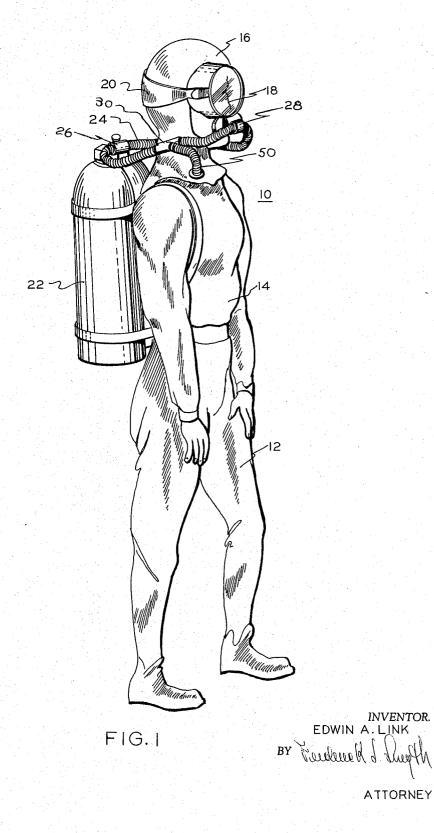
## March 7, 1967

E. A. LINK PROTECTIVE SUIT

3,307,540

Filed March 10, 1964

2 Sheets-Sheet 1

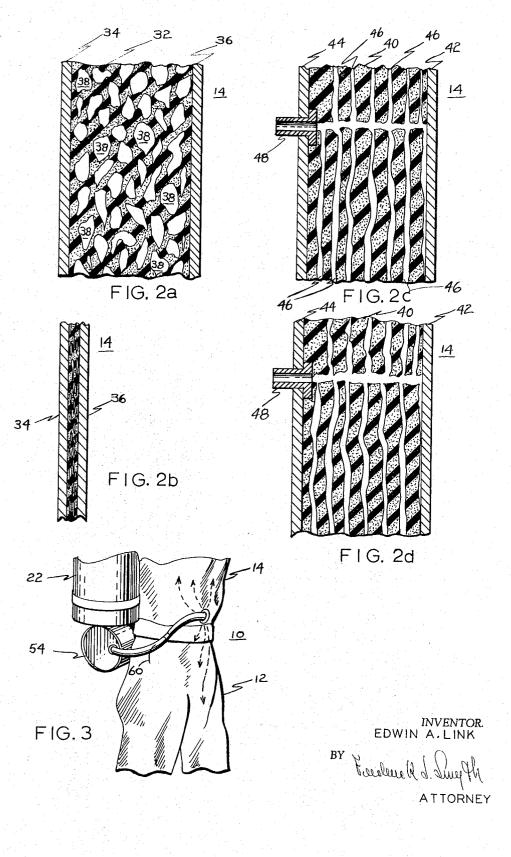


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# **United States Patent Office**

### 3,307,540 Patented Mar. 7, 1967

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#### 3,307,540

PROTECTIVE SUIT Edwin A. Link, Binghamton, N.Y., assignor, by mesne assignments, to Ocean Systems, Inc., New York, N.Y., a corporation of New York Filed Mar. 10, 1964, Ser. No. 350,836 9 Claims. (Cl. 128–142.3)

This invention relates to a protective suit and more particularly to an improved diving suit.

For many years it has been the custom for underwater divers to wear cumbersome canvas suits together with a heavy metal helmet and chest plate. Further, in order to ensure adequate protection against the pressure of the water, which increases linearly with depth, as well as to 15 provide insulation against the coldness of the water, air is, in general, provided at a pressure slightly in excess of the surrounding water pressure, to inflate the canvas and thereby maintain the suit out of contact with the diver's body. The large volume of air necessary for this 20 purpose, however, adds excess buoyancy to the diver and has equipment, thus requiring the addition of added weights in order that the diver may remain vertically submerged. As a result, such diving apparatus adds approximately 200 pounds to the diver's weight, and se- 25 verely restricts the movements of the diver when underwater.

Recently, a new form of diving suit has been designed, fabricated out of foam rubber, which provides adequate 30 insulation to the wearer by maintaining the water out of contact with the diver's body. Because the foam rubber has an indeterminate number of minute gas bubbles entrapped therein, this form of diving suit provides additional insulating properties since the entrapped gases ex-35 hibit low heat conductivity. This type of suit is that commonly worn by "frogmen" and scuba divers. To be effective, such suits must fit the body as tightly and perfectly as possible, in order to obtain the insulation advantages afforded by the combination of the rubber and 40 entrapped gas bubbles. Further, since the insulation from the surrounding water temperature is not obtained through the use of a large volume of air internal of the suit the magnitude of the weights required to be added to reduce the diver's net buoyancy is minimized, allowing 45 the diver a large increase in his freedom of movement while submerged. However, while foam rubber suits are acceptable for shallow water diving, or very quick deep dives, they are ineffective for normal deep dives since at depths in excess of about 100 feet, the increased water 50 pressure operates to compress or flatten the sponge rubber, and the suit thereby loses its heat insulation value previously provided by the entrapped gas bubbles. In order to overcome this problem, various attempts have been described in the prior art which include mechanical 55 and/or fixed pressurized members being attached to either the inner or outer surface of the suit to thereby reduce or control the compression of the suit by the pressure of the surrounding water. Although each of these attempts have achieved some measure of success, it has been gained 60 only by sacrificing, to a large degree, the diver's freedom of movement.

According to the present invention, however, there is provided an improved sponge rubber diving suit which retains its heat insulating qualities even at depths in excess of 400 feet without limiting the diver's mobility. Briefly, the invention comprises a foam rubber diving suit provided with a plurality of interconnected paths throughout the inner portion of the rubber between the smooth inner and outer skins. All of the paths are then connected to either the diver's breathing apparatus, which has a conventional pressure regulator connected thereto, or 2

to a separate gas supply which is also pressure regulated. In this manner the insulating qualities of the suit are retained independent of depth, since the small volume of air or gas present in the paths is maintained at a pressure slightly in excess of the surrounding water pressure and functions in a manner exactly analogous to the above described minute gas bubbles at shallow depths. Note should be made of the fact that, since the path volume required is extremely small, corresponding in fact to the 10 total volume of the gas bubbles, no significant added buoyancy is supplied to the wearer thereof and no additional weights are necessary other than those employed with the foam rubber suits of the prior art. Additional note should be made of the fact that the suit of the invention can be safely electrically heated in contradistinction to the suits of the prior art wherein sweating and other factors create hazards, all as more particularly hereinafter described.

It is an object of the invention, therefore, to provide an improved protective suit.

Another objective of the invention is to provide an improved foam rubber diving suit.

Yet another object of the invention is to provide a foam rubber diving suit operable at greater depths than foam rubber suits of the prior art.

Still another object of the invention is to provide a diving suit which is effectively pressurized yet does not add significantly to the wearer's buoyancy.

A further object of the invention is to provide a diving suit that can safely be electrically heated.

The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts, which will be exemplified in the constructions hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a pictorial representation of a preferred embodiment of the invention.

FIGS. 2a through 2d are partial cross-sectional views of both foam rubber diving suits of the prior art and according to the present invention, useful in understanding the operation of the invention.

FIG. 3 is a partial pictorial representation of another preferred embodiment of the invention.

Referring now to the drawings, FIG. 1 illustrates a preferred embodiment of the protective suit provided by the invention. As there shown, a suit 10 is divided into lower or pants section 12 and an upper portion or jacket 14. Each of sections 12 and 14 are fabricated to fit the body of the wearer as tightly and perfectly as possible, and the terminal portions thereof, such as the wrist, neck, and leg openings, normally include either elastic portions or securable members to effectively provide a water tight seal. Additionally, pants 12 and jacket 14 overlap about the waist of the wearer to also provide a water tight seal. Further, although the diver is shown as wearing a pair of soft slinners or the like, it will be understood by those

of soft slippers or the like, it will be understood by those skilled in the art, that during those time intervals the diver is submerged, a pair of "flippers" or fins are generally worn to increase the diver's speed and mobility. A soft neoprene helmet member 16 encases the diver's head, and a viewing part 18 positoned by a retaining device 20 is effective to provide the diver with a protected viewing area by maintaining the water out of contact with the diver's eyes while submerged. Additionally, a self-contained tank of breathing mixture 22 is supported about the diver's shoulders in order to provide the diver with a properly pressurized breathing supply, by means of flexible tubing 24, pressure regulating valve 26, and intake-outtake valve 28.

It will be noted that up to now the embodiment of the invention being described appears to be identical with many of the known rubber diving suits of the prior art. Referring again to FIG. 1, however, it will be seen that flexible tubing 24 includes a Y-shaped junction device 30 which diverts a portion of the breathing mixture from tank 22 to and within suit 10. Further, it should again be noted that a pressure regulating valve 26 is connected 10 in series between tank 22 and tubing 24 in order that the breathing mixture delivered to the diver is always maintained at a pressure which exceeds the pressure exerted by the surrounding water by a few pounds per square inch (p.s.i.). Therefore, the portion of the breathing 15 mixture diverted to suit 10 by junction device 30 is likewise maintained at a slightly greater pressure than the external water pressure. Before continuing with the operation, features, and advantages provided by this and other embodiments of the invention, it is believed that 20 the construction and fabrication of the suit itself should be examined in detail, in order that a more clear understanding of the invention will be attained.

Referring now to FIGS. 2a through 2d, there is illustrated partial sectional views of the foam rubber suits 25 of the prior art and according to the present invention when the diver is submerged at relatively shallow depths, that is, in the order of 100 feet or less, as well as when the diver is submerged at significantly greater depths of the order of 400 feet. FIG. 2a shows a section of jacket 30 14, by way of example, according to the prior art. As there shown, jacket 14 is fabricated of a length of foam rubber 32 having a thickness of 3% to 34 inch, although other and different thicknesses may be employed as desired. Bonded to the external surfaces of foam rubber 35 32 are first and second sections of smooth, flexible rubber-like material 34 and 36, which generally is selected to be neoprene, although again, other and different materials may be substituted therefor as desired.

As illustrated, the length of foam or sponge rubber 40 includes a plurality of entrapped gas bubbles 38, which generally are independent one from another. Depending upon the conditions of manufacture, of course, as well as the random distribution of the bubbles, one or several groups of bubbles, may share a common opening, but conventional foam rubber is fabricated to pro- 45 vide the material as shown in FIG. 2a. It further should be understood that the gas within each of bubbles 38, which usually is air, is normally entrapped at atmospheric pressure. Thus, when a diver, wearing a suit fabricated from the material illustrated in FIG. 2a, operates sub- 50 merged at depths up to about 100 feet, the pressure exerted by the water upon the suit is not sufficient to completely overcome the opposing pressure exerted by the plurality of entrapped gas bubbles, resulting in that although the overall thickness of the suit is reduced some- 55 what, yet the heat insulation qualities provided by the suit, that is, the low value of thermal conductivity imparted by the gaseous volume within the foam rubber, are not materially reduced.

However, drastic changes are introduced into the suit 60 insulation qualities when the diver descends to depths in the order of 400 feet. At these depths, where the water pressure exceeds atmospheric pressure by about 180 p.s.i., the pressure exerted by each of the plurality of bubbles 38 is now ineffective to withstand the water pressure, and 65 the suit collapses to the form shown in FIG. 2b. As there illustrated, the inner and outer neoprene layers 34 and 36 are virtually in contact. Under these conditions, the suit has lost essentially all of its insulating qualities, and the temperature of the outer surface of 70neoprene layer 34 is essentially that of the water. It is for this reason, that the wet diving suits of the prior art have not proved useful at depths much in excess of approximately 100 feet, except for relatively quick deep

though the surface and shallow water temperature may be such that a heat insulating protective suit is not necessary, the temperature at 400 feet is still measured in the thirty degree temperature range. In general, it can be stated that at depths of 400 feet and greater the water temperature is relatively independent of the surface temperature and conditions, being only slightly modified by underwater current streams.

Referring now to FIG. 2c, there is shown a sectional view of the diving suit of the present invention, again employing jacket portion 14 for example. As illustrated, this suit also employs a center foam rubber layer 40 bonded between a pair of smooth, flexible neoprene layers 42 and 44. However, note should be made of the fact, and this is an important feature of the invention, that foam or sponge rubber layer 40 differs markedly from that of layer 32 illustrated in FIG. 2a. Rather than a plurality of individual entrapped bubbles 38, the plurality of individual bubbles are interconnected to form a number of channels 46 extending throughout foam rubber layer 40. In this manner, the heat insulating qualities afforded by the foam rubber-gas space combination are retained and further, as will be described, these qualities are retained even when the suit is worn at depths of approximately 400 feet. Further, although layer 40 is depicted in somewhat idolized style in FIG. 2c, it should be understood that although the foam rubber may, in fact, be obtained with the regularly spaced parallelly spaced channels shown in FIG. 2c, the actual spacing is not required, it being sufficient, according to the invention, that the great majority of bubbles be interconnected one to another, in order that the major portion of the material between layers 42 and 44 be maintained at a selectable yet variable pressure.

Also shown in FIG. 2c is a valve member 48 which is effective to couple the diverted portion of the breathing supply from Y-shaped device 30 through a flexible base 50 (see FIG. 1) to each of channels 46. Remembering again that a pressure regulating valve is employed to maintain the pressure of the breathing supply slightly greater than the surrounding water pressure, the operation of the protective suit should now be apparent, and which is further emphasized by a comparison of FIGS. 2b and 2d. As hereinbefore stated, FIG. 2b shows the result of submerging the various wet diving suits of the prior art to a depth of 400 feet, a depth sufficient to result in the collapse of the suit by the external water pressure and the destruction of the majority of the necessary heat insulating qualities. FIG. 2d, however, shows the result of submerging the wet diving suit of the invention to a similar depth of 400 feet, and it is readily seen that the same form and shape is retained as that illustrated in FIG. 2c for surface or shallow depth submersions. This feature is attained as a result of automatically and continuously maintaining the pressure of the foam rubber region 40 of the suit bonded between neoprene layers 42 and 44, at a pressure substantially equal to the pressure exerted by the external water, so that the heat insulating qualities of the suit remain unaffected by the submerged working depth of the wearer. Additionally, although member 48 has been described as a valve, it should be understood that member 48 may be selected from any of the various fittings operable to couple flexible tubing 50 to all of the channels 46.

It is also contemplated by the invention that the protective suit can be heated if such should be desired or necessary. In general, the body heat of the wearer of the suit is sufficient to provide a comfortable environment provided only that the body heat is not permitted to escape, that is, that the protective suit maintain high insulating qualities at each of the working depths selected by the wearer. However, in those isolated instances at which it is necessary to provide additional heat, resistance wiring can be intermeshed throughout foam rubber layer 40, the ends of which are connected to a source of electrical dives. This is true even in tropical regions where al- 75 power attached to the diver. In this manner, a shock5

free heating system is provided since the diver is completely insulated from the electrical wiring by continuous neoprene layer 42, and, further, the electrical wiring is intermeshed, and the thermal heat generated thereby is completely contained, within a waterproof area.

As is well known by those skilled in the art, when operating at depths greater than approximately 100 feet, it is generally preferred that the diver be supplied with a breathing mixture containing helium and oxygen, with the helium to oxygen ratio increasing in direct proportion 10to the working depth, in order to eliminate the possibility of nitrogen narcosis. As a particular example, at a depth of 200 feet the breathing mixture comprises 97% helium and 3% oxygen, while at a depth of only 40 feet the oxygen content is raised to total 21% of the overall mixture. 15 Additionally, a submerged diver standing in a vertical position is subjected to a pressure gradient of about 2 to 3 p.s.i., that is, the pressure in the vicinity of the diver's head is about 2 to 3 p.s.i. less than the pressure at his feet. For each of these reasons it is often desirable to 20 employ a separate gas source to maintain the foam rubber layer pressurized, and, further, to connect this source to either the mid-position of the suit, or, alternatively, to a number of vertically spaced positions along the suit. In this manner, a particular gas or gas mixture can be 25 selected to enhance the insulation qualities of the suit independent of the breathing mixture, and the pressure gradient along the suit can be minimized.

Further, it should also be noted that the present invention additionally contemplates a protective diving suit 30 which excludes the use of an automatic internal pressure regulating accessory. As more particularly explained in my copending application Serial No. 335,251 filed January 3, 1964, for Underwater Capsule, it appears desirable to provide a device or apparatus which enables men to live 35 and work on the floor of the ocean at extreme depths for an extended period of time. For this reason, I have described in the above-referred to copending application both a diving cylinder to transport and sustain one or more human operators, as well as an inflatable under- 40 among those made apparent from the preceding descripwater house.

The divers occupying either the cylinder or underwater house or the immediate vicinity thereof would, in general, be provided with my novel protective suit as hereinbefore described. Additionally, however, the diver can descend 45 in the cylinder or the inflatable house and thereafter open up the valves on the suit and allow the pressure to equalize to that maintained in the submerged cylinder or dwelling. The diver can then, of course, exit from the dwelling with the same pressure in the suit as that of the dwelling as well as ascending or descending a reasonable distance without the suit changing appreciably in size. It should be understood, however, that if the diver descends from the surface with the vents of the suit closed, the suit would naturally be compressed and collapsed as would  $_{55}$ the conventional suits of the prior art, yet upon entering the submerged cylinder or underwater house, and the suit valves then opened, the now equalized pressure is effective to restore the suit to its normal size and shape, thereby providing the necessary heat insulating qualities to the 60 diver.

Referring now to the drawings, FIG. 3 illustrates a section of this preferred embodiment of the invention. As there shown a separate gas source 54 is secured to the lower surface of tank 22. Pressure regulated gas 65 from source 54 is then delivered by flexible tubing 60 to and within suit 10 as before with the exception that in FIG. 3 the gas is supplied to the central portion of the suit in order to reduce the pressure gradient. It is important to note that source 54 is required to contain a 70 minimum volume of gas, since during submerged operation the gas is employed merely to provide pressure to foam rubber layer 40 and is neither lost nor dissipated. Additionally, in order to obtain the maximum amount of insulation possible, it is preferred that the gas employed 75 material, both of the layers and said soft pliant material

exhibit a low value of thermal conductivity, k. Helium has a k value of  $0.344 \times 10^{-3}$ , and when the suit is inflated by the breathing mixture, sufficient insulation is obtained even at depths of 400 feet. However, gases such as carbon dioxide and nitrogen have k values of  $0.0340 \times 10^{-3}$ and  $0.0566 \times 10^{-3}$ , respectively, and to improve the suit insulating qualities, it is preferable to employ such gases when separate source 54 is used.

It is additionally contemplated by the invention to provide an alarm indication when the suit fabric is torn or ripped while submerged. As stated above, normally little or no gas is delivered by source 54 while the diver is submerged. However, should the suit be torn by coral or other submerged objects so that one or more of channels 46 is connected to the water, an increase in the flow rate of the gas from source 54 is obtained. The gas from source 54 is not exhausted immediately because of the relatively narrow diameter of each of channels 46, yet the flow rate increase can be employed to provide the diver with a warning, such as a vibration, visible signal, or the like, to return to shallow depths, since the heat insulating qualities of the suit at the depth of 400 feet is being lost.

What has been described is an improved wet diving suit which, while maintaining all the advantages of the prior art, is also effective for extended time periods at depths greater than heretofore possible. In summary, a novel combination of features have been illustrated which prevent the collapse of a foam rubber diving suit without materially increasing the net buoyancy of the diver. These features result from providing pressurized support only for the foam rubber itself rather than throughout a large volume, in order that the overall suit is relatively unaffected by the surrounding water pressure. The suits of the present invention, while exhibiting general utility in the diving art, are particularly adapted for use with my copending invention Serial No. 335,251, filed January 3, 1964, for Underwater Capsule.

It will thus be seen that the objects set forth above, tion, are efficiently attained, and since certain changes may be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A protective suit for allowing the wearer thereof to operate in water wherein the surrounding water pres-50 sure is above atmospheric comprising,

- (a) a first smooth flexible layer, an outer surface of which is in contact with the wearer;
- (b) a second smooth flexible water impermeable layer completely surrounding and spaced apart from said first smooth flexible layer, an outer surface of which is in contact with the water;
- (c) the space between said first and second layers being substantially occupied by a soft rubber-like pliant material including a plurality of interconnected channels therethrough arranged to form a closed gas circuit between said first and second smooth flexible lavers:
- (d) means for supplying gas to all of said interconnected channels, and
- (e) means for maintaining said gas within said interconnected channels at a pressure substantially equal to said surrounding water pressure.
- 2. The suit of claim 1 wherein said first and second smooth flexible supporting layers are neoprene.

3. The suit of claim 1 in which an inner surface of the first flexible layer is bonded to one side of the soft pliant material and an inner surface of the second flexible layer is bonded to another side of said soft pliant

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in combination being shaped to fit and adhere to the body of a wearer as tightly and perfectly as possible.

4. The suit of claim 1 in which the gas supply means to said interconnected channels provides breathing gas and means are provided for passing a portion of such Б breathing gas to the wearer's face in parallel flow relation to the gas supplied to said interconnected channels.

5. The suit of claim 1 including breathing gas supply means separate from said means for supplying gas to said interconnected channels, and conduit means for 10 passing such breathing gas to the wearer's face.6. The suit of claim 5 wherein said gas supplied to

said interconnected channels is carbon dioxide.

7. The suit of claim 5 wherein said gas supplied to said interconnected channels is nitrogen.

8. The suit of claim 1 in which the soft pliant material is foam rubber.

9. In an improved wet diving suit including a layer of foam rubber bonded between inner and outer layers of neoprene and adapted to maintain the wearer within a 20waterproof environment and further including a pressure regulated source of breathing gas mixture, the improve-

ment consisting of said foam rubber exhibiting a plurality of interconnecting paths arranged to form a closed gas circuit between the inner and outer neoprene layers rather than a plurality of entrapped gas bubbles and means coupling a portion of the pressure regulated breathing gas mixture to said plurality of interconnecting paths whereby the thickness of said diving suit is adjustable by the quantity of gas in the interconnecting paths and relatively independent of the applied external water pressure without a corresponding increase in the net buoyancy of said suit.

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