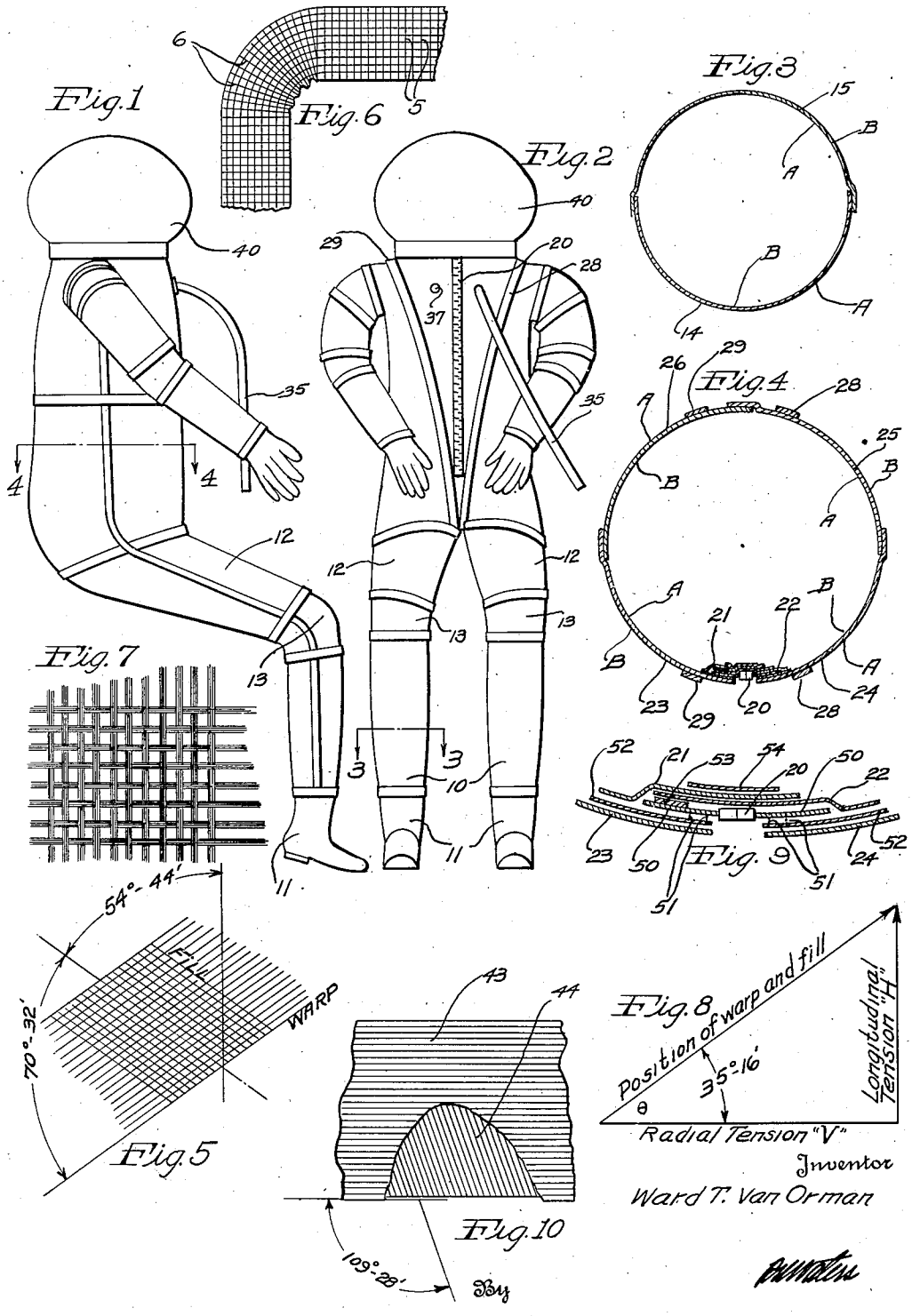
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STRUCTURE

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STRUCTURE

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This invention relates to generally cylindrical fabric structures, including truncated, conical sections with gently sloping sides, etc., which are adapted to be filled with a fluid under pressure. The fluid may be a gas or a liquid. According to this invention, the fabric used in such cylindrical structures may be formed from square-woven fabric by racking it, or two-ply, pickless fabric may be used. Whatever the fabric, the textile elements—i. e., threads if basket-weave and cords if two-ply pickless—meet one another in an obtuse angle, preferably of about 109° 28′, with the projection of the axis of the cylinder approximately bisecting this obtuse angle.

When a cylindrical structure in which the textile elements meet one another at an angle of approximately 109° 28′ is placed under pressure, the longitudinal tension in the fabric is balanced by the radial tension. There is, therefore, no tendency for the cylinder to grow in either direction at the expense of the other. Also, in a fabric structure of this type, one obtains maximum strength with the minimum weight of material.

There is an advantage in using this type of cylindrical structure in many fabric products. The advantages may be due chiefly to the saving in material and consequent saving in weight, as in the construction of lighter-than-air craft, or they may lie in the improvement in the physical properties inherent in such structures, as will be more fully explained in what follows.

In lighter-than-air construction the sections of a ship near its center are generally cylindrical. When made of a balanced fabric, i. e., when constructed according to this invention, the amount of material employed may be kept at a minimum. The necessary strength may be obtained with the lightest weight cloth. This means an increase in the carrying power or pay load of the ship.

Many types of hose are now usually braided. A wrapped hose of two-ply or woven fabric is much cheaper to construct. If an unbalanced structure is used, such as that produced by using conventional, square-woven fabric on the bias, one of two things will happen when pressure is created within the hose by the passage of water or other fluid through it: either the hose will increase in diameter and decrease in length, or it will decrease in diameter and increase in length. This will depend upon whether the radial or longitudinal tension is the greater. Any such tendency of the fabric to grow in one direction at the expense of the other is overcome by constructing the hose according to this invention.

The invention will be more particularly described in connection with the construction of a pressure garment, such as a suit for an aviator or diver. The garment fits loosely on the wearer, and the space between the garment and the wearer is filled with a gas under pressure. Air or oxygen is normally used, and this is breathed by the wearer. Fresh gas is supplied continually, and the spent gas is continually bled from the suit. The space within the suit is kept under a pressure of two or three or four or more pounds greater than the pressure on the outside. A diver will maintain the suit under a pressure of one or two pounds above that of the depth of water at which he is working. An aviator who flies at very high altitudes will maintain the pressure within the suit at a pressure several pounds greater than that found at these high altitudes. If the suit is to be used by a diver, it, of course, must be waterproof. This is not essential in an aviator's suit. However, the fabric must be gas tight for both types of suits.

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According to this invention, the cylindrical members of the suit, such as the arms and legs and trunk, are made of woven fabric or two-ply pickless in which the textile elements meet at an obtuse angle. Although in the preferred form of the invention the angle is substantially 109° (or more exactly, 109° 28′), there are advantages in using a substantially larger or smaller obtuse angle. This will be explained in what follows.

The suit may be designed to be worn in the sitting position or to be worn in the standing position, or by designing it for an intermediate position as shown in the drawing, its shape can most conveniently be changed to accommodate a person whether in the sitting or standing position. The arms may be designed to hang at the side or rest in the lap or may be designed to normally assume any other desired position, preferably a position which approaches a mean of the positions the wearer will be required to assume while wearing the suit. The head piece may be of fabric, with transparent eyes, although a transparent dome is preferably used. The dome may be fastened to the balance of the suit in any usual or suitable manner.

The invention will be further described in connection with the accompanying drawing, in which Fig. 1 is a side view of a suit in perspective. Fig. 2 is a front view of the suit in perspective; Fig. 3 is an enlarged section on the line 3—3 of Fig. 2; Fig. 4 is an enlarged section on the line 4—4 of Fig. 1; Fig. 5 illustrates the relation of the textile elements to one another and to the axis of the suit member. Fig. 6 illustrates the flexing of a

member made of square-woven fabric which is not laid on the bias. Fig. 7 illustrates a basket-weave; Fig. 8 is a diagram which will be used in explaining the invention; Fig. 9 is an enlarged detail of the closing device shown in Fig. 4; and Fig. 10 is a piece of two-ply fabric with a part of one ply broken away.

If square-woven fabric is used and the warp is parallel with the axis of a cylindrical member of the suit, as is customary in the manufacture of clothing for ordinary wear, the member cannot be flexed without placing a strain on the warp on one side of the member and retracting the warp threads on the opposite side of the member. For example, suppose the member in question is a knee or arm. Fig. 6 illustrates the warp 5 in any such member running parallel with its axis. The fill 6 is perpendicular to this. In the bent portion of the member, it is obvious that on the outer side of the bend the warp 5 is placed under tension, and on the under side of the bend the warp members are compressed.

If the fabric is placed on the bias, pantographic action of the warp and fill or cords gives greater flexibility to the fabric. This assumes, of course, that the fibers are not too tightly woven to preclude such movement during flexing. The flexibility of the garment, however, is not solely dependent on the warp and fill or cords being placed on the bias.

The most flexible structure is that in which the threads or cords are under the least tension. If some threads or cords are taut and others are not under tension, the flexibility is not as great as when none of the threads or cords are taut; i. e., when all of the threads or cords are under equal stress. This is true in a balanced structure; e. g., in a cylinder in which the radial tension balances the longitudinal tension. The determination of the angle required between the textile elements to produce such a balanced, cylindrical structure will be explained by reference to Fig. 8 and the following calculations:

If "P" is the unit pressure and "D" is the diameter of the cylinder, we know that for a cylinder:

$$\text{Longitudinal force} = h = \frac{\pi D^2 \times P}{4}$$

$$\text{Radial force} = v = \text{force per unit length} \times \text{length}$$

$$\text{Force per unit length} = \frac{D \times P}{2}$$

Now, assuming that the length is that length in which the warp and fill, when placed at the proper angle to one another, make one complete revolution, then

$$\text{Length} = \pi D \times \tan\theta$$

$$\therefore v = \frac{D \times P}{2} \times \pi D \times \tan\theta = \frac{\pi D^2 P \tan\theta}{2}$$

Assuming now that θ is the angle which produces h and v components which exactly balance the stress in the cylinder, by referring to Fig. 8 and using the above values, we see that:

$$\text{Tan}\,\theta = \frac{h}{v} = \frac{\frac{\pi D^2 P}{4}}{\frac{\pi D^2 P \tan\theta}{2}} = \frac{1}{2\tan\theta}$$

$$\text{Tan}^2\theta = \frac{1}{2},\ \tan\theta = \sqrt{\frac{1}{2}} = .707$$

$$\therefore \text{Angle } \theta = 35^\circ\ 16'$$

This is the acute angle between the textile elements and a plane passed through the cylinder at right angles to its axis. The angle between the textile elements and a projection of the axis is, therefore, 54° 44'. The obtuse angle between the textile elements is twice this or 109° 28'. For practical purposes, an angle of approximately 109° is satisfactory. This is illustrated in Fig. 5.

Although the greatest flexibility is obtained by using fabric with the textile elements at an angle of 109° 28' to one another, the use of fabric in which they meet at any obtuse angle (either larger or smaller than 109° 28') gives a more flexible suit member under pressure than can be obtained from square-woven fabric. This is because the obtuse angle allows greater elongation than square-woven fabric. For instance, in one fabric which was tested the fabric was racked to 109° 28', and the elongation measured along an axis bisecting this angle was approximately twice that of the conventional square-woven fabric placed on the bias. The elongation of the racked fabric along an axis perpendicular to that mentioned was only about one-half that of the conventional square-woven fabric. The elongation of fabric racked to different angles varies accordingly. The same is true of two-ply fabric with the cords at an obtuse angle to one another. From this it is evident that any cylindrical suit member made of any fabric in which the textile elements meet at any angle substantially greater than a right angle, with the axis of the member approximately bisecting the angle, will be more flexible than if the member is made of square-woven fabric.

The warp and fill of woven fabric may be originally woven at an obtuse angle, but it will generally be preferable to produce the desired fabric by racking square-woven fabric, such as basket-weave. This may be done as described in U. S. Patent 1,763,569. The preferred method of obtaining the desired angle between the warp and the fill is to use square-woven fabric and distort it on a preparation table before it is coated. Further distortion of smaller magnitude may be done by using a spreading machine equipped with off-angle let-off bars, guides or drags so that the fabric is drawn to one side as it leaves the spreader, and the fill will no longer lie transverse across the sheet at a 90° angle, but at an angle of about 109° 28' to the warp. The fabric distortion need not all be accomplished in a single passage through the spreader, but may be increased in each successive passage through the spreader until the desired racking is obtained.

The fabric is preferably made of high tenacity material, such as Sea Island, Sak or Pima cotton, or a high tenacity rayon, such as the double Fortisan type, or other high strength, continuous filament yarn, such as nylon, etc. With such high strength materials a fabric of low gauge may be employed, and this, in itself, lends flexibility to the fabric structure.

A loosely woven, sleazy fabric lends itself to racking more readily than a tightly woven fabric. A basket-weave fabric, such as that with 3 x 3 woven groups illustrated in Fig. 7, or one with 5 x 5 woven groups or the like, may advantageously be used.

The fabric is made gas impervious by treatment with rubber or another plastic, preferably applied in the form of a thick cement. It is desirable not to impregnate the fabric as this will increase its stiffness. Strongly adherent coatings are to be used, and adhesives, such as one part

of methylene diphenyl diisocyanate to ten parts of the rubber or other plastic, may be desirable to obtain the adhesion required.

A cylinder formed of the racked fabric, when inflated, may show a marked tendency to twist due to the difference in the elongation of the warp and fill or to certain stresses set up in the fabric. To nullify such distortion, the various cylindrical members of the suit or other structure are preferably made up by reversing circumferentially adjacent pieces of fabric. For example, as shown in Fig. 2, the lower leg portion 10 is made as a different unit from the boot 11 to which it is later attached. Also, the thigh 12 is made as a separate member. These are united by the knee 13. Each of these members 10, 12, and 13 is made of racked fabric with the warp and fill forming an obtuse angle, which in each member is approximately bisected by a projection of the axis of that member on it. The members 10, 12, and 13 are each made up of two sections—a front and back. This is illustrated by Fig. 3, which shows an enlarged section of the lower leg member. The front and back portions of the leg member are indicated by the numerals 14 and 15, respectively. In assembling these members, the two halves of the pattern are reversed; that is, the coating A on the outside of the front half of the leg member is placed on the inside of the back half of this member. The side coated B, which is the inner side of the front member 14, then becomes the outside of the back member 15. By reversing adjoining pieces which make up the members 10, 12, and 13, the tendency of any one piece to distort the member is practically nullified by the opposite tendency of the adjoining piece. Similarly, each arm member is made up of two pieces which are likewise reversed.

The upper and lower trunk members are each advantageously made of four sections, as illustrated. Each is made from racked fabric with the obtuse angle of each member substantially symmetrical with respect to the projection of its axis. Fig. 4 shows an enlarged section through the lower trunk member. The front of the garment is shown as being closed with the zipper 20. Any suitable closing means may be employed.

Fig. 4 shows flaps 21 and 22 adjoined to different sections 23 and 24 of the lower trunk member overlapping behind the zipper to prevent the escape of air through the zipper when the suit is inflated. The rear sections of the trunk member are indicated by the numerals 25 and 26. As indicated by the letters A and B, which refer to opposite sides of the uncut fabric, the alternate, adjoining pieces which make up the lower trunk member are reversed. 24 is reversed with respect to both 23 and 25. 25 is reversed with respect to both 24 and 26. 26 is reversed with respect to both 25 and 23, and 23 is reversed with respect to both 26 and 24. This gives a balanced structure which shows minimum distortion on inflation.

If two-ply, pickless cord fabric is used, the plies coated with uncured rubber or other curable plastic are placed on one another so that the angle between them is the desired obtuse angle. As shown in Fig. 10, the cords 43 in one ply make an angle of 109° 28′ with the cords 44 in the other ply. The rubber coating is cured with the plies in this relation.

Fig. 9 gives details of the zipper-closing device shown in Fig. 4, with the different parts spaced from one another to show the construction most clearly. The two parts of the zipper 20 are united to fabric tapes 50, which are sewn by the stitches 51 to the reinforcing strips 52, which are cemented to the pieces 23 and 24 of coated fabric. A cushion 53, which may be rubberized fabric, is provided to insure an airtight seal between the flap 22 and the section 23 of the coated fabric to which one section of the zipper is attached. The member 54 is a stiffening member, such as a metal strip, which prevents the suit from buckling when the wearer bends forward. It insures an airtight seal between the two flaps 21 and 22.

Fig. 4 shows in section the front and back of reinforcing straps 28 and 29 which pass over the shoulders and under the crotch of the suit.

Attachments for supplying air and for bleeding the waste air may be provided in any desired manner. These are illustrated by the feed hose 35 and the spring-balanced pressure-relief valve 37.

The helmet 40 is of transparent plastic, such as Plexiglas, although any suitable helmet may be used, and it may be fastened to the balance of the suit in any desired manner. The gloves may be made as desired. Various attachments, such as heating pads, etc., may be supplied as desired.

This application is in part a continuation of my application Serial No. 458,515, filed September 16, 1942.

What I claim is:

1. A generally cylindrical structure of woven fabric which is adapted to be inflated and in which the warp and fill form an angle of substantially 109° which is substantially bisected by a projection of the axis of the structure thereon.

2. A generally cylindrical structure of two-ply, pickless cord fabric which is adapted to be inflated, in which the cords of one ply form an angle of substantially 109° with the cords of the other ply, the angle between the cords being substantially bisected by a projection of the axis of the structure thereon.

3. A generally cylindrical structure of woven fabric which is adapted to be inflated and in which the warp and fill form an angle of substantially 109° which is substantially bisected by a projection of the axis of the structure thereon, circumferentially adjacent pieces of the fabric being reversed.

4. A generally cylindrical fabric structure which is adapted to be inflated and in which the textile elements, such as cords, threads and the like, form an angle of substantially 109° to one another, which angle is substantially bisected by a projection of the axis of the cylinder thereon, circumferentially adjacent pieces of the fabric being reversed.

5. A generally cylindrical structure of racked, woven fabric which is adapted to be inflated and in which the warp and fill form an angle of substantially 109° which is substantially bisected by a projection of the axis of the structure thereon, circumferentially adjacent pieces of the fabric being reversed.

6. A pressure garment with a generally cylindrical member formed of two halves, each half being formed of square-woven fabric which is racked so that the warp and fill meet at an angle of substantially 109° which is substantially bisected by a projection of the axis of the member thereon, and each half of the fabric being reversed with respect to the other half.

7. A pressure garment with a generally cylin-

drical member formed of four sections, each section being formed of square-woven fabric which is racked so that the warp and fill meet at an angle of substantially 109° which is substantially bisected by a projection of the axis of the member thereon, alternate circumferentially adjacent sections of the fabric being reversed with respect to the section on each side of it.

8. A pressure garment formed with a member which is generally cylindrical in shape and made of woven fabric in which the warp and fill form an obtuse angle, which member is so placed in the garment that a projection of the axis of the member substantially bisects the obtuse angle.

9. A pressure garment formed with a member which is generally cylindrical in shape and made of a plurality of pieces of racked woven fabric in which the warp and the fill form an obtuse angle, in which member circumferentially adjacent pieces of fabric are reversed, which member is so placed in the garment that a projection of the axis of the member at least approximately bisects the obtuse angle.

10. A pressure garment formed with a member which is generally cylindrical in shape and made of a plurality of pieces of two-ply, pickless cord fabric with the cords in one ply at an obtuse angle to the cords in the other ply, in which member circumferentially adjacent pieces of fabric are reversed, which member is so placed in the garment that a projection of the axis of the

member at least approximately bisects the obtuse angle.

11. A pressure garment comprising a generally cylindrical member fabricated from racked fabric in which the textile elements such as cords, threads and the like forming the fabric are disposed in angular relation to each other, circumferentially adjacent portions of the fabric comprising the member being reversed to balance said member upon inflation thereof.

12. A pressure garment certain parts of which are fabricated in generally tubular form from at least two superposed coextensive plies of pickless cord fabric, the cords in one ply being disposed in angular relation to the corresponding cords of the other plies for producing a substantial balance between radial and longitudinal tension introduced to the part by the inflation thereof.

13. An inflatable generally tubular body formed of at least one ply of cord fabric in which one set of generally parallel cords is disposed in angular relation to another set of generally parallel cords for producing a substantial balance between radial and longitudinal tension introduced to the body by the inflation thereof, said angular relation being of the order of substantially 109° with the angle being substantially bisected by the projection of the longitudinal axis of the body in the plane of the fabric.

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