United States Patent [19]

Marcus

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[54] **DIVING SUIT HEATER**

[75] Inventor: **Douglas Larry Marcus,** Baltimore, Md.

[73] Assignee: **Joseph M. Schwartz,** Lutherville, Md. ; a part interest

[22] Filed: **Dec. 12, 1972**

[21] Appl. No.: **314,373**

[52] **U.S. Cl.** **126/204,** 61/70, 62/5, 128/142.7

[51] **Int. Cl.** **F25b 9/02**

[58] **Field of Search** ..... 2/2.1 R, 2.1 A; 62/5; 126/204; 128/142.2, 142.7 X; 61/70 X, 71

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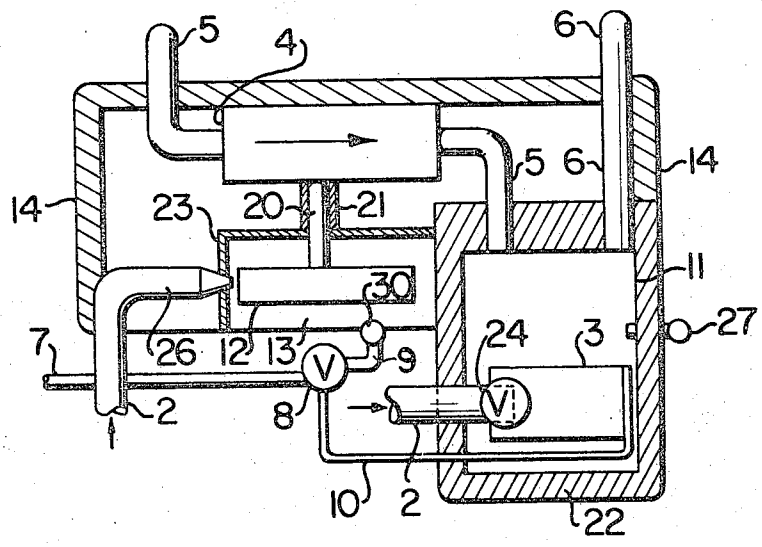
Primary Examiner—William F. O'Dea
Assistant Examiner—Peter D. Ferguson
Attorney, Agent, or Firm—Abraham A. Saffitz

[57] **ABSTRACT**

A self-contained, portable heating system to be used by a diver which consists of an aerothermodynamic heat source commonly known in the art as the Vortex tube used for heating the compressed breathing gas, a heat exchanger to heat a circulating fluid and exchange heat with the breathing gas, and a pump which is driven by the compressed breathing gas to circulate the heated fluid through an insulated, channeled diving suit or underdress.

5 Claims, 10 Drawing Figures



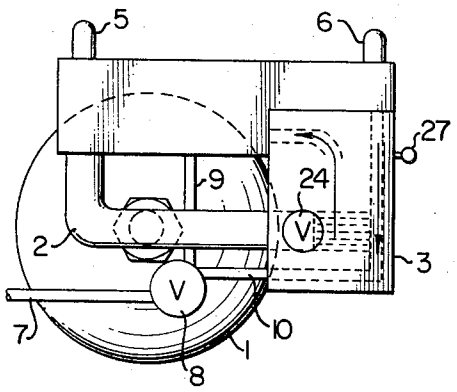


FIG. 1

FIG. 1A

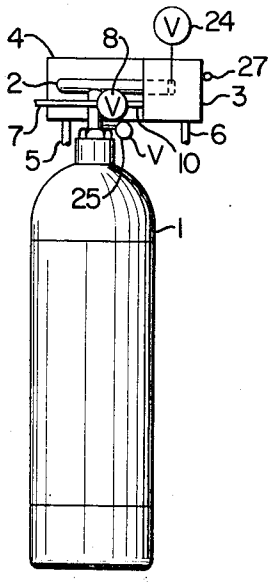


FIG. 1B

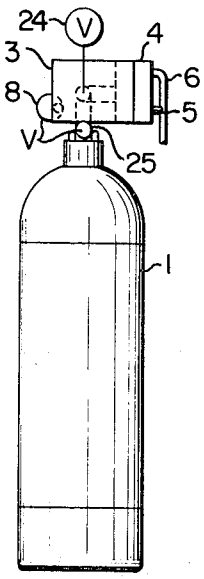


FIG. 2

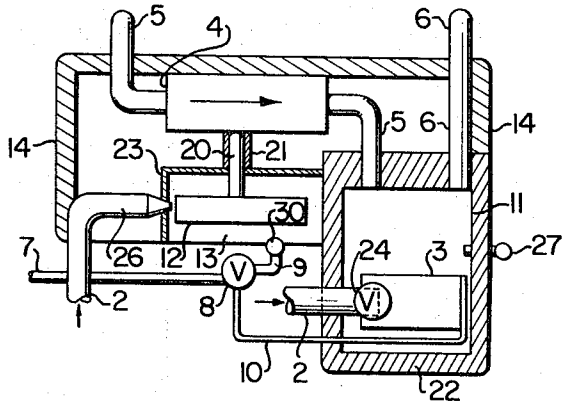


FIG. 2A

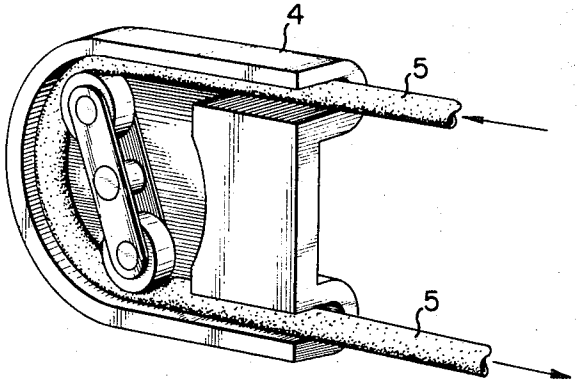
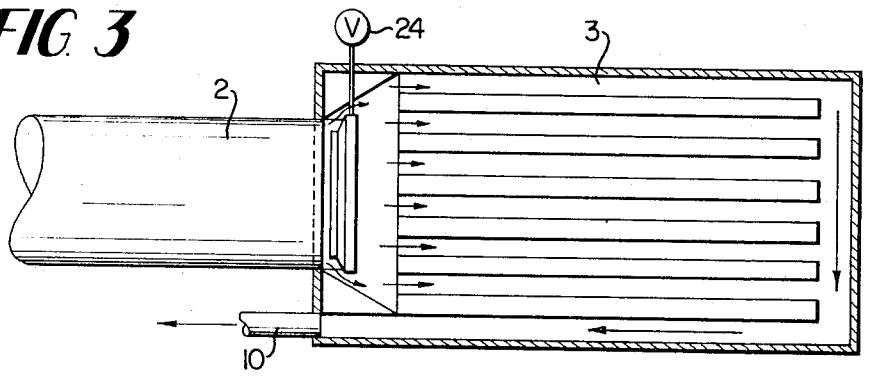


FIG. 3



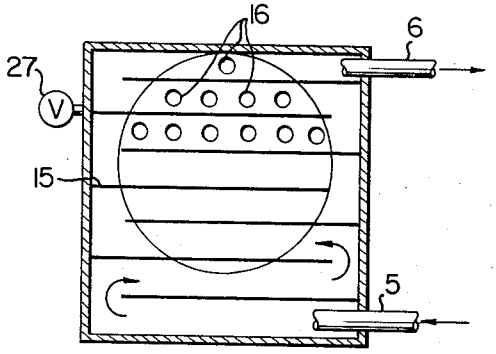


FIG. 3A

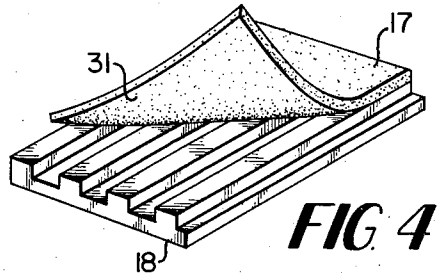


FIG. 4

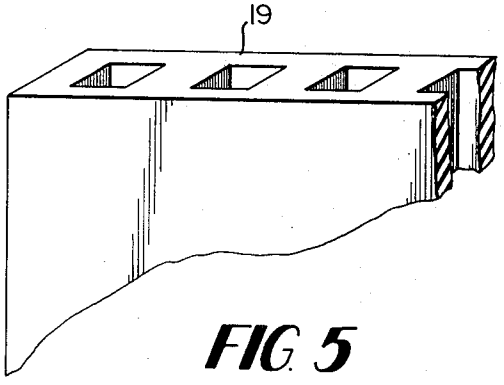


FIG. 5

FIG. 6

DIVING SUIT HEATER

BACKGROUND OF THE INVENTION

The present invention is based upon the discovery of Georges Ranque of France (U.S. Pat. No. 1,952,281, December, 1931) concerned with a method for automatically obtaining from a compressible fluid (gas or vapor) under pressure, a current of hot fluid and a current of cold fluid and the transformation of the initial fluid into two currents of different temperatures taking place without the help of any movable mechanical organ, but merely through the work of the molecules of fluid upon one another.

A fact as old as diving itself and becoming increasingly important as divers go deeper for longer periods, is that heat must be provided for the diver. The object of any dive is to achieve useful work — and a diver will achieve useful work safely and efficiently — if he is warm and comfortable.

Steps taken toward providing diver comfort have included the use of a wet suit, generally made of foamed neoprene as insulation, and the development of a water tight multiple clothing layered dry suit for colder temperatures. Due to heat losses encountered with the two different types of suits, it has become evident that a heat replacement system is necessary for deep or prolonged dives. At present, no suit alone is capable of keeping a diver in proper heat balance (77° F skin temperature) for very long periods of time. This heat must be provided from an external source.

SUMMARY

The ideal method of keeping a diver warm would be a self-contained heating unit. The requirements for this type of equipment are quite stringent as free swimmers are limited by the size and weight of the heat source. Also, positive and accurate control of the temperature provided is necessary, and the system must be failsafe to insure that the diver cannot be burned. One most important item, overlooked in prior art is that the entire system must be simply constructed so as to appeal to manufacturers for its economic production requirements as well as to users for its low cost and low maintenance.

Many methods have been tried including isotope, electrical and chemical heat sources; all with the distinct disadvantages of high cost or excessive weight. Through experimentation in heater systems, the capillary suit or tubulated wet suit has evolved as a spinoff of the liquid loop undersuit developed for Apollo astronauts. The basic idea is simply to heat a fluid (liquid or gas) and move it through tubes impregnated in the neoprene wet suit, transmitting heat to the diver.

The present source for hot and cold air streams is compressed gas at ambient temperature and is used in the tube as described in the U.S. Pat. No. 1,952,281 to Ranque. This same source is present on a diver in the form of a tank of compressed breathing gas. Because this cylinder is filled with very high pressure gas (up to 2,400 pounds per square inch), it is necessary that the pressure be reduced to ambient for the diver's use. This is accomplished by a regulator which is essentially an air valve whereby the motion of a diaphragm against a spring-lever system imposes work upon the high pressure air reducing it to a breathable pressure. The work done by the regulator to reduce air pressure is, however, lost during the conventional throttling process. By replacing the regulator with Vortex tube and air powered circulating pump, the gas cylinder could then be used to provide a heat source, a driving force for the circulation of a heated fluid (liquid or gas), and with this work extracted from the gas breatheable air could be obtained as before.

A liquid heat exchange fluid is desirable when helium-oxygen mixtures are used. Helium readily diffuses into the pores of many types of suit materials, sometimes causing rupture of the material during rapid decompression when the helium cannot diffuse out of the pores. It is feasible to use the hot gas directly (without a pump or heat-exchanger) when air is used for the breathing mixture. The warm air would be discharged from the Vortex tube at a pressure higher than ambivnt. This higher pressure would keep the circulating passages inflated providing ample passage for flow just as in the case of a fluid.

The hot gas can now be passed through a fluid-filled heat exchanger (water, seawater, ethylene glycol, etc.). The heated fluid, can then be moved by an gas-driven pump through a channelled diving suit of material shown in FIG. 5. A prime consideration besides heat input is heat retention since a working diver can dissipate in excess of 600 BTU's per hour. FIG. 4 shows laminated suit material with the features of heat insulation/reflection and simplicity in fabrication. The gas exhausted after driving the pump (supplied from the cold side of the Vortex tube) can be mixed with the heat exchanger exhaust (hot side of the Vortex tube) at a collecting valve and therefrom sent on to the diver to breathe as if a standard regulator had been used. This valve can act as a simple regulator to check the pressure of the air to be breathed. As already noted, the pump and heat exchanger may be omitted, if air is to be used as the breathing gas.

The priority for supplying heat (direction of flow of the heated fluid) is based on those areas of the body which lose heat most rapidly. The appendages required greater insulation and heat input because of decreased body mass, hence, less blood flow. The hands, feet, arms and legs require special attention in the order of heating for that reason. The upper torso (neck and shoulder area) can be heated afterwards. The fatty areas of the body retain heat the longest as well as dissipate the majority of the body heat (although at a slower rate than the rest of the body). Because of this heat retention capability, the lower torso can be heated with lower temperature heat input. That is to say, as the heated fluid within the suit passes over the body areas previously indicated heat is transferred, cooling the fluid somewhat and it is this lower temperature heat input that provides comfort to the rest of the body.

As previously mentioned, the laminated, internally heat reflective suit can be employed to improve retention of body heat. This suit can be made of 'channeled' layer of neoprene, FIG. 4, and covered with a layer of neoprene coated with any thermally reflective insulation. In the interest of economy, for manufacturing this suit for consumers who already own a diving suit, an under-suit can be substituted for the aforementioned channeled suit. This under-suit is simply a tubulated vest, gloves and booties to be worn underneath a standard diving suit. It is generally agreed upon, in the art, that 200 Kcal/hr. are required to maintain a diver's skin temperature at 77° F. With this as a basis, the potential work of a standard diver's cylinder (71.2 cubic feet)

has been found to be approximately 350 watts when utilized over a 1 hour time period. To maintain the 77° F. environment, 132.9 watts are required. It thus appears that more than twice the energy requirements are available. Also, with an improvement in the insulating characteristics of the diving suit, the heat retention will reduce the required amount of heat input. Adequate heat can be supplied as long as the air holds out.

If the life support systems are on the surface and connected to the diver through air lines as is the case with some prolonged dives (to avoid carrying several air cylinders) the portable suit can still be used by feeding off of the air line. As before, this system works as long as compressed gas is available.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a top plan view of a preferred embodiment of diving suit heater in accordance with the invention.

FIG. 1A is a front elevational view of FIG. 1.

FIG. 1B is a side elevational view of FIG. 1.

FIG. 2 is a schematic view of the aerothermodynamic heating unit of FIG. 1 and as disclosed herein.

FIG. 2A is a schematic view of the preferred embodiment of air driven pump which is shown as a detail of FIG. 2.

FIG. 3 is a detail of the heat exchanger which is a detail of FIG. 2.

FIG. 3A is a side view of the interior of FIG. 3.

FIG. 4 is a perspective detail showing the thermally reflective/insulating material in the diving suit of FIG. 6, where fluid circulation is provided in accordance with the invention.

FIG. 5 is a detailed perspective view of the channeled diving suit material used in the suit of FIG. 1.

FIG. 6 is a front perspective view of the diving suit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIGS. 1, 1A, 1B, 2 and 2B schematically illustrate the embodiment of the complete diver heater. This system is designed to be worn atop the divers tank (gas cylinder) 1, and sit behind the diver's head, out of the way. The Vortex tube 2 takes compressed gas continually from the diver's tank 1 through a flow control valve 25. Gas flow is divided in the Vortex tube into cold and hot streams whose temperature is regulated by flow control valve 24. The hot stream of gas, still under pressure passes through heat transfer tubes 16 in the heat exchanger 3, FIG. 3. The friction of this high velocity, high temperature gas causes both the end of the Vortex tube 2 and the heat transfer tubes to become very hot (controlled to in excess of 400° F.), transferring heat to the fluid located in the heat exchanger 3. The gas is exhausted from the heat exchanger through exhaust tube 10 and then enters the mixing (collecting) valve 8. The cold stream of gas, still under pressure, passes through pumping chamber 14, FIG. 2, and enters the watertight turbine chamber 13 where the high velocity gas exhausts through a nozzle 26 and impinges on the blades of the rotor (turbine) 12 causing it to rotate. The torque created by the turbine rotation is transmitted to the pump 4 by drive shaft 20 supported on bearing surface 21. The pump then circulates fluid (the pump could be any suitable pump known to the art, but the preferred embodiment is shown in FIG. 2A) through tubes 5 and 6. The cold fluid is carried by tube 5 from the divers suit through the pump 4 and the heat exchanger FIG. 3, where the fluid passes around the heat transfer tubes 16 and is direced by baffles 15 to insure good mixing action and proper heat transfer. The hot fluid exits the heat exchanger through tube 6, to the diver's suit. This process of heat transfer continuously takes place while air is available.

After creating the aforementioned torque on the turbine 12 the cold stream of gas is exhausted from the turbine chamber 13 through check valve 30 and exhaust tube 9 and then enters the mixing valve 8. The mixing valve 8 accepts the two streams of air, originally separated by the Vortex tube, and combines them once again to create a lower (than tank pressure) gas source for breathing due to the work extracted from the gas by the Vortex tube, heat exchanger and pump. Valve 8 acts as a simple regulator to maintain required breathing pressure and volume. The flow control valve 25, FIG. 1, reduces air losses by allowing the required gas to enter the Vortex tube at the proper flow rate so as to minimize waste at valve 8 which would exhaust any excess air. Breathing gas, on demand, is taken by the diver from valve 8 through tube 7 which connects to a standard diver's mouthpiece (similar to one on a single-hose type regulator) known in the art.

Virtually any type of gas driven pump can be used to circulate the heated fluid through the divers suit. Only one of the preferred embodiments is shown here, that of the 'dry pump' in FIG. 2A, which moves the fluid along by compressing flexible tubing containing fluid with rotating rollers. Relief valve 27 is used to fill and empty the heat exchanger before and after use of any fluid to be used as a heat transfer medium. It is most convenient to use available water so that upon submersion the relief valve will allow water to fill the system and vent any air in the heat exchanger. Other fluids could be used such as ethylene glycol which is a good heat transfer agent. All encasements 14, 22 and 23, FIG. 2, are soundproof and water tight to reduce any disturbances underwater and eliminate any corrosion of working parts. The outer covering can be of any material that is water-resistant but it is recommended that a thermoplastic be used for strength, lightness and color versatility in addition to the aforementioned requirements of noise insulation and corrosion resistance. For systems using air as the breathing gas, the hot air is sent directly from the Vortex tube discharge to the suit. Air exhausted from the suit can be mixed with the cold Vortex tube discharge and used as breathing gas.

The diving suit, FIG. 6, is novel in that it takes the state of the art wet suit and the tubulated diving (see Carter U.S. Pat. No. 3,367,319) suit and combines them into a channeled diving suit made of the material shown in FIG. 4. The suit is laminated which would add only minimal expense in that layer 18, FIG. 4, is supply extruded as usual only with the extrusion die in the shape necessary to give 18 the multi-channel character. Layer 18 is to be made of neoprene or any other diving suit material recognized in the art. Layer 17 can be made of standard neoprene or a better insulating material that reduces the diver's radiant heat loss. Any water resistant, flexible, light-weight material can be used for this outer layer with a built in reflective layer 31 sprayed on or laminated metallic foil to 17 for radiant heat reduction.

This suit must be made of material in the configuration shown not only to allow the circulation of heated fluid for extra heat input but most importantly for body heat retention for, even without the heating unit, this suit should prove to be a better heat retainer than is available at present. With the channels filled with air regulated to ambient pressure (even if not circulating) the air-filled pockets would provide excellent insulation. Also, the air-pressurized channels would reduce the usual compression of the suit material which presently reduces the effective insulation thickness as the ambient pressure increases. The construction of this suit is no different than any other except for this specially designed material. No details are to be added here as to the specific design including the location of manifolds, flow patterns, etc. as these are known to the art and would not be changed except for the material shown in FIG. **4.** When the two layers of the suit are bonded (adhesive, sewn, etc.), the ideal "flow through" material **19** is obtained FIG. **5.**

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

1. A portable heating system for attachment to a pressurized oxygen containing gas source used for breathing in combination with a protective diving garment of the wet suit variety and adapted to supply a heated fluid through tube means in said protective dividing garment in order to warm the same, comprising:

connection means adapted for connecting to said oxygen containing breathing gas source;

a vortex tube connected to said connecting means to heat the breathing gas;

a heat exchanger;

said vortex tube having a first outlet means to said heat exchanger and a second outlet means; said heat exchanger having an inlet fed with hot gas from said first outlet means of said vortex tube and having an exhaust tube which carries the gas after heat exchange in the exchanger to mixing valve means serving to regulate the gas pressure for breathing purposes;

a gas driven turbine fed by cold gas from said second outlet means of said vortex tube in combination with pump means driven by said turbine to circulate heat transfer fluid through said heat exchanger;

a heat transfer fluid in said heat exchanger selected from the group consisting of fresh water, sea water and ethylene glycol;

valve means to control air flow and venting from said pressurized oxygen containing breathing gas source;

tube means in the diver's suit which are connected to the heat exchanger to carry said heat transfer fluid for heating the diver;

said mixing valve means being fed by the exhaust gas from the turbine and the exhaust gas from the heat exchanger to regulate gas pressure for breathing purposes; and,

insulated water tight chambers to protect the turbine-pump combination and seal the heat exchanger.

2. The combination as set forth in claim **1** including a pressurized oxygen containing gas source.

3. A combination as set forth in claim **1** in which the tube means in the protective diving garment are of the wet suit variety and comprise a relfective metal layer for radiant heat loss reduction.

4. A combination as set forth in claim **1** in which said tube means are provided with insulation to minimize heat loss.

5. The combination as set forth in claim **1** in which said heat exchanger is provided with insulation to avoid heat loss from the environment.

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