Dec. 13, 1966 R. R. MESSICK 3,291,126

AIR COOLING UNIT FOR PROTECTIVE CLOTHING AND THE LIKE

Filed July 2, 1963 2 Sheets-Sheet 1

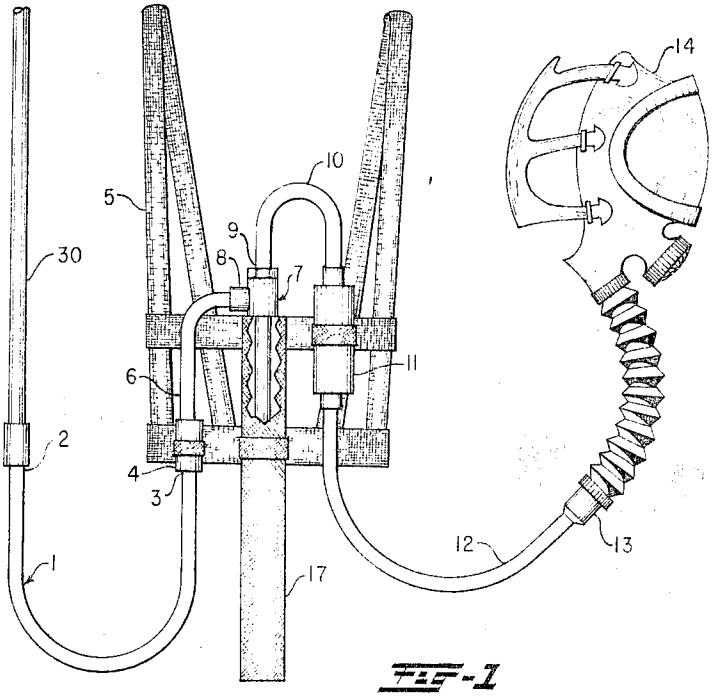


FIG-1

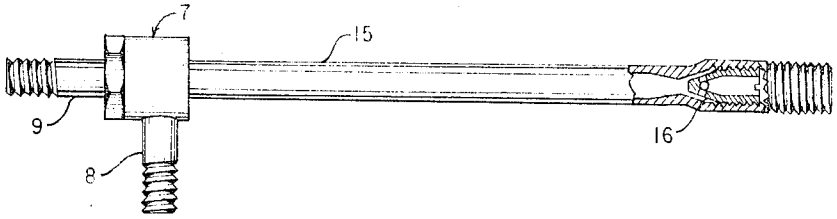


FIG-5

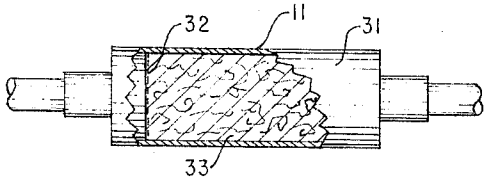


FIG-4



FIG-3

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Filed July 2, 1963 2 Sheets-Sheet 2

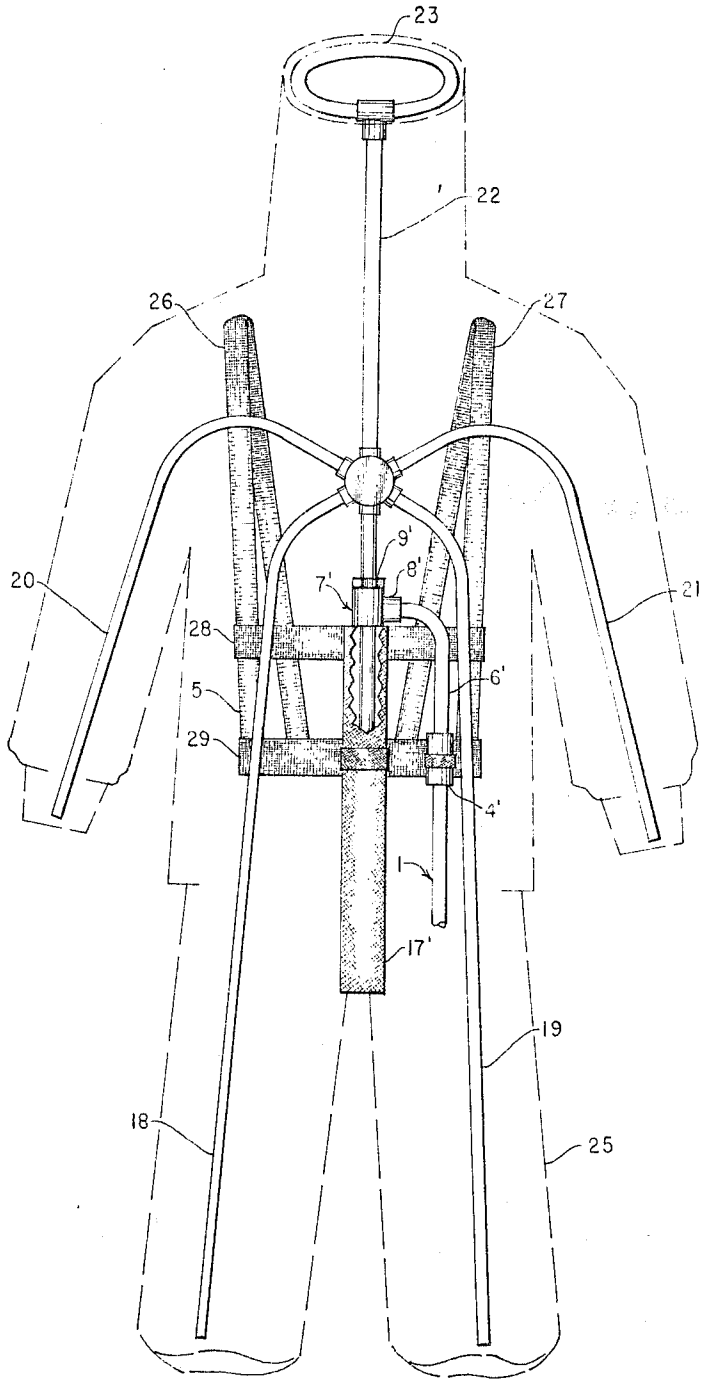


FIG-2

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3,291,126

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3,291,126

AIR COOLING UNIT FOR PROTECTIVE CLOTHING AND THE LIKE

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7 Claims. (Cl. 128—142.4)

This invention is related generally to fluid cooling systems such as air refrigeration units. More particularly it relates to a device for cooling gas supplied to cooling and breathing systems which are used in conjunction with protective clothing such as breathing air face masks, and ventilated suits.

In many industries, particulary in the chemical, atomic, and metal-working fields, it is frequently necessary for personnel to carry out manual operations in areas where the atmosphere is at high temperatures and may contain toxic or poisonous gases and vapors, or may be contaminated with radioactivity, or subject to heavy dust conditions. Persons engaged in this kind of work are required to wear some type of protective clothing or equipment and usually must be supplied with a source of pure air suitable for breathing. The protective clothing and equipment required is dependent upon the particular hazards and ambient conditions, and may comprise a breathing air face mask, a non-porous hood to protect the head, or an overall non-porous jacket to cover the upper portion of the body. This equipment is usually associated with other protective clothing of one or more layers such as heavy cotton duct coveralls that will increase the discomfort of working in high temperature areas. In some cases of poisonous gas or vapor atmosphere, or one of dangerous radoactive dust particles, as in the atomic energy industry, a complete impervious suit covering the entire body is required. Such a suit will require that air be supplied for maintaining suitable ventilation as well as for breathing.

This protective equipment and clothing is often necessary for operations such as spray painting, sandblasting, handling of acids, and other dangerous chemicals, gases, or vapors, or working in radiochemical separations or reactor plants, welding, and for use in high temperature areas in steel, aluminum and other metal processing and fabrication plants. There are many instances in these fields where men must work in contaminated atmospheres, atmospheres lacking sufficient oxygen, and/or temperatures of 100° F. or greater. In these cases, a man in a non-porous suit or heavy protective clothing may become so overheated in a short period of time (frequently less than 30 minutes) that the progress of the operation must be interrupted to allow the man to withdraw to normal atmospheric conditions for his health and safety. This limited use of manpower results in much expense to industry. The provision of an adequate method and means of supplying breathing air for breathing and cooling to a man working under such adverse conditions to assure maximum productivity and morale has been an industrial problem of long standing. Apparatus and methods heretofore known have not adequately solved this problem.

To provide men with breathing air through flexible hoes of various lengths (15'–150' is the normal range), supplied from conventional sources such as portable or

stationary air compressors and cooled by conventional refrigeration means, and distributed through piping or hose distribution systems is highly inefficient and ineffective because the air will be reheated by the atmosphere before it gets to the men. In locations where the temperature is 100° F. or greater, 10 feet of exposed hose carrying cooled air can increase the air temperature 30° F. before it reaches the user, and in lengths of approximately 60 feet, practically all of the original cooling will have been lost. Insulating the hose will be of some help, in runs not to exceed 50 feet, but this substantially increases the expense, by a factor of about 10, and makes the hose much more cumbersome for the worker. Use of liquid air back packs is employed in some instances, however the handling of liquid air is expensive, difficult and dangerous, and these units are relatively high in cost, approximately $1,000 per man. In some cases industry currently uses such crude devices as barrels of ice water with immersed air coils, which can be located near a job, in an effort to provide cooled breathing air.

As devices for cooling a sufficient volume of compressed air for industrial breathing air purposes are not readily available on the commercial market, custom portable units have been fabricated that will cool 4 to 6 men. But these are relatively expensive, costing about $4,000 to $5,000 a unit. Such equipment, however, has very limited use and offers little improvement over the stationary distribution systems previously referred to. Whereas such a unit is portable, because of its weight, which is usually about 700 pounds, it frequently cannot be located close to a job and air hoses from the unit to the users are subject to the usual transfer of heat to the cooled air. Locating the units close to a job to reduce the heat pickup presents the problem of limited use or short life, or of ultimate total loss of the expensive unit due to corrosive chemicals and vapors, or from radioactive contamination.

Accordingly, it is an object of the instant invention to provide a means for supplying cooling and breathing air, or gases, to be supplied to persons working in toxic, poisonous, dusty, high temperature, and/or radioactive atmospheres, which is safe, effective, light in weight, and small in size so as not to interfere with the activity of a working man even though he may be in tight, close locations and have to maneuver around, over, and through a maze of equipment.

It is a further object of the invention to provide such an air cooling means which can be attached directly to the body of a man as supplemental equipment to prevent loss of air cooling to the ambient surroundings and which can be utilized in conjunction with breathing air or gases supplied at moderate pressure.

It is a still further object of the invention to provide a device capable of cooling compressed breathing air that can be located close enough to the person using it to work effectively in high temperature areas and requires substantially no maintenance.

It is another object of the invention to provide such an apparatus which is simple in design, inexpensive to manufacture, is subject to minimum loss or damage due to use, and will effectuate maximum morale and productivity of persons using the invention.

The air cooling system in accordance with the present invention is comprised of a supply duct means, or flexible tube, which is adapted to be attached to a stationary air,

or gas, supply system under moderate pressures, a vortex tube the inlet end of which is connected to the flexible supply tube, a conduit or flexible tube for conveying the cold air from the cold outlet of the vortex tube to the breathing control apparatus such as a face mask, or for distributing the cold air to various positions within a ventilated suit, a muffler means connected to the cold air conduit, or integral therewith, for muffling the high-pitched noise produced by the vortex tube, and insulated duct means for exhausting the hot discharge from the vortex tube.

The device used to cool the compressed air for the breathing air cooling system of this invention is a vortex tube specially designed for this purpose. The vortex tube was patented by Georges Joseph Ranque in U.S. Patent No. 1,952,281, issued March 27, 1934. Many versions, shapes, sizes and capacities of this tube have been designed and produced over the years. It operates principally by receiving air of moderate pressure, forcing the air into a vortex or centrifugation at about one million r.p.m. with the astonishing phenomena that a cold air stream is ejected at one end of the vortex tube unit and a hot air stream is ejected at the other end. Vortex tubes for this invention have been designed and fabricated to weigh less than a wrist watch (1¾ ounces) and with a length of less than 10 inches. More rugged tubes have been produced for this invention which weigh approximately 8 ounces and are approximately 12½ inches in length. Small vortex tubes can be clipped on a belt like a fountain pen, whereas larger ones can be worn on waist belts, shoulder harnesses, shoulder slings, etc. Additional objects and advantages of this invention will become apparent from a reading of the following description when taken in conjunction with the accompanying drawing, in which:

FIG. 1 is a schematic illustration of the cooling system as used with a face mask;

FIG. 2 is a schematic illustration of the invention as used with a complete suit;

FIG. 3 is an enlarged view of the cold distribution tube;

FIG. 4 is a partially cut away elevation view of a muffler used in the invention; and

FIG. 5 is an elevation view of the vortex tube used in the invention.

Referring to FIG. 1, wherein the device of the invention is utilized in conjunction with a face mask, flexible feed line **1** is connected at one end **2** to a source of gas suitable for breathing which is piped to the room or area in which the device is to be used. The opposite end **3** of the flexible feed line is connected to a quick disconnect coupling **4** of a type which is well known in the fluid handling industry. The coupling **4** is preferably affixed to a harness **5** which is designed to be worn by a person using the invention and supported by means of shoulder straps. From the coupling **4** an additional segment **6** of the feed line extends to the vortex tube generally indicated at **7**, which is also fastened by some suitable means, such as a strap, to the harness. Line **6** is connected to the inlet **8** of the vortex tube and is securely clamped thereto by some suitable clamping or nipple device, for example, which is leakproof. The cold outlet **9** of the vortex tube is connected by a suitable conduit means **10** to the inlet of muffler **11**, the outlet of which is connected by a flexible conduit **12** to the inlet **13** of face mask **14**.

The hot end of the vortex tube opposite to the cold outlet is comprised of an elongated tubular extension **15** containing a needle valve **16** near its outer extremity, the function of which will be explained below. A suitable conduit is attached to the extreme end of the outlet assembly for conducting the hot gas to the exhaust position. The entire outlet portion of the vortex tube including the extension conduit is encased in thermal insulation **17** to prevent heat from being conducted to the worker.

In the use of this device, the gas feed line supplies a suitable source of breathing gas, such as air, at a predetermined pressure to the vortex tube. When the end **2** of feed line **1** is connected to this source of gas and the shut off valve, not shown, in the stationary line **30**, is open the gas line pressure is supplied through flexible feed line **1**, coupling **4**, and line **6** to the inlet **8** of the vortex tube. The hot discharge assembly of the vortex tube includes an elongated tube **15** (FIG. 5) which is integral with the vortex tube and contains at its outer end a needle valve **16**, the adjustment of which controls the temperature differential between the hot and cold discharge ends of the vortex tube. Accordingly, this valve may be used to control the temperature of the gas supplied to the user. Of course the vortex tube used in this invention must be designed of a particular size and style to produce the desired temperature of gas at the cold outlet which is obtainable from the feed line pressure and yet be compact and light in weight so as to be readily manipulable and easily carried by the wearer.

The vortex tube designed principally for the invention is made of stainless steel, has an overall length of about 12½ in., weighs about 7½ oz. and will operate at a wide range of pressures and air volumes. However, the optimum conditions are compressed air from 65 to 90 p.s.i. at a flow rate of about 20 to 25 c.f.m. with a distribution of 75% of the volume to the cold end and 25% to the hot end. This will produce a cold air stream having a temperature of from about 40 to 65° F. below that of the air supplied. For most industrial conditions this means supplying cold air to a breathing system of from about 30 to 75° F. and a hot air discharge of from about 160 to 250° F. This distribution of air between the hot and cold discharges as well as the temperature of these two streams is a direct function of needle valve **16** that controls the amount of air discharged from the hot end. The valve **16** is illustrated as being recessed in the hot exhaust end of the vortex tube, in which case it is designed to maintain a preset position. However, this valve may be mounted with an external knob to enable adjustment during use.

The gas at the desired temperature is conveyed from the cold outlet end of the vortex tube through a muffler **11** to the face mask. It is characteristic of vortex tubes to produce a high pitched noise which must be muffled to protect the health and safety of the wearer. It has been found that this noise is sufficiently offensive to cause the wearer to become ill in a short period of time. The invention provides a muffler **11** to overcome this objectionable characteristic of the vortex tube.

Without some muffling means the vortex tube will create noise levels of from 90 to 105 decibels (db). The maximum noise level that a person can safely endure for any appreciable time is 85 db. This level has been established by the American Academy of Ophthamology and Otolaryngology. Without muffling, the noise from the vortex tube will make the average person ill in less than two hours, the illness being manifested by headaches, ear ringing, and nausea. Also, it is impossible to carry on a conversation satisfactorily with or between those persons using such a device. The muffler **11** must be small in size and light in weight to be easily supported on the harness and yet must be efficient enough to reduce the objectionable vortex tube noise to a tolerable level.

A muffler design which has been found to be most feasible is shown in FIG. 4 and consists of a hollow cylindrical canister **31** made of soft plastic material having a perforated plastic screen **32** at each end and a porous mass of soft fibrous material **33**, such as cotton, wool, nylon, Orlon, or fiber glass, in the central portion between the screens. The muffler may have a length of from 2 to 4 inches and a diameter of 1 to 2 inches. The sound waves emanating from the vortex tube are damped by this muffler to the extent that the noise level is reduced to between about 70 to 78 db. With the mufflers

described above there is no limit on the hours a person may use this invention and conversation at normal levels is no problem. In some cases it may be desirable or necessary to provide a muffling means on the hot discharge end of the vortex tube.

FIGURE 2 illustrates the invention as used for supplying cooling and breathing air to a plastic suit which completely covers the wearer. In this embodiment feed line **1**, coupling **4**, feed line **6**, harness **5**, extension line **6**, and vortex tube assembly **7**, are the same as in the embodiment illustrated in FIG. 1. However, since the instant embodiment is used for cooling the interior of the suit as well as providing breathing air, an elaborate cold air distribution system is provided. Specifically, the cold air from outlet **9'** of the vortex tube is conveyed through distribution lines **18** and **19** to and through substantially the length of the leg portions of the suit. The cold air is also conveyed through the substantial length of the arm portions of the suit by distribution lines **20** and **21**. The cold air is conveyed to the head piece by extension line **22** which leads to distribution ring **23** at the upper portions of the head piece. The distribution lines to the leg and arm portion are closed at their remote ends such as by sealing for example. The desired distribution of the cold air is affected by providing outlets spaced lengthwise along these distribution tubes, such as narrow slots, or slits, **24** as illustrated in the enlarged view of the tubes in FIG. 3. The distribution tubes **18**, **19**, **20**, **21** and **23** are all provided with these outlet slots, or slits, **24** in a manner to provide optimum distribution of the cold air to maintain substantially uniform temperature within the suit.

The plastic suit **25** may be of some commercially available type such as a thin, inexpensive, disposable type widely used today in various industries and may be one or two piece. The extremities of the suit at the hand and feet section are generally sealed somewhat by elastic bands or the like which fit about the gloves and shoe covers also worn by the wearer to prevent the ingress of the ambient gas atmosphere in which the person is working. In most plastic suits these sealed sections will permit the egress of the gass within the suit which is supplied by the instant invention. If necessary however, the plastic suit can be provided with a suitable exhaust port such as a flap, to assume that the clean air from the supply system is always maintained within the suit and prevent the contaminated atmosphere from leaking into the suit. The distribution lines are made of a relative soft flexible plastic tube such as polyvinyl chloride, soft rubber, or neoprene, for example. The quality of these tubes in combination with the outlets **24** provide the sound muffling necessary to eliminate the objectionable high-pitched noise produced by the vortex tube. However, an additional muffler such as the type described above in connection with embodiment of FIGS. 1 and 5, may be provided if desired.

The outlet assembly from the hot end of the vortex tube is well insulated as at **17'** and the discharge end extends through the suit to facilitate external discharging of the hot gas.

The harness is made of some suitable fabric such as woven cotton or nylon, for example, and in the embodiments illustrated consists of shoulder straps **26**, **27** which have cross pieces **28**, **29** for supporting the couplings, vortex tube, muffler, and exhaust line in the manner illustrated.

Satisfactory operation of this vortex tube cooling unit has been accomplished with an air system supplying air at a pressure of about 85 p.s.i., a moisture content preferably not exceeding 15 grains per pound of dry air, and air that is free of oil, grease, and inclusions of any kind which would be harmful to the user if inhaled. In areas where the temperature exceeds 95° F. and active work is done, satisfactory cooling is affected by an air flow of 15 to 20 c.f.m., and a temperature at the cold end not exceeding 50° F. The use of high pressure air in the application of this invention has been found to be quite safe. For example in the case of a maximum creditable accident, where the feed line **1** might be disconnected and exhausts directly into the interior of the plastic suit without passing through the vortex tube (which reduces the pressure to a range of 9–15 p.s.i.) a line pressure of 85 p.s.i. has been found not to create the least hazard to the wearer when the total volume is controlled below 60 c.f.m. by the breathing air distribution system.

The plastic tubing used to supply gas to the vortex tube may be inexpensive, lightweight, flexible tubing, or hose (plastic), having an inside diameter of from about ⅜ to ½ inch capable of sustaining an internal pressure up to about 150 p.s.i.

Although two embodiments of the present invention have been illustrated and described, it will be apparent to those skilled in the art that various changes and modications may be made to the present disclosure without departing from the spirit of the invention. The invention is not intended to be limited to the embodiments described but should be limited only by the scope of the appended claims.

What is claimed is:

1. A device for cooling breathing air comprising a source of air under pressure, a vortex tube, conduit means for conducting the pressurized air to the inlet of said vortex tube, a face mask that completely seals the wearer's face from the atmosphere and includes an exhaust valve, conduit means for conducting air from the cold discharge end of the vortex tube to said face mask, muffler means connected between the vortex tube and the face mask to deaden the air noise produced by the vortex tube, means for insulating the hot discharge end of the vortex tube, means for strapping the vortex tube and muffler means to the body of a person wearing the face mask.

2. The device of claim **1** wherein the vortex tube is provided with a valve means in the hot discharge end to control the temperatures of the air at the cold and hot discharge ends.

3. A device for supplying cooling and breathing air to a person wearing a protective suit comprising, a suit of impervious material completely enveloping the wearer, a source of air under pressure, flexible conduit means for conducting said air under pressure, a vortex tube for cooling the air, means for coupling said conduit means to the inlet of said vortex tube, means for connecting the cold discharge end of the vortex tube to the suit, means for distributing air from the cold discharge end of the vortex tube to positions within the suit to provide adequate cooling and breathing air, means to muffle the air noise produced by the vortex tube, valve means in the hot discharge end of the vortex tube to control the cold and hot air, means to insulate the hot discharge end of the vortex tube, means for supporting said coupling, vortex tube, and muffler means on the body of the person and within the suit, said hot discharge end extending through the suit to the exterior thereof.

4. The device of claim **3** wherein said valve means is a throttle valve the adjustment of which controls the temperatures at the hot and cold discharge ends.

5. The device of claim **4** wherein said valve is disposed at the outer extremity of the hot discharge end of the vortex tube.

6. The device of claim **3** wherein said muffler means is connected between the cold end of the vortex tube and the suit and comprises a hollow cylindrical canister open at both ends, a screen over each opening, and a porous mass of material filling the canister between said screens.

7. The device of claim **3** wherein said cold air distributing means comprises flexible tubes made of soft plastic

material extending to the head portion and through the arm and leg portions of the suit, said tubes being provided with outlets spaced along their lengths.

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