Sept. 10, 1963 R. H. SHACKSON 3,103,104

PORTABLE GAS CONDITIONING APPARATUS

Filed Sept. 11, 1962 4 Sheets-Sheet 1

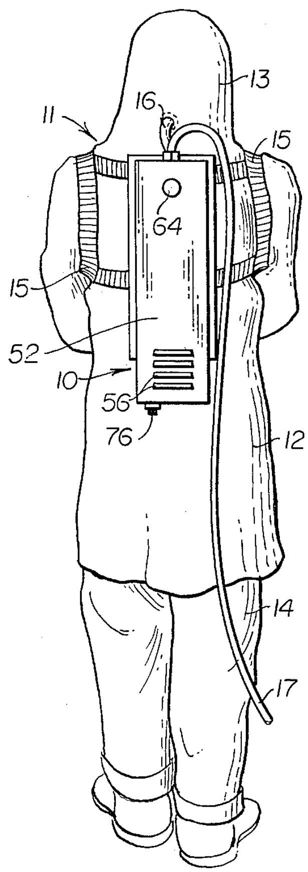

Fig. 1

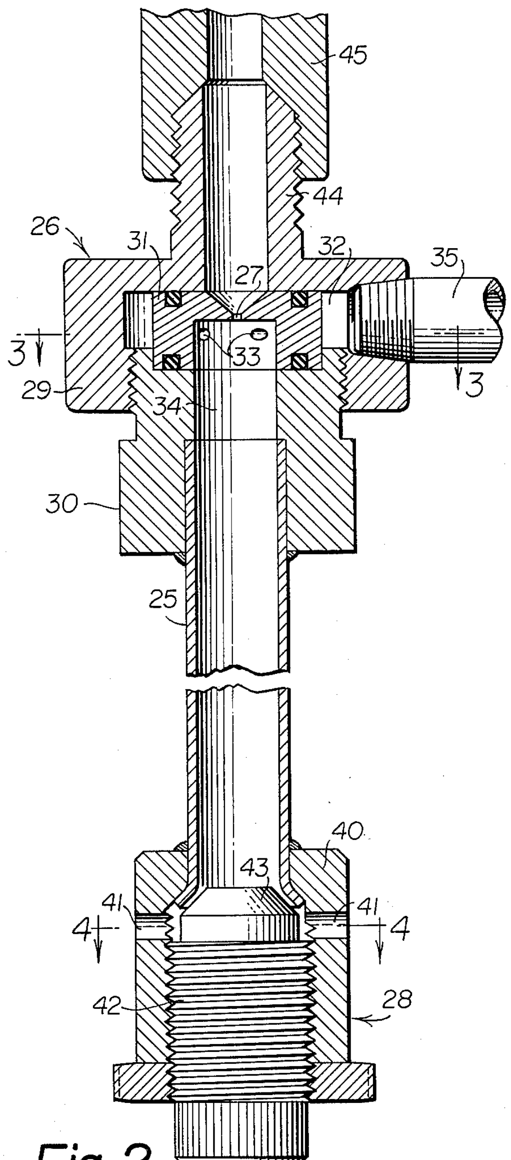

Fig. 2

INVENTOR.
RICHARD H. SHACKSON
BY Watts & Fisher, Attys.

PORTABLE GAS CONDITIONING APPARATUS

Filed Sept. 11, 1962 4 Sheets-Sheet 2

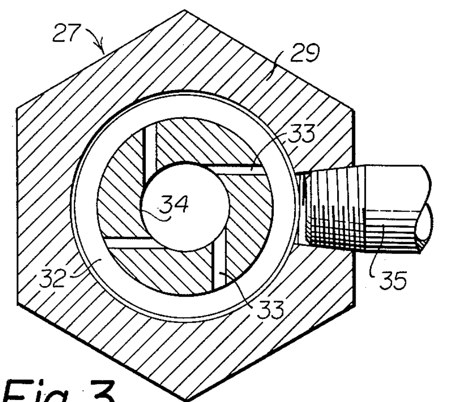

Fig. 3

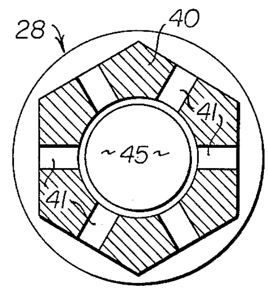

Fig. 4

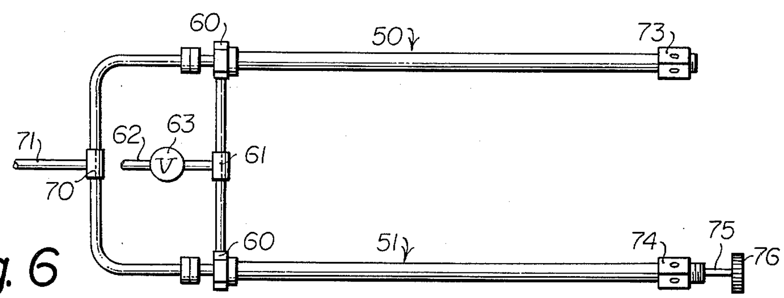

Fig. 6

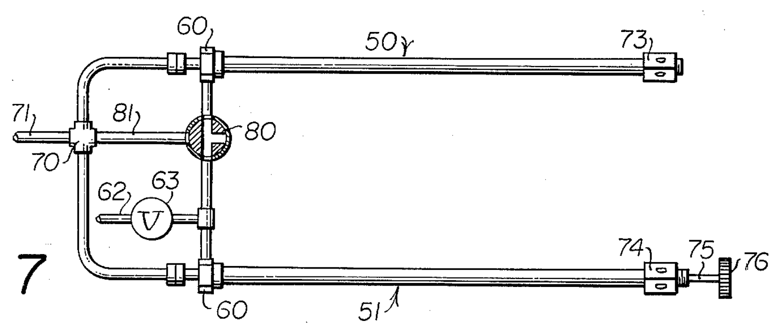

Fig. 7

INVENTOR.
RICHARD H. SHACKSON
BY Watts, & Fisher, Attys.

PORTABLE GAS CONDITIONING APPARATUS

Filed Sept. 11, 1962 4 Sheets-Sheet 3

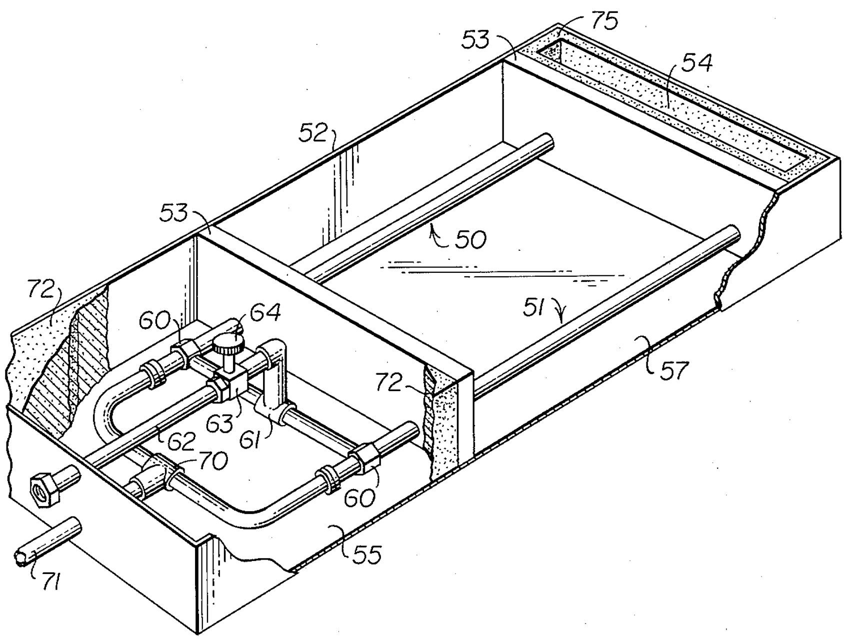

Fig. 5

INVENTOR.
RICHARD H. SHACKSON
BY Watts & Fisher, Attys.

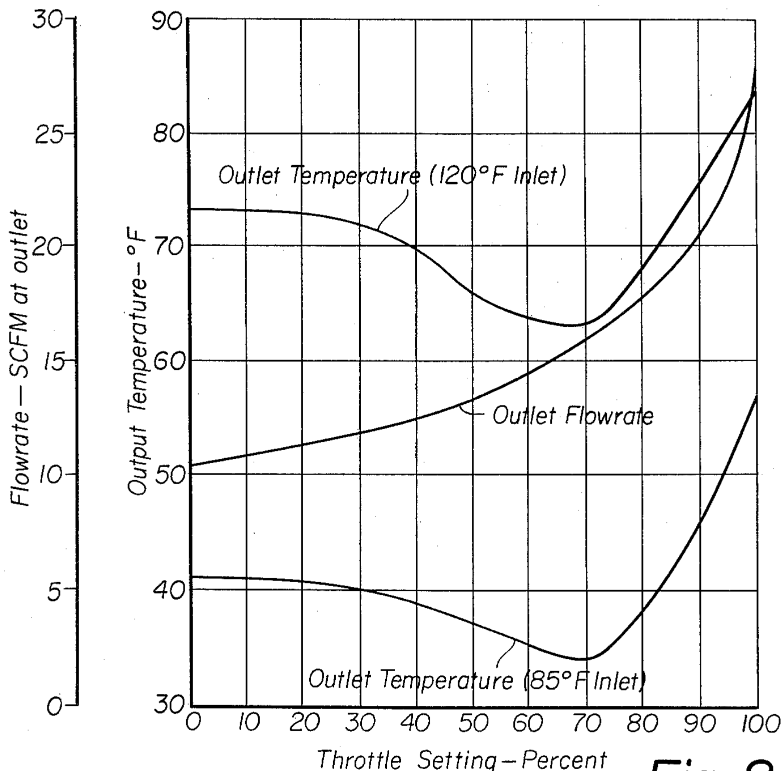

Fig. 8

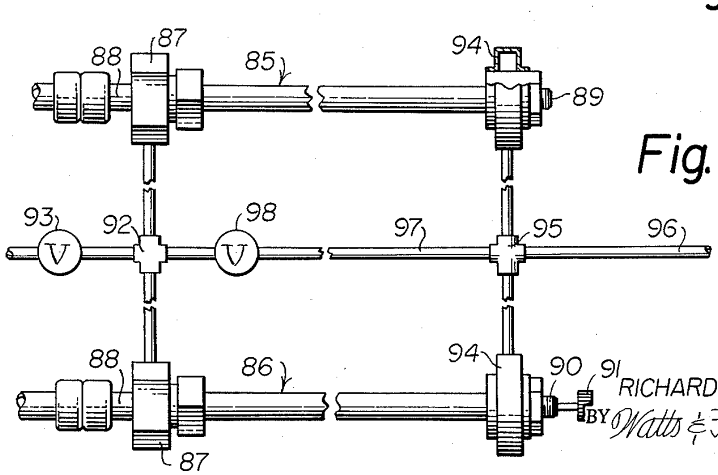

Fig. 9

INVENTOR.
RICHARD H. SHACKSON
BY Watts & Fisher, Attys.

United States Patent Office

3,103,104

Patented Sept. 10, 1963

1

3,103,104
PORTABLE GAS CONDITIONING APPARATUS

Richard H. Shackson, Hudson, Ohio, assignor to Cleveland Technical Center, Inc.

Filed Sept. 11, 1962, Ser. No. 222,857
15 Claims. (Cl. 62—5)

This invention relates generally to gas conditioning apparatus, and more specifically to a new and improved system for supplying a gas at controlled flow rates and regulated temperature conditions.

The invention is particularly concerned with providing a portable air cooling system capable of supplying cool air at controllable flow rates to the protective clothing worn by workers in various hazardous occupations. By way of example, the portable cooling apparatus comprising the invention is particularly adapted to be attached to the protective suits worn by workers in aluminum reduction operations, foundries, chemical plants, and other industries where protection is required against high temperatures, toxic and/or corrosive vapors, dust, or fine powders. The invention also satisfies the existing need for an effective system for supplying cool air to the helmets worn by sandblast personnel in the performance of their duties. In addition to these production applications, the novel and improved portable cooling apparatus can be used to advantage in cooling the emergency protective suits worn by fire-fighting personnel, miners, mine rescue workers, decontamination personnel, and the like.

A need for an effective portable cooling apparatus capable of being used in the manner described has existed in various industries for many years. Heretofore, it has been customary to supply air for cooling and breathing purposes from a centralized source, such as from an air compressor, through long hoses which trail after the worker and are connected to his suit or to a mask. Since the heat of compression and the high ambient temperatures often result in the supply air being in excess of 120° F., it has been necessary to resort to comparatively crude cooling devices, such as coils immersed in a tank of cold water or to air cycle turbines which are complex, noisy and expensive. Not only are some of these devices inefficient, but, because they are not portable, it has been required to locate the cooling devices near the air source rather than at the suit or other enclosure intended to be cooled. Such an arrangement also is inefficient, since the air passing through the long hoses can pick up heat from the surroundings before reaching the suit. Moreover, it has been difficult to maintain a desired flow rate because of the high friction losses which occur during the flow of air through the supply hoses.

While the portable gas conditioning apparatus of the invention has been described as being particularly suitable for use in cooling protective clothing, it will hereinafter become apparent that the novel apparatus can be used for other purposes. In addition to providing an effective cooling system, the apparatus also can be used for heating. Thus, the portable apparatus can be connected to clothing or other enclosures intended to be used as protection against cold ambient temperatures.

Accordingly, it is an object of the invention to provide a portable gas conditioning apparatus capable of supplying gas at controlled rates and regulated temperature conditions.

Another object of the invention is to provide a portable air cooling apparatus which may be attached to protective clothing such as worn in applications of the type described above.

A more specific object of the invention is to provide a portable gas conditioning apparatus adapted to be attached to a protective suit or the like and to be supplied by a central air source, whereby the gas from the source is

2

conditioned and exhausted into the suit in a manner which can be selectively regulated by the wearer.

A further object of the invention is to provide a portable gas conditioning apparatus which is capable of cooling or heating gas to obtain desired temperature conditions.

In accomplishing the foregoing objects and overcoming the disadvantages of the prior art, the invention contemplates a preferred system which utilizes a plurality of Ranque or Hilsch vortex tubes. Vortex tubes have been known for a number of years and the phenomena involved have been extensively discussed in the prior art literature. The device is the essence of simplicity and consists essentially of a straight piece of pipe including an air inlet for tangentially introducing air or other gas into the pipe and creating a high speed vortex flow, the vortex being characterized by an axially moving shell of relatively hot air and a core of relatively colder air. Because of this vortex phenomenon, two fractions of gas may be caused to issue from the pipe at temperatures which are above and below the temperature of the supply gas. For the purposes of illustration, one commercially acceptable embodiment of a vortex tube hereinafter will be discussed in detail.

When a plurality of vortex tubes are combined in the novel manner contemplated by the present invention, a gas conditioning apparatus is provided which is lightweight and thus can be conveniently attached to protective clothing or the like and carried by the wearer. Furthermore, the operating characteristics of the portable, vortex gas conditioning apparatus which is provided can be selectively regulated by the user even though the supply air is furnished from a central source which also may supply air to similar units, as well as to other types of apparatus. More particularly, it is possible for each user to regulate both the temperature and flow rate of the gas issuing from the gas conditioning apparatus to suit his particular working conditions. In the past, this individual control has not been possible.

Since vortex tubes do not involve any moving parts and are of a relatively simple construction, the gas conditioning apparatus of the invention is inexpensive and is substantially maintenance-free. Further, the disadvantages of the prior art systems described above in which the cooling devices are usually located at the source are avoided with the invention because of its portability.

Although, as noted above, vortex tubes have been known and used prior to the present invention, the principle of operation remains in dispute and has never been clearly understood. Because of the fact that no one can cogently explain why the tube operates in the manner that it does, it is not at all obvious how to improve the recognized inefficiency of the tube and how to adapt it to specific commercial uses. For each proposed application of a vortex tube, it is usually necessary to thoroughly investigate the operating conditions and requirements and then to construct new tube arrangements which will satisfy these operating conditions and requirements in the most optimum manner. For these reasons, commercial applications of the vortex tube principle have been limited. In the specifically disclosed applications of the present invention, it was found that a single vortex tube designed to operate efficiently from standard industrial compressed air systems did not possess the required characteristics for supplying cooled air to protective clothing. More particularly, it was found that, when the conventional vortex tube was adjusted to obtain a desired outlet flow rate of cooled air, the temperature of the cooled air usually was so low that the air could not be introduced comfortably into the clothing. For example, at desirable outlet flow rates, the temperature of the cooled gas could be 30° F. or lower. Conversely, it was found that, when a single vortex tube was adjusted to obtain cooled air at a usable temperature, the flow rate usually was either too low or too high. Further, since the temperature of the cooled air depends upon the temperature of the inlet air to the vortex tube, it was found that with relatively low inlet air temperatures the air furnished to the suit was too cold for comfort, regardless of how the tube was adjusted.

The present invention overcomes the foregoing problems by providing a novel arrangement of a plurality of vortex tubes, preferably two, which are uniquely combined and controlled to provide desired outlet temperatures and flow rates throughout a wide range of supply air temperatures. In this manner, a satisfactory suit temperature and flow of air to the suit can be maintained regardless of the supply air temperature.

Other objects and advantages of the invention will become apparent from the following detailed description and the accompanying drawings.

In the drawings:

FIGURE 1 is a view illustrating one specific application of the novel gas conditioning apparatus provided by the invention;

FIGURE 2 is a cross-sectional view of an illustrative vortex tube assembly;

FIGURE 3 is a cross-sectional view taken on the line **3—3** of FIG. 2;

FIGURE 4 is a cross-sectional view taken on the line **4—4** of FIG. 2;

FIGURE 5 is an isometric view, with portions broken away, of one embodiment of the invention;

FIGURE 6 is a view schematically illustrating the vortex tube arrangement embodied in the construction shown in FIG. 5;

FIGURE 7 is a view schematically illustrating a modified vortex tube arrangement;

FIGURE 8 is a graph showing the operating characteristics of the preferred embodiment of the gas conditioning apparatus; and,

FIGURE 9 is a view schematically illustrating still another modification of the vortex tube arrangement.

Referring now to the drawings, and to FIG. 1 in particular, there is shown a system embodying the gas conditioning apparatus **10** of the invention for supplying cooled air to a protective suit **11**. The suit **11** is shown as including a knee-length smock or cloak **12** and an integral hood or helmet **13**. The gas conditioning apparatus **10** is carried on the back of the wearer **14** by straps **15** and is operatively connected to the neck of the suit by a conduit **16**. A supply conduit **17** connects the unit **10** to a source of air under pressure (not shown) such as an air compressor. With this novel arrangement, it will be seen that the cooling unit **10** is conveniently carried by the wearer immediately adjacent the protective suit instead of being located at the source of air, as is customary in the prior art arrangements.

It is to be understood that the system shown in FIG. 1 is merely illustrative of one application to which the invention is particularly adapted, and that it is not limiting of the new and novel concepts herein set forth. Similarly, it is to be understood that the specifically illustrated suit **11** is only one form of protective clothing known in the industry, and that the invention can be used with equal advantage with other types of clothing.

Reference is next made to FIGS. 2, 3 and 4 which show a known type of vortex tube construction suitable for use in the gas conditioning apparatus provided by the present invention. The vortex assembly shown in these drawings includes a tube **25** having an air inlet assembly **26** at one end for introducing air into the tube and creating a high speed vortex characterized by an axially moving shell of relatively hot air and an inner core of relatively colder air. An axially disposed cold air outlet **27** is provided at the inlet end of the tube **25** for releasing the cold air fraction of the vortex and a throttle valve **28** is connected to the opposite end of the tube for releasing at least part of the hot air fraction.

The air inlet assembly **26** is shown to include a top cap structure **29** which is threaded to engage a tubular head member **30** that forms an integral part of the tube **25**. The tubular head **30** supports a jet body **31** within the top cap structure **29** so as to define an annular chamber **32**.

The jet body **31** has a plurality of jet passageway openings **33** which are formed to receive air from the annular chamber **32** and direct the air tangentially into the bore **34** of the tubular head **30**. Air is supplied to the chamber **32** by the flexible conduit **17** (FIG. 1). The conduit **17** either may be directly connected to the top cap structure **36** or it may be connected to a nipple **35** which is threaded through the wall of the cap. As shown, the jet body **31** also defines the cold air outlet **27** which is located upstream from the openings **33**.

The throttle valve assembly **28** may include a collar **40** that is rigidly connected to the end of the tube **25**. This collar **40** is formed with a plurality of outlet ports **41** and is internally threaded to receive an axially adjustable valve stem **42**. The valve stem **42** is provided with a head **43** which cooperates with the outwardly flanged end of the tube **25** to provide for the peripheral escape of hot air from the tube from the ports **41**.

In use, it will be understood that air under pressure is introduced into the chamber **32** through the supply conduit **7** and the nipple **35**. From the chamber **32**, the air tangentially enters the tubular head **30** and then the bore of the tube **25**. In this manner, a high speed vortex is created wherein a shell of continually moving, relatively hot air flows toward the throttle end of the tube, while a core of relatively colder air flows toward the outlet **27**. The cold air fraction may pass through the outlet **27** into a tubular extension **44** of the top cap structure **29**. A coupling **45** may be used to connect the conduit **16** (FIG. 1) to the tubular extension **44** so that the cold air may pass into the suit **11**.

The construtcion of the unit **10** is best shown by FIGS. 5 and 6. As shown in FIG. 5, the unit includes a pair of vortex tube assemblies **50** and **51** which may be of the type described above. These vortex tube assemblies are mounted within a light-weight housing **52** which is formed of a suitable material, such as aluminum or the like. The housing **52** is provided with longitudinally spaced partitions **53** which define hot and cold end areas **54** and **55**, respectively, within the housing. Vents **56** (FIG. 1) are provided in one wall of the housing **52** to permit the hot air from the area **54** to escape to the surrounding atmosphere.

Air is supplied to the inlet assembly **60** of the vortex tubes **50** and **51** by means of a manifold arrangement **61**. The manifold **61** includes a pipe **62** which extends through the end of the housing and to which supply conduit **17** may be connected. A shut-off valve **63** preferably is provided in connection with the pipe **62**. As shown, the operating handle **64** of the valve **63** extends through a wall of the housing so that the unit conveniently can be connected and disconnected from source at the will of the user.

The cooled air issuing from the cold ends of both vortex tubes is joined by means of an outlet manifold connection **70** which also includes a pipe **71** that extends through the end of the casing **52**. The actual connection of the unit **10** to the suit **11** may be formed in the illustrated manner by a relatively short length of flexible conduit **16** that is connected to the pipe **71**, or, alternatively, the manifold **70** may be connected directly to the suit.

According to the preferred construction, the cold end area **55** surrounding the vortex inlet assemblies **60** and the cold air manifold **70** is insulated to increase the efficiency of the unit and to prevent condensation. As shown, the cold end insulation is formed by means of a foamed-in-place urathane rubber **72** or similar material. It will be apparent, however, that other insulation may be used for the indicated purpose.

The hot air outlet valves 73 and 74 of the tubes 50 and 51, respectively, are located in the hot end area 54 of the casing. Since the temperature of the air issuing from the valves 73 and 74 may be in excess of 200° F. the hot area 54 also is insulated as indicated at 75 in order to reduce the outside temperature of the cooling unit to a safe value. As noted above, the hot air is permitted to escape to the surrounding atmosphere through the vented openings 56 (FIG. 1) in the casing.

As is known, the temperature and flow rate of the air fractions issuing from the cold and hot ends of a vortex tube can be controlled by adjustment of the hot air throttle valve. In general, with the throttle valve in a nearly closed position, the hot air fraction is at maximum temperature and minimum flow rate, while the cold air fraction also is at maximum temperature but at a maximum flow rate. As the throttle valve is opened from its nearly closed position, the temperatures of both air fractions, as well as the flow rate of the cold air fraction will decrease, while the flow rate of the hot air fraction increases. At an intermediate throttle setting which is dependent upon the particular construction of the vortex tube, the cold air fraction will reach a minimum temperature beyond which further opening of the throttle valve will again produce a temperature rise.

As has been previously discussed, the operating characteristics of a single vortex tube are such that the temperature of the cold air fraction varies widely depending upon the setting of the throttle valve and the temperature of the supply air. Thus, when the throttle valve is set to obtain the required flow rate of air to the protective suit or other cooled space, the temperature of the cold air fraction is often too low to be comfortable.

In accordance with the present invention, the disadvantageous operating characteristics of conventional vortex arrangements are avoided by pre-setting the vortex assembly 50 to obtain maximum flow efficiency from the air outlet which, in the illustrated embodiment, is the cold air outlet. By "maximum flow efficiency," it is meant that the throttle valve 73 is set so that the temperature of the cold air fraction is slightly greater, in the direction of greater flow rates, than the minimum temperature obtainable. Stated differently, maximum flow efficiency is obtained when the hot air throttle valve is slightly closed from the setting which achieves minimum temperature of the cold air fraction. While this setting for maximum flow efficiency differs with the particular vortex tube construction, it is usually such that the cold air fraction is in the range of from 65 to 85% of the total air supplied to the vortex tube, and, preferably, 80%.

The operating characteristics of the other vortex tube assembly 51 are controllable and to this end, the stem 75 of the throttle valve 74 is extended through the end wall of the housing 52 and is provided with a control knob 76.

The resulting characteristics of the cold air flow from the pre-set vortex assembly 50 and the controlled vortex assembly 51 are generally indicated by the graph in FIG. 8 in which the temperature and flow rate of the cold air fraction are plotted against various throttle settings for the variable assembly 51. As will be seen in the graph, a supply air temperature of 120° F. provides an adjustable output temperature ranging from approximately 63° F. to 85° F., and a flow rate of from approximately 11 to 30 standard cubic feet per minute. The volume of cold air flow which can be obtained with this arrangement is substantitally twice that obtainable with a single tube; however, the characteristic temperature curve is substantially modified so that it is possible to obtain a desired cold air temperature at the required outlet flow rate. For example, it will be seen that with the 120° air supply temperature, it is possible to obtain an outlet flow rate of approximately 17 standard cubic feet per minute by setting the throttle valve 74 approximately 80% closed.

At lower inlet temperatures, the temperature curve of the cold air fraction retains its shape and moves downward, as indicated by the lower temperature curve produced by an 85° F. air inlet temperature. With extremely low inlet temperatures, the temperature of the air may be too cold for comfort when used in the illustrated suit cooling system. In order to overcome this difficulty, there is shown in FIGURE 7 a modified arrangement of the vortex tube assemblies 50 and 51. This modified arrangement is essentially the same as that shown in FIG. 6 except that a by-pass valve 80 is provided in the inlet air manifold 61 upstream from the air inlet assembly 60 of the fixed tube 50. As shown, the by-pass valve 80 is a three-way valve which may be connected to the outlet pipe 71 through a pipe 81.

When the by-pass valve 80 is in the position illustrated, the vortex assembly arrangement will function in the same manner as that discussed above in connection with the arrangement of FIG. 6. However, by rotating the valve 90°, it is possible to disconnect the fixed or uncontrolled vortex assembly 50 from source and to permit a portion of the supply air to pass directly into the outlet air manifold 70. The effect of this arrangement is generally to flatten the temperature curves shown in the graph of FIG. 8 and to displace them in an upward direction to thereby provide satisfactory suit temperatures at supply air temperatures which are lower than shown in the graph.

As will be apparent from the foregoing, the novel vortex assembly of the invention provides for a new and useful application of the vortex principle. In particular, the use of a fixed vortex tube, which is set to operate at maximum flow efficiency, in combination with a controllable vortex tube provides unique operating characteristics, whereby it is possible to obtain a cold air flow at desired temperatures and flow rates.

The arrangement of the vortex tubes within the partially insulated housing 52 forms a portable unit 10 which can be conveniently carried and controlled by the user. More specifically, the user can control the temperature and outlet flow rate of his unit to suit the particular working conditions even though the unit is supplied by a central source which also may furnish air to other units under other working conditions, as well as to other apparatus. As noted above, the unit is relatively inexpensive and maintenance-free, since no moving parts are involved.

FIGURE 9 illustrates still another embodiment of the invention wherein two vortex assemblies 85 and 86 are connected to serve as a heating unit. The vortex assemblies 85 and 86 are generally of the construction described above and will be understood to include air inlet assemblies 87, cold air outlets (not shown) which are in communication with pipes 88, and hot air throttle valves 89 and 90, respectively. As in the case of the previously described embodiments, the vortex assembly 85 may be considered a fixed tube set to operate at maximum flow efficiency and the vortex assembly 86 as a variable tube that is operated by the control knob 91.

Air is supplied to the inlet assemblies 87 through a manifold 92. This manifold may include a shut-off valve 93 which is similar to the previously discussed valve 63.

In this modified embodiment of the invention, annular housings 94 are provided around the hot air outlet ports (not shown) of the throttle valves 89 and 90. These housings 94 are connected together by a manifold arrangement 95 which includes an exhaust line 96. If desired, the inlet manifold 92 and the exhaust manifold 95 may be connected by a pipe 97. As shown, another shut-off valve 98 is disposed in connection with the pipe 97.

In operation, air is supplied through the manifold 92 to the inlet assemblies 87 of the vortex tubes 85 and

86. The hot air fraction of the resulting vortex which issues through the throttle valves 89 and 90 is manifolded into the exhaust line 96 which may be connected to any enclosure which is to be heated. As previously discussed, the temperature of the hot air fraction can be controlled under a range of air supply temperatures by suitable adjustment of the control valve 90.

The valve 98 may be used when the temperature of the air supply is such that the resulting temperature of the hot air fraction is too hot for the use intended. By opening the valve 98 it is possible to pass a portion of the supply air directly into the manifold 95 so that it is mixed and exhausted with the hot air fractions from the vortex assemblies. In this manner, the temperature curve of the hot air fraction is lowered so that usable temperatures can be obtained.

Many other modifications and variations of the invention will become apparent to those skilled in the art in view of the foregoing detailed disclosure. Therefore, it is to be understood that, within the scope of the appended claims, the invention can be practiced otherwise than as specifically shown and described.

What is claimed is:

1. A gas conditioning apparatus for supplying gas at regulated temperature conditions and flow rates comprising a plurality of vortex assemblies, each of said votex assemblies including a tube, gas inlet means to said tube for tangentially introducing supply gas and creating a high speed vortex, said vortex being characterized by an axially moving shell of relatively hot gas and a core of relatively cold gas, and gas outlet means for releasing gas from said tube, said gas outlet means for each tube including a cold gas outlet and a throttle valve defining a hot gas outlet, the throttle valve of one of said assemblies being set to obtain a predetermined gas outlet flow rate and temperature from the associated outlet means and the throttle valve of another of said assemblies being adjustable so as to obtain variable gas flow through the outlet means of said another assembly, and means forming a gas outlet manifold connecting corresponding gas outlets of said vortex assemblies.

2. The apparatus as claimed in claim 1 including a gas supply manifold connected to the gas inlet means of all of said vortex assemblies.

3. The apparatus as claimed in claim 2 wherein said gas supply manifold includes a by-pass valve disposed upstream from the gas inlet means to said one vortex assembly, whereby said one assembly can be disconnected from source.

4. The apparatus as claimed in claim 1 including a gas supply manifold connected to the gas inlet means of all of said vortex assemblies, and controllable by-pass means connecting said gas supply manifold to said gas outlet manifold, whereby a portion of the supply gas can be selectively exhausted into said outlet manifold.

5. The apparatus as claimed in claim 4 wherein said by-pass means includes a by-pass valve located upstream from the gas inlet means of said one vortex assembly.

6. A cooling system including gas cooling apparatus comprising an assembly of at least two vortex tubes, each of said tubes including gas inlet means for tangentially introducing gas and creating a high speed vortex characterized by an axially moving shell of relatively hot gas and a core of relatively cold gas, and a cold gas outlet, means connected to said inlet means for supplying gas to be cooled, release means for releasing hot gas from one of said tubes, said release means being set to obtain a flow of gas from the cold gas outlet of said one tube having a predetermined temperature and flow rate, a throttle valve connected to another of said tubes for releasing hot gas therefrom, said throttle valve being adjustable so that the outlet flow rate of cold gas from said another tube can be varied, said system including means connecting the cold gas outlets of said tubes to mix the cold gases issuing therefrom.

7. The apparatus as claimed in claim 6 where said means connected to said inlet means includes a by-pass valve upstream from said one tube, whereby said one tube can be disconnected from source.

8. The apparatus as claimed in claim 7 wherein said by-pass valve is connectable to said means connecting the cold gas outlets when said one tube is disconnected from source.

9. A portable gas conditioning apparatus comprising a housing, a pair of vortex tubes mounted in said housing, each of said tubes including gas inlet means for tangentially introducing gas and creating a high speed vortex therein, and gas outlet means, said outlet means including a cold gas outlet and hot gas discharge means, the hot gas discharge means of one of said tubes being set to obtain cold gas outlet flow of predetermined flow rate and temperature, said predetermined flow rate being in the range of from about 65% to about 85% of the gas flow supplied to said one tube, the hot gas discharge means of the other of said tubes including an adjustable throttle valve extending through a wall of said housing, whereby the temperature and flow rate of the cold gas flow from said tubes can be varied, and manifold means connected to said gas outlet means, said manifold means including means connecting the cold gas outlets of said tubes.

10. The gas conditioning apparatus as claimed in claim 9 wherein said manifold means further includes means forming a supply manifold in said housing connected to said inlet means for supplying gas thereto.

11. A gas conditioning apparatus comprising a housing, a pair of vortex tubes mounted in said housing, each of said tubes including gas inlet means for tangentially introducing gas and creating a high speed vortex therein, and gas outlet means, said outlet means including a cold gas outlet and hot gas discharge means, the hot gas discharge means of one of said tubes being disposed within said housing and adjusted to obtain gas flow of maximum efficiency from the gas outlet means of said one tube, the hot gas discharge means of the other of said tubes including an adjustable throttle valve extending through a wall of said housing, manifold means connected to said gas outlet means, supply manifold means connected to said gas inlet means for supplying gas thereto, and a by-pass valve in said supply manifold means upstream from said one tube.

12. A portable gas cooling apparatus comprising a housing having a cold end and a hot end, a pair of vortex tubes carried in said housing, each of said tubes including a cold gas outlet in said cold end, gas inlet means connected to each tube for tangentially introducing gas therein and creating a vortex, manifold means disposed in said cold end of said housing, said manifold means including means connecting said inlet means and means connecting said cold gas outlets, hot gas discharge means connected to each tube in said hot end of said housing, the hot gas discharge means of one of said tubes being set to obtain a cold gas temperature which differs from a minimum cold gas temperature obtainable from said one tube in a direction of maximum cold gas flow rate, the hot gas discharge means of the other of said tubes including an adjustable throttle valve having a control element extending through a wall of said housing, whereby the outlet temperature and flow rate of the combined cold gas components from said tubes can be varied, and said housing having an opening so that the hot gas components from said tubes can be exhausted to the atmosphere.

13. The apparatus as claimed in claim 12 wherein said hot and cold ends of said housing are insulated from each other.

14. The apparatus as claimed in claim 13 including a by-pass valve upstream from the inlet means of said one tube, whereby said one tube can be disconnected from source.

15. The apparatus as claimed in claim 14 wherein said one tube is constructed to obtain a cold gas discharge which is approximately 80 percent of the gas supplied to said one tube.

References Cited in the file of this patent

UNITED STATES PATENTS

2,650,582	Green	Sept. 1, 1953
2,819,590	Green	Jan. 14, 1958
2,839,900	Green	June 24, 1958