

July 28, 1970

M. F. PIEL
MATERIAL FOR THE MANUFACTURE OF FITTED
DIVING SUITS AND SUITS MADE THEREOF

3,521,628

Filed Jan. 31, 1967

2 Sheets-Sheet 1

Fig. 1

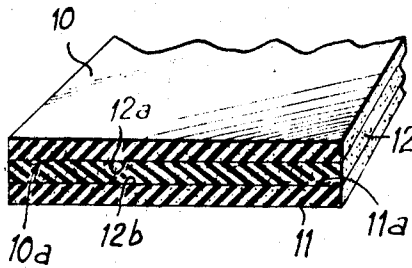


Fig. 2

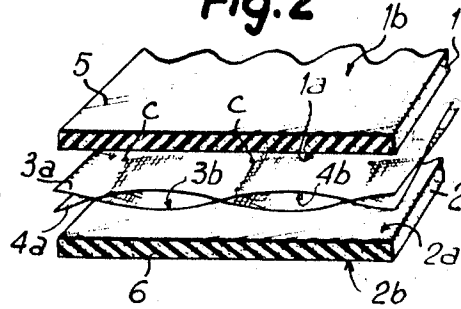


Fig. 3

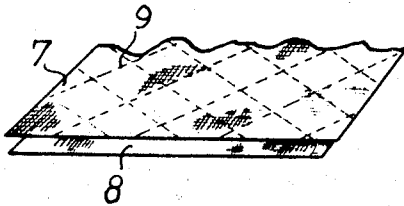


Fig. 4

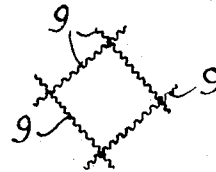


Fig. 5

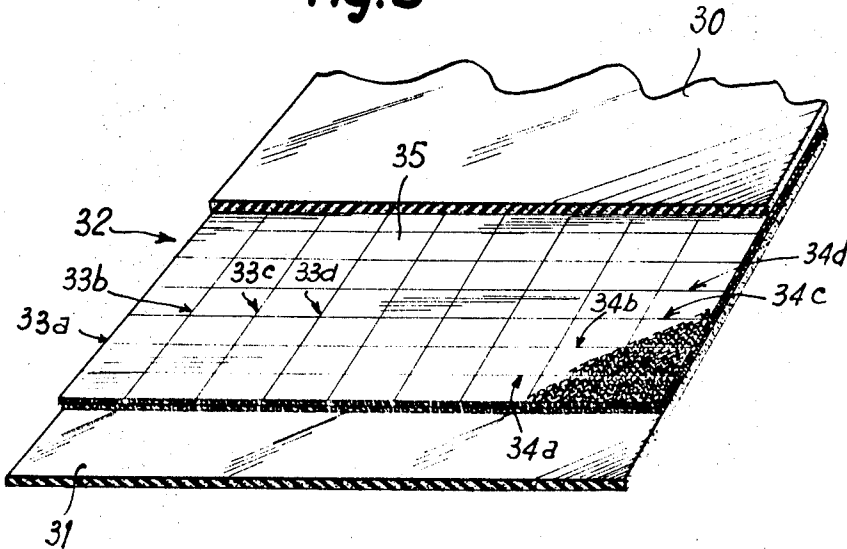
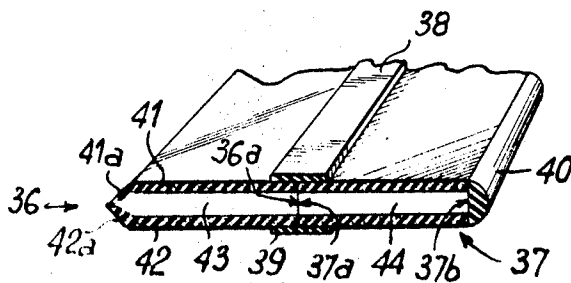


Fig. 6



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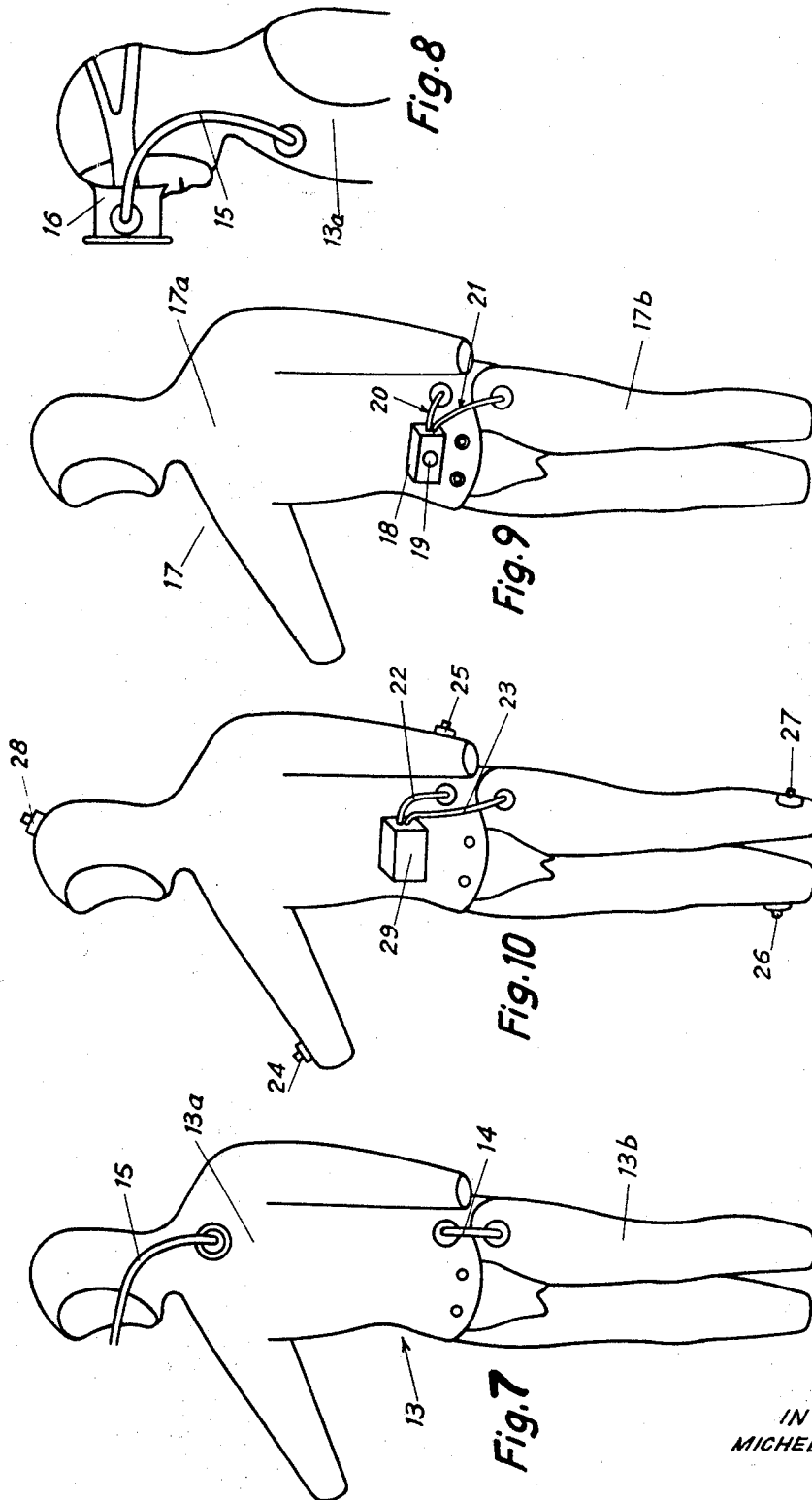
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MATERIAL FOR THE MANUFACTURE OF FITTED DIVING SUITS AND SUITS MADE THEREOF

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47,852

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U.S. Cl. 128—142.5

9 Claims

ABSTRACT OF THE DISCLOSURE

A material for the manufacture of heat-insulating diving suits comprising, between two impermeable and elastic sheets, an insertion space containing an interposed material attached to the opposite faces of the sheets and permitting the admission of a fluid in'to said space, the interposed material keeping the sheets parallel when the fluid pressure tends to force them apart against the action of the external pressure. Also a suit or a part of a diving suit made from the said material.

The present invention relates to a material for the manufacture of fitted diving suits intended to keep the wearer's body warm, and also to the suits made from the said material.

A material which is commonly used for the manufacture of a diving suit of the kind referred to above is cellular rubber of the neoprene type, used in the form of sheets. This rubber consists of a large number of closed and non-communicating cells which contain an occluded gas, which gives the material its heat-insulating properties. A material of this kind has been described for example in U.S. Pat. No. 2,981,954.

Suits manufactured from this material have the disadvantage that their thickness becomes reduced when the wearer is diving, due to the effect of the increasing pressure of the water on the suit and the resulting compression of the cells of gas. This reduction in thickness causes a substantial diminution of the isothermal properties of the suit, and the invention is intended to overcome these drawbacks and to obtain a suit adapted for diving to considerable depths.

In its characteristic form, the material of the invention comprises two sheets which are impermeable and elastic in all directions, with a space interposed between the sheets and containing an inserted material attached to the opposite faces of the sheets and permitting the admission of a fluid into the space formed between the sheets, in such manner as to maintain the sheets substantial parallel to each other when the pressure of the said fluid acts to keep the sheets separated from each other, against the external pressure.

The elastic and impermeable sheets, i.e. through which water cannot pass from one face to the other, are advantageously sheets of cellular rubber with closed cells, of neoprene for example.

The essential properties required of the sheets are in fact impermeability and elasticity; the material described above is particularly advantageous, as is well known, for its remarkable elasticity, but it is only cited here by way of example.

Thus, it is not excluded to utilize as a sheet a very elastic but non-impermeable material which is subsequently rendered impermeable by an appropriate treatment which does not adversely affect its elasticity.

In one form of construction of the material according to the invention, the interposed material is a material of cellular structure with communicating cells, having

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a thickness substantially equal throughout the extent of the material.

The two impermeable elastic sheets are fixed by adhesion on each side of the said cellular interposed material. In an alternative construction, an impermeable sheet is first formed, and then the interposed material is formed on this sheet, after which the other impermeable elastic sheet is placed over this material.

There is preferably employed a cellular interposed material having a density as low as possible, which assists in giving good thermal insulation properties to the material. For this purpose, a foam of plastic material such as polyurethane or polyester, etc., or a latex foam, having a density less than 0.1, are particularly suitable.

Such a structure of the inserted material has however the drawback of being weak and of making difficult the adjustment of the fluid pressure to be introduced into the diving suit.

In fact, this cellular material does not permit easy circulation of this fluid right through the material, and may give rise to local excess pressures due to inadequate distribution of the fluid pressures.

In addition, it necessitates a relatively high-fluid pressure at the points where the fluid is introduced into the material, in order to take account of the pressure losses created by the cellular structure, and this increases the likelihood of appearance of excessive local pressures.

Thus, the interposed material having a weak structure is liable to reach, at least at certain points, the limit of its resistance to tearing when the two sheets of rubber between which it is fixed and to which it is stuck are separated from each other by the effect of the fluid pressure introduced into the material.

For these reasons, in another form of construction of the interposed material, this latter is constituted by two parallel layers of elastic fabric sewn to each other by appropriate seams, these seams forming for example a large number of connecting points or lines distributed over the extent of the opposite faces of the layers, the two impermeable and elastic sheets being applied to the other faces of these layers and being fixed to them by sticking or other means.

Very satisfactory results are obtained by utilizing a knitted fabric as the interposed material.

More precisely, in the preferred form of embodiment of the invention, the material interposed between the elastic and impermeable sheets is constituted by an elastic knitted fabric which is equivalent to two thicknesses of knitted stockinet which are joined to each other by a chequer pattern of knotting.

In fact, this knitted fabric is an elastic tubular jersey comprising a number of parallel tubes periodically closed by lines of cross rib-stitches parallel to each other.

In addition, elasticity in all directions is ensured by the choice of a suitable textured fibre, such as for example nylon or Rilsan, which have been subjected to "Helanca" treatment, or elastic fibres such as "Laykra" fibres. In fact, it is necessary to distinguish between the elastic deformation of a knitted fabric due to the choice of the stitch and the stretch in all directions of an elastic or knitted fabric. In the former case, it is only a question of the slip of the stitches one with respect to the other, and any increase in dimensions in one direction is accompanied by a reduction in the other direction, always with a modification of the dimensions of the stitch. If a knitted fabric of this kind is uniformly stuck down on an elastic support, it will lose its properties of deformation by the stitches, since the latter can no longer slide with respect to each other. The adhesive locks the knitting and the final result is no longer elastic. On the other hand, when the thread

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employed is itself elastic, the possible elongation of the knitted fabric is real, even simultaneously in all directions, without making use of any slip of the stitches, and for this reason, the sticking down does not modify the elastic properties.

A knitted fabric of this kind can be manufactured industrially on a straight knitting machine with two beds, set and programmed to produce alternately and successively in a repetitive manner, a tubular stockinet comprising a number of parallel tubes and a line of rib stitches over the whole width of the machine in order to close the said tubes.

For the manufacture of a material for diving suits, it is an advantage to arrange the elastic knitted fabric between two sheets of rubber, such as for example sheets of the neoprene type or other cellular rubber which is essentially elastic in all directions, the sheets having each received on their faces which will be in contact with the knitted fabric, an application of an appropriate adhesive solution, the solvent of which is allowed to evaporate, the assembly constituted by the knitted fabric inserted flat between the rubber sheets being subjected to pressure under heat.

The whole of the method which has just been described is similar to that described in French patent application No. PV 916,223 filed on Nov. 22, 1962 in the name of Michel Piel with the title "A Method of Sticking an Elastic Fabric on Cellular Rubber and its Application to the Industrial Manufacture of Isothermal Clothing."

A precaution to be taken during the pressing operation is to arrange a leakage from the interior of the rubber sheets towards the exterior, for example by leaving the knitted fabric locally uncovered over a very small part of its surface, in order that during pressing, the air existing between the two sheets of rubber due to the interposition of the knitted fabric, can escape through this leakage point.

The thickness of the rubber sheets will normally be comprised between 1 to 4 mm.

The material thus produced has consequently the form of a thick composite sheet of cellular rubber, in the centre of which there is a continuous and thick layer of knitted fabric and also a uniform and geometric succession of small hollow spaces communicating with each other at the knotting points which define them.

The material obtained by the method which has been described above is then fitted with one or more tubes which provide communications between the insertion space inside the two sheets of rubber in which the knitted fabric is housed, and an appropriate source of fluid, this fluid being intended to increase the distance between the two sheets of rubber, this distance being limited by a large number of connections formed between the two sheets by the knitting.

In practice, the space between the two sheets of rubber, which was initially 2 mm. for example, can reach a value comprised between about 2 and 10 mm., and preferably between 4 and 6 mm., due to the effect of the fluid pressure. The nature of the knitted fabric permits very rapid inflation and deflation of the material, since the tubes and the lines of rib stitches permit the fluid to circulate very freely, which is an important advantage of the use of a knitted fabric of this kind as an insertion between the rubber sheets.

In particular, as will be described later, the constancy of the thickness of the material forming the suit can be ensured at any depth by putting the insertion space under pressure, resulting from its supply with gas through a pressure-reducing valve doubled by a valve. The material has very good resistance to this pressurization, since this may reach a value of 1 kg. per sq. cm. without bursting the material. By acting on the value of this pressure, this resistance to pressurization enables the thickness of the material forming the suit to be

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slightly modified at will, and in consequence its buoyancy in immersion can be varied, which is a great advantage for the diver since he can readjust his buoyancy irrespective of his position and the load which he is carrying.

For a diving suit having a developed surface of 2 sq. mm. for example, 6 litres of fluid are sufficient to obtain between the two water-tight layers a thickness which is considered appropriate in the majority of cases.

The diagrammatic drawings which accompany this specification illustrate by way of example various methods of construction of a material and a diving suit according to the invention.

FIG. 1 is a perspective view with a section through the thickness of one form of construction of the material of the invention for the manufacture of diving suits, in which the inserted material is a cellular material.

FIG. 2 is a perspective view with cross-section of an alternative form of the material, in which the inserted material is constituted by an assembly of two elastic fabrics, this assembly being shown separated from the impermeable sheets.

FIG. 3 is a diagrammatic perspective view of an alternative form of construction of the interposed material.

FIG. 4 is a diagram to a larger scale of a detail of FIG. 3.

FIG. 5 is a diagrammatic perspective view with parts broken away of an alternative form of the material, in which the interposed material is a tubular stockinet fabric.

FIG. 6 is a perspective view with cross-section, illustrating the assembly and fluid-tightness means of the material of the invention.

FIG. 7 is a perspective view of a diving suit in accordance with the invention.

FIG. 8 is a perspective view to a larger scale of the upper portion of this suit.

FIGS. 9 and 10 are perspective views of alternative forms of the diving suit.

FIG. 1 shows a form of construction of the material, in which this latter comprises, between the impermeable and elastic sheets 10 and 11, which in the case considered, are of cellular rubber with closed cells, an interposed cellular material 12 with communicating cells, the faces 12a and 12b of which are respectively stuck to the inner faces 10a and 11a of the sheets.

The thickness of each sheet is comprised for example between 1 and 3 mm., and that of the cellular inserted material is comprised for example between 2 and 4 mm. This material has preferably a density lower than about 0.06, and still better, of the order of 0.02.

FIG. 2 is a diagrammatic view in perspective of an alternative form of embodiment of the invention, in which the inserted material is constituted by two elastic fabrics 3 and 4, on the outer faces 3a and 4a of which the sheets of cellular rubber with closed cells 5 and 6 are fixed by sticking, and in which the inner faces 3b and 4b are coupled together by a plurality of connections such as seam points c, uniformly spaced apart, which gives the material a slightly padded external appearance.

The connections between the fabrics may be short elastic connections made in such manner that the fabrics are in contact at the connection points, or alternatively these connections may have a certain length which defines the maximum permitted distance between the fluid-tight layers when the material is internally filled with fluid.

They may be effected by welding, riveting, sticking or by local seams.

The distance between two adjacent points of attachment must be sufficient to permit the passage of a fluid into the insertion space between the two layers, and the determination between these layers of an average distance

apart of the order of 3 mm. for example, due to the effect of the said fluid; on the other hand, this distance should be sufficiently small to prevent the local formation of a swelling under the effect of this pressure. In practice, a distance of 1 to 3 cm. between the points of attachment is suitable in most cases.

FIG. 3 illustrates very diagrammatically, the impermeable sheets having been removed, a construction in which the two elastic fabrics 7 and 8 (shown without thickness) are connected to each other by elastic seams with a zig-zag stitch (FIG. 4 shows to a larger scale a part of these seams) which can be obtained with a padding machine fitted with an appropriate head.

FIG. 4 shows a preferred alternative form of construction of the material, in which the insertion material is a tubular knitted jersey of elastic fibres, forming a number of parallel tubes closed here and there by lines of transverse rib stitches parallel to each other.

In FIG. 5 there has been shown very diagrammatically the material of the invention with parts broken away so as to enable the structure to be seen, namely two sheets of rubber 30 and 31, with the tubular stockinet 32 between these sheets. This stockinet fabric is formed by a series of parallel tubes determined by connections 33a, 33b and 33c, which tubes are closed at intervals by transverse lines of rib stitching 34a, 34b, 34c, etc.

It will be understood that the drawing is essentially diagrammatic and that the indications given below will make it easier to understand by an example, how a stockinet fabric of this kind can be produced industrially on a straight knitting machine of the type described above.

For example, the machine can be set to No. 7 English gauge, one needle in five being in the heel-forward position, the other needles having their heels at the bottom on both beds, and the programme set for the machine is for example to form a line of rib stitches followed by ten lines of tubes alternately on the front bed and rear bed, then a line of rib stitches, etc., the positions of the actuating cams of the needles being limited to the bottom and medium positions, so that the needles with heel forward are always at work.

In other words, the two beds work alternately during one period to form the tubular stockinet with a number of tubes, the de-limitation of the tubes being due to the continuous rib stitches of the needles with forward heels, and then work simultaneously for a shorter period so as to form a line of rib stitches, etc.

The machine is supplied with a thread of synthetic elastic material, for example with a nylon thread which has been subjected to a treatment to make it elastic, for example a Helanca type treatment.

It is of course possible to vary the dimensions of the tubes in width by varying the distribution of the needles with heels forward, while the dimensions in length of the tubes (that is to say the dimensions in the direction of movement of the completed fabric from the machine) can be varied by modifying the space between the lines of rib stitching. The gauge of the machine can also be regulated.

It is preferably desired to obtain a knitted fabric which is neither too thick nor too thin; the first condition would result in fact in a high consumption of material, and the second would produce a fabric of insufficient thickness. A machine gauge 7 supplied simultaneously with three threads of Helanca-treated nylon of 80 deniers each, set and programmed as indicated above, gives a knitted fabric which is very satisfactory for utilization as an intermediate material between two sheets of rubber for the manufacture of a material assembly according to the invention. This has a thickness of about 2 mm., a weight of 250 grams per sq. m. and an elastic stretch in all directions of about 200%.

The width of the tubes is preferably of the order of 2 cm. and the transverse knottings are spaced apart by the

same distance in order to obtain square successive hollow zones.

The stockinet thus knitted is arranged flat between the sheets of rubber, the faces of which applied against the stockinet have previously been given a coating of adhesive solution, the solvent of which has been allowed to evaporate. The assembly is pressed and heated at the same time so as to re-activate the film of adhesive deposited on the sheets.

It will of course be understood that the invention is not limited to a particular method of sticking the stockinet fabric to the sheets of rubber and the above method has been described as a preferred example.

The material obtained is remarkably resistant to tearing by reason of the elasticity and the strength of the inserted material and of the large number of sticking zones of this material to the sheets between which it is enclosed, practically all the outer surface of the stockinet being stuck to the sheets.

The manufacture of a diving suit from this material is carried out according to the invention in such manner that the insertion spaces in which the interposed material is located communicate with each other.

The joining together of the various parts constituting a single portion of the suit can be effected by any appropriate means which ensures a communication between the various insertion spaces and the fluid-tightness of the coupling zones.

FIG. 6 illustrates an example of coupling between two pieces of material 36, 37, in which this is obtained by butting together the previously glued sections 36a, 37a, of these parts, and covering the coupling zone by two butt-strips 38, 39, which may be thin sheets of rubber or any other suitable material stuck to the suitable position of the outer faces of the joined parts.

In the figure, the interposed materials of each piece have not been shown, but only the insertion spaces 43 and 44 in which the insertion materials are housed.

FIG. 6 also shows an example of construction of an edge of a piece of clothing by means of an elastic bead 40 stuck on the section 47b to be closed, and an example of construction of an edge by pinching together the extremities 41a and 42a of the fluid-tight sheets 41 and 42, with sticking together of the extremities brought into contact with each other, all arrangements being made so that there is no interposed cellular material between the fluid-tight sheets at the zone of the extremities. Water-tightness of the edge could also be obtained by covering with a suitably folded elastic strip, or again by suitable folding of one of the fluid-tight sheets 41, 42.

The cutting out of the various parts can of course be arranged so as facilitate the communication between the insertion spaces of these parts (raglan cutting of the sleeves for example).

The material or the suit obtained from the material may comprise additional coatings, for example an elastic fabric arranged and suitably fixed by adhesion or otherwise on the outer and/or inner face of one and/or the other of the two sheets or a layer of flocking. It is not necessary to describe these arrangements in detail, since they are already known to those skilled in the art.

The insertion materials described above permit the presence of a fluid between the elastic sheets in the insertion space between the sheets which, as a whole, is substantially flat, the two sheets remaining substantially parallel to each other.

It should be observed that in case of accidental local damage to one of the elastic and impermeable sheets and evacuation of the fluid through the tear in question, everything finally takes place as if the diving suit were reduced to a dress essentially constituted by the two sheets, and it is for that reason that the invention preferably provides that these sheets are constituted by a material which is itself isothermal, such as a cellular rubber with closed

cells, in sheets having a thickness in the vicinity of 2 mm. for example, so that in such a case the diver is still protected by an isothermal suit having an adequate thickness (about 4 mm.).

The fluid to be introduced into the suit may be an incompressible fluid, for example oil, or another liquid. The choice of a liquid as a filling fluid has the immediate advantage of rendering the suit incompressible.

The liquid may be introduced into the suit by means of a single pipe opening into the insertion space referred to above.

In order to do this, the invention provides for the arrangement of the diving suit in a caisson, the pipe dipping into a receptacle containing the selected liquid, after which, a vacuum is created in the caisson in order to expel all the air contained in the suit, this air escaping through the pipe and through the liquid in the form of bubbles. When it is considered that all the air in the suit has been expelled, it is only necessary to restore the air pressure gradually inside the caisson in order to cause the liquid in the receptacle to penetrate progressively into the suit, the pipe being closed or eliminated at the end of the operation.

While the liquid forms a simple means of obtaining incompressibility during deep diving, on the other hand it increases the weight of the diving suit and may have heat insulation properties inferior to those of a gas, and it is for this reason that the invention provides preferably for the use of a gas to fill the insertion space between the two fluid-tight sheets, but this is associated with means for systematically compensating for the variations of external pressure by a corresponding variation of the said gas, so that the layer of gas in the suit remains of substantially constant thickness when the external pressure varies, given that the effectiveness of the diving suit depends on the value and the uniformity of this layer.

This pressure must be equal to or preferably slightly greater than the external pressure acting on the suit. Now it is known that between the pressures which are applied to the feet and the head of a diver in the water, there exists a difference in pressure which may reach 200 grams per sq. cm. for a diver of 2 m. in height located vertically in the water. This being so, the pressure value which should exist in the insertion space can be defined as equal to the value of the pressure P which exists at the level of the geometric centre of the diver (for example at the level of the stomach) increased by 100 grams per sq. cm.

Under these conditions, the difference in pressure between the internal pressure in the insertion space and the external pressure will be zero at the level of the feet, equal to 100 grams per sq. cm. at the level of the stomach, and to 200 grams per sq. cm. at the level of the head, if the diver is vertical.

In order to maintain these characteristics during the movements of the diver, it is necessary to ensure an additional supply of gas for any increase in the depth of immersion, and an escape of the said gas for any reduction of the pressure, which can be obtained by a device comprising a source of compressed gas, the flow-rate of which is controlled by a diaphragm regulator of known type associated with a pressure-reducing valve calibrated to 100 grams per sq. cm., the regulator and the valve being placed at the level of the stomach.

The regulator can be avoided by ensuring a continuous delivery of the gas which is as small as desired, the valve then delivering continuously.

The choice of the position on the stomach with a regulation of the pressure to $(P+100)$ grams per sq. cm. is governed by the fact that this position makes it possible to give a minimum value to the over-pressure, but it is not excluded from the invention to choose another position and in consequence to adopt another regulation pressure.

This is especially the case when the material utilized comprises a spongy interposed material having a certain thickness.

In this case, the spongy material offers a certain resistance to compression which may be of the order of 200 grams per sq. cm. Consequently, the corresponding diving suit may retain its thickness, even if there exists in the insertion space a pressure which is 200 grams per sq. cm. lower than the external pressure. In consequence, this suit may be supplied simply by putting the insertion space into direct communication with any desired point of the breathing circuit.

FIGS. 7 to 10 give diagrammatic perspective views of various forms of construction of a diving suit in accordance with the description which has been given above.

In FIG. 7, the suit 13 comprises a jacket 13a, of which one part forms the helmet, and a pair of trousers 13b the internal insertion spaces of the jacket and trousers being put into communication by means of a pipe 14. The gas which is introduced into these spaces through a pipe 15 is simply air taken from the breathing circuit of the diver by a suitable branch pipe, for example extracted from the interior of the diver's mask 16 (FIG. 8), so that it is always automatically at a suitable pressure since the air of the breathing circuit is itself effectively controlled by a regulator device, as is well known.

In FIG. 9, the suit 19 also comprises a jacket with helmet 17a and trousers 17b, the insertion spaces of which, between the fluid-tight sheets, are supplied with a gas which is derived from an appropriate source, a cylinder of compressed gas, for example, contained in a supply unit 18 which comprises a pressure-reducing valve and a calibrated decompression valve 19 for the evacuation of the gas to the outside when the pressure of the gas is greater than the external pressure, and connecting pipes 20 and 21 for introducing the gas into the insertion spaces of the jacket and trousers.

The supply unit 18 may advantageously be fixed on the suit, at the level of the centre of average pressure.

In order to obtain the desired circulation of gas, the supply zone will be preferably located at the geometric centre of the suit, and the decompression valve will be replaced by a number of valves placed at the extremities of the suit, so that the circulation takes place from the centre towards the extremities.

FIG. 10 shows a perspective view of a diving suit of this type, in which the gas is introduced continuously into the insertion spaces by means of the pipes 22 and 23 and escapes continuously from these spaces through valves arranged as far as possible from the points of introduction, for example through valves 24 and 25 at the extremities of the arms, valves 26 and 27 at the extremities of the legs, and a valve 28 at the top of the head.

It is to be understood that in this disclosure, suit means a garment encompassing the whole body of the diver or a garment encompassing only a part thereof, f.i., a hood, a boot, a trousers, a jacket, said garment being characterized by the fact that it comprises two impermeable and elastic sheets in parallel with an insertion space therebetween and a pipe for introducing fluid into said insertion space, said insertion space containing an interposed material attached to said sheets and keeping them parallel when the pressure of said fluid tends to force them apart.

What is claimed is:

1. A material for the manufacture of heat-insulating diving suits, comprising two impermeable and elastic sheets in parallel with an insertion space therebetween, said impervious space containing an interposed material attached to said sheets and made of two parallel layers of elastic fabric connected to each other by a plurality of elastic connections providing small hollow spaces communicating with each other, said interposed material permitting the admission of fluid into said space and keeping the sheets parallel when the pressure of said fluid tends to force them apart.

2. A diver's garment the structure of which comprises the impermeable and elastic sheets in parallel with an insertion space therebetween, said insertion space containing an interposed material attached to said sheets and made of two parallel layers of elastic fabric connected to each other by a plurality of elastic connections providing small hollow spaces communicating with each other, and a pipe for putting said insertion space in communication with a compressed fluid source for introducing fluid into said insertion space, said interposed material keeping the sheets parallel when the pressure of said fluid tends to force them apart.

3. A diver's garment according to claim 2 wherein said fabric is an elastic tubular jersey comprising a number of parallel tubes closed by lines of cross rib-stitches parallel to each other.

4. A material in accordance with claim 1 wherein said interposed material consists of a knitted elastic fabric.

5. The material of claim 4 wherein said knitted fabric is an elastic tubular jersey comprising a number of parallel tubes closed by lines of cross rib-stitches parallel to each other.

6. The material of claim 5 wherein said jersey is knitted with thread of synthetic elastic material.

7. The diver's garment of claim 2 wherein said pipe is connected to a source of gas.

8. The diver's garment of claim 2 and further comprising a breathing circuit, said breathing circuit being connected to said pipe.

9. The diver's garment of claim 7 wherein said structure comprises a valve controlling the evacuation of the gas to the outside from insertion space.

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U.S. Cl. X.R.

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