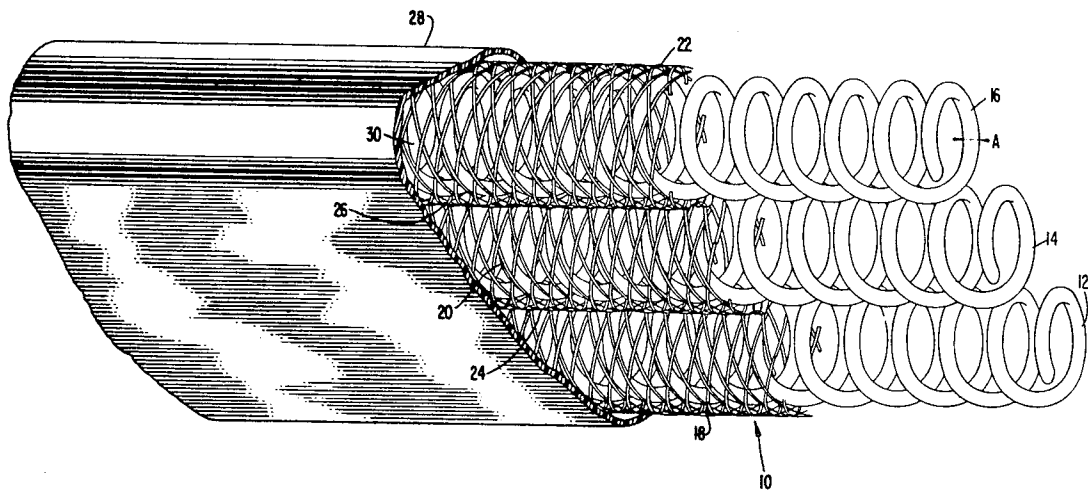
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|-----------|---------|--------------------|---------|
| 947,046   | 1/1910  | Sugg.....          | 138/138 |
| 2,917,568 | 12/1959 | Moorman et al..... | 156/143 |
| 3,449,199 | 6/1969  | Mead .....         | 161/47  |

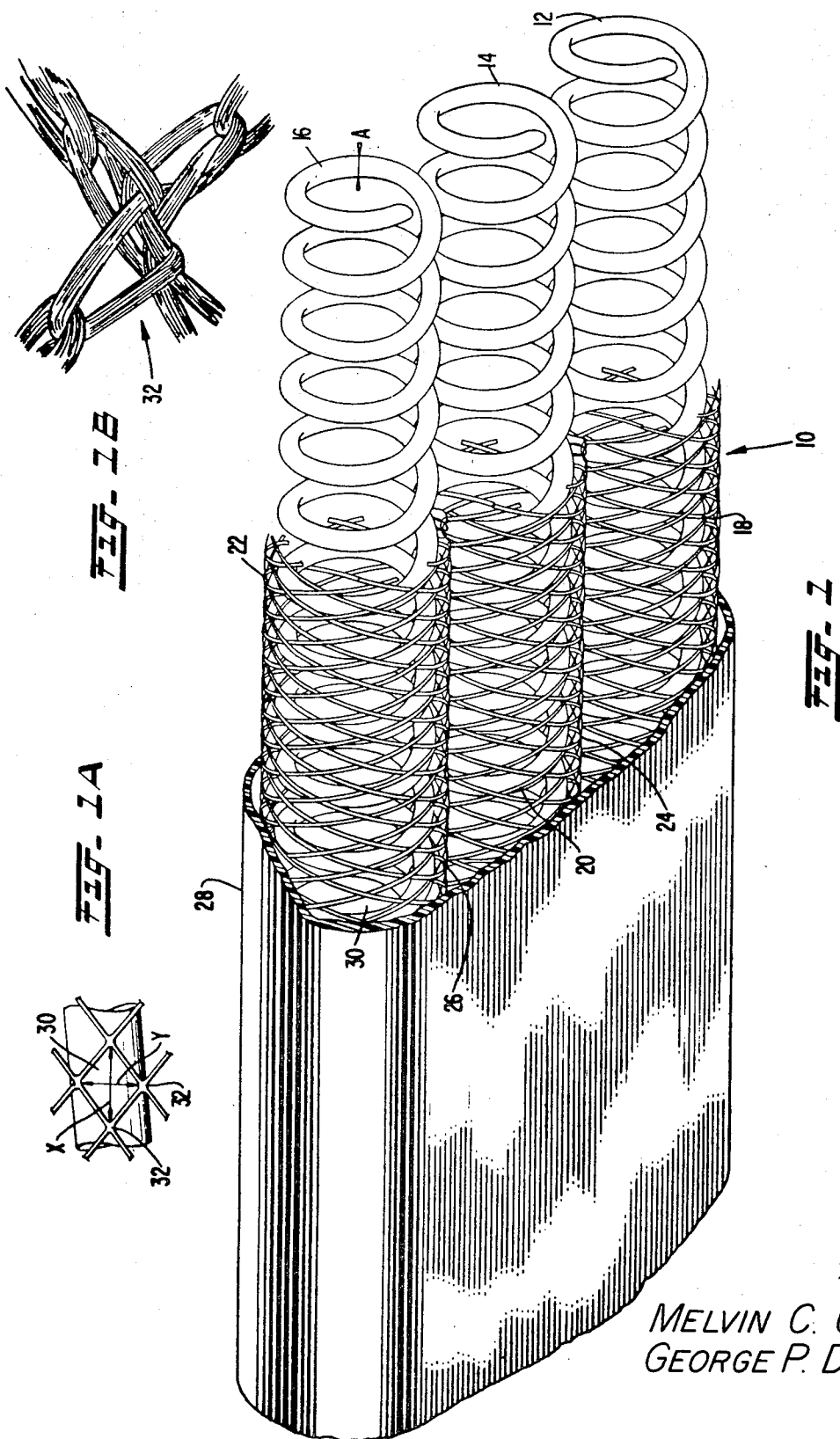
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[57] **ABSTRACT**

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

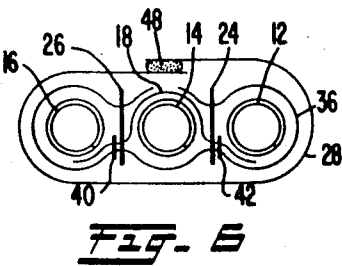
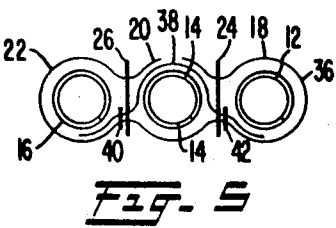
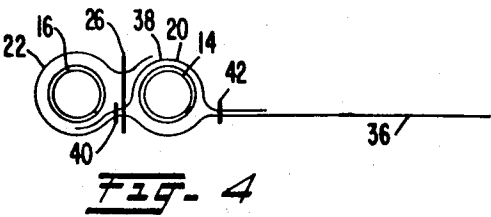
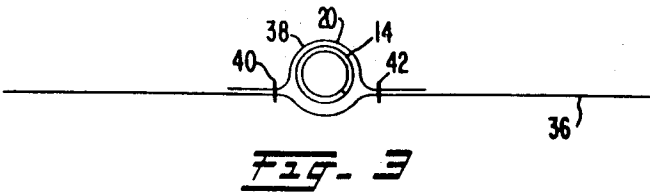
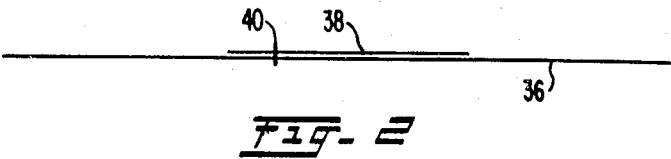
**3 Claims, 8 Drawing Figures**





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## METHOD FOR FORMING CRUSH RESISTANT CONDUIT

This application is a division of applicants' copending application Ser. No. 782,283 filed December 9, 1968, now U.S. Patent 3,616,818, Crush Resistant Conduit.

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).

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 U.S. Pat. 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 lift 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 as 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 neoprene-coated 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 method of forming a flexible conduit comprising surrounding a plurality of helical coils with open mesh flexible sleeves, joining said sleeves longitudinally of said conduit between said coils, dipping said sleeves and coils in an adhesive to lock said sleeves to said coils, and surrounding said sleeves and coils with a gas impervious flexible cover.

2. A method according to claim 1 including the step of curing said adhesive.

3. A method of forming a flexible conduit comprising providing three flexible coils, placing one of said coils over a first sheet of mesh-like fabric having a width at least equal to the distance around all three coils, placing a second sheet of said fabric over said coil having a width approximately equal to the distance around a coil, joining said sheets on each side of said coil, placing the remaining coils on each side of said one coil and wrapping the ends of said first sheet around them, joining said ends to said sheets adjacent said one coil, dipping said coils and sheets in adhesive, and surrounding said coils and sheets with a flexible gas impervious cover.

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