

[54] **VORTEX TUBE COOLING SYSTEM**

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 [58] Field of Search **62/5**

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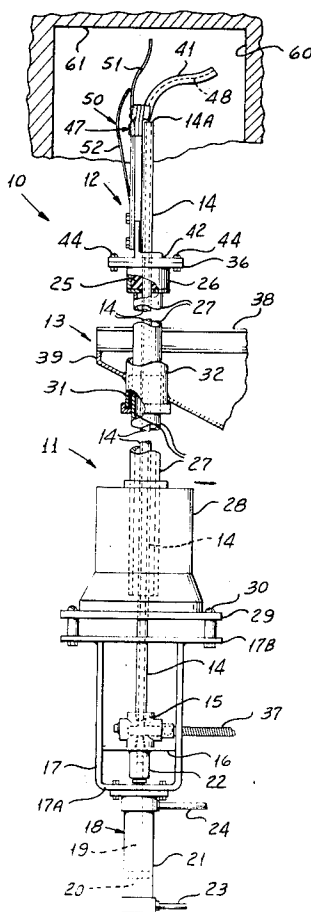
[57] **ABSTRACT**

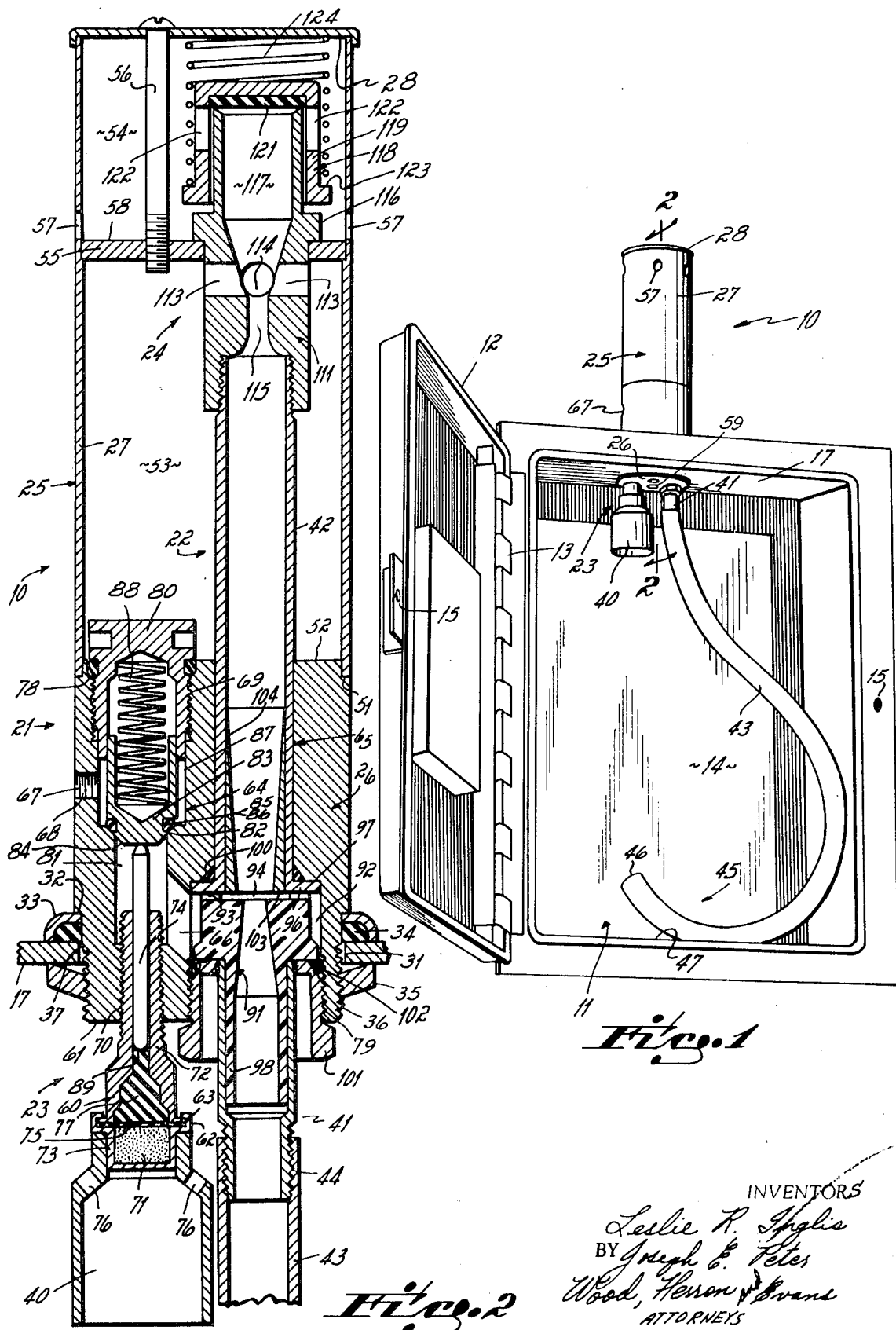
A cooling system particularly adapted for sealed and substantially sealed, and unsealed enclosures, the system making use of a vortex tube. The cold tube portion of the vortex tube is ducted into the enclosure and the hot tube portion of the vortex tube is ducted to the atmosphere. In preferred form, a high

pressure air inlet valve is interconnected with the vortex tube's generator, the inlet valve being controlled by a thermostat adapted to sense the temperature within the enclosure. An exhaust structure is provided to discharge enclosure air and hot tube air to the atmosphere, the exhaust structure being interconnected with the enclosure as well as with the hot tube. The exhaust structure admixes air exhausted from the enclosure and air exhausted from the hot tube prior to discharging the combined flows. The exhaust structure includes an aspirator for admixing the enclosure air and the hot tube air, and a single pressure relief type outlet valve for exhausting the admixed air to the atmosphere.

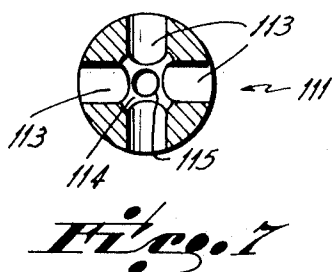
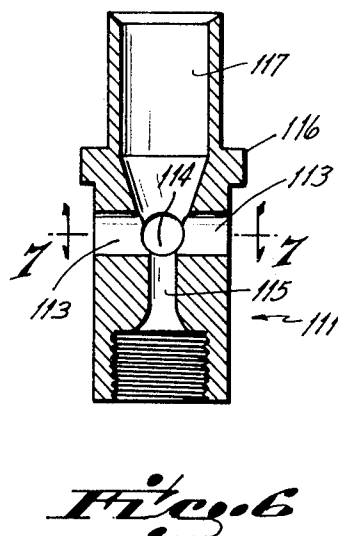
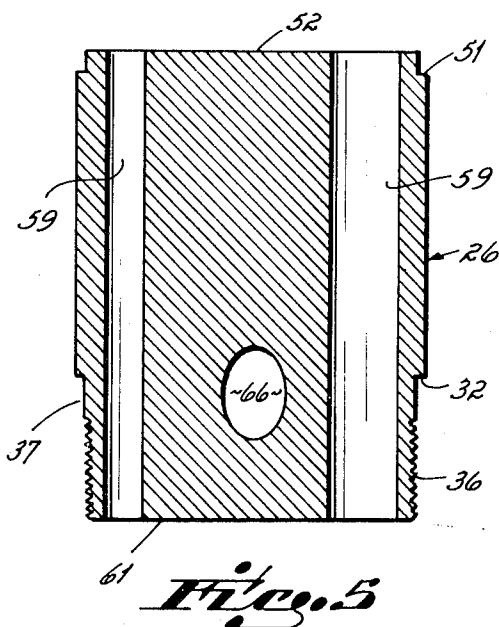
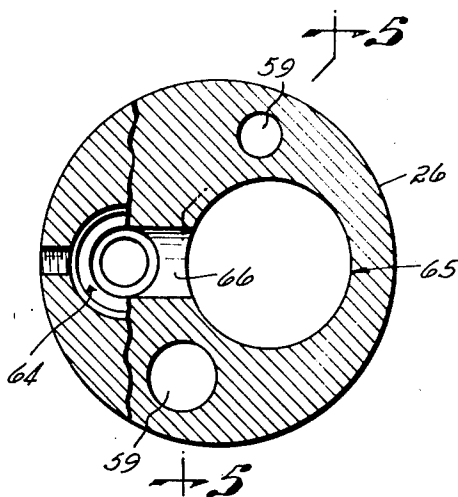
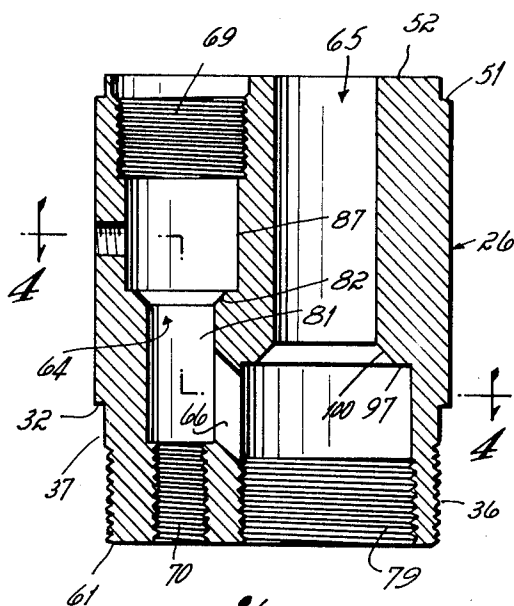
In operation, the thermostat senses the temperature inside the enclosure and causes the inlet valve to open when that temperature exceeds a predetermined level. The open inlet valve admits high pressure air to the vortex tube's generator where, through the well known action of the vortex tube, a cold air flow is developed in the cold tube toward the enclosure and a hot air flow is developed in the hot tube toward the exhaust structure. As the cold air flow is admitted into the enclosure, the air in the enclosure is driven out of the enclosure and at least part is piped to the exhaust structure where it is admixed with the hot air flow from the hot tube. Thereafter, the mixed flow of enclosure air exhaust and hot tube air exhaust are discharged to the atmosphere through the single relief type outlet valve. When the inside of the enclosure is cooled to the desired temperature level as sensed by the thermostat, the inlet valve is closed, cold air flow into the enclosure ceases, and the exhaust relief valve reseals the entire enclosure in the case of sealed and substantially sealed enclosures.

22 Claims, 7 Drawing Figures





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VORTEX TUBE COOLING SYSTEM

This invention relates to cooling systems and, more particularly, relates to a cooling system that makes use of a vortex tube.

The problem of cooling enclosures, whether they are sealed, substantially sealed, or unsealed to their surrounding environment, is well known. This is particularly the case where the enclosure houses machines or methods or manufactures or compositions that are adversely affected by temperatures elevated above room or ambient temperature. Such a problem becomes particularly acute in the case of enclosures containing electrical equipment where heat buildup within the enclosure occurs from use of the equipment and/or from the environment within which the enclosure is positioned. For purposes of this application (a) an unsealed enclosure refers to an enclosure which is closed but where no effort has been made to seal the inside of the enclosure from dirt or dust or splashing liquids, (b) a substantially sealed enclosure refers to an enclosure which is closed to dirt or dust or splashing liquids, and (c) a sealed enclosure refers to an enclosure which is gas tight as well as closed to dust, dirt and liquids.

It is apparent that enclosures, and particularly those which must remain substantially sealed or sealed to the atmosphere during their operating life, cannot be readily ventilated. With no device to enhance cooling of the enclosure, cooling of the inside of same must depend upon conduction of heat from the inside through the enclosure's housing and radiation and convection from the housing to the surrounding environment to dissipate any internally confined heat. Further, such a cooling process can only occur when the outside environment temperature is less than the temperature inside the enclosure.

In the case of electrical equipment, panel boxes which house electrical and/or electronic controls and/or other types of electrical equipment are often placed in hot industrial environments near machines, ovens, or heat treating facilities, and the atmospheric or outside environment surrounding the panel boxes then may cause the temperature to increase inside the enclosure. Further, the controls and/or other types of electrical equipment may generate heat which is retained inside the boxes, particularly in sealed and substantially sealed panel boxes but also in unsealed boxes. Of course, no matter what the heat source when the temperature exceeds a certain safe level inside the panel box it must be lowered to maintain optimum operating conditions for the equipment and to protect against its damage.

If actual failure of the electrical or electronic controls or other electrical equipment inside the panel box does not occur, it is oftentimes the case that performance of this electrical equipment is adversely affected. Many electronic elements will fail completely if they are allowed to exceed certain temperature levels. Therefore, such electronic controls must be provided with absolute protection against such temperatures. This is particularly true of solid state devices such as transistors.

Electrical controls may also be adversely affected by heat. For example, electrical controls for motors are often installed in a metal panel box, and the box must be sealed or substantially sealed in many installations to meet the requirements of organizations such as the Joint Industrial Commission and the National Electrical Manufacturers Association. Sealing or substantial sealing of these panel boxes aids in eliminating electrical and fire hazards caused by undesirable environments within which the panel boxes may be positioned, but it also creates cooling problems in these panel boxes. An example of these problems is the nuisance tripping of electrical controls for motors which occurs when the controls overheat. Generally, an electrical control for a motor senses the current drawn by the motor and uses a small proportional amount of it to operate a heater. When the motor is overloaded, stalled, or shorted, it draws a larger than normal amount of current causing the heater in the control to heat up substantially. The excess heat generated by the heater causes a break in the circuit to the motor, thereby protecting the motor from damage. But

nuisance tripping occurs due to the presence of too much heat in the panel box from sources other than motor overload, e.g., heat generated by the controls within the box or the outside environment surrounding the box, which causes the motor to shut off even though it is drawing only a normal amount of current. Obviously, nuisance tripping can be quite expensive in terms of down-time costs not only for workers depending upon the continuous operation of the electric motors but also in terms of maintenance men who must be called to examine the troublesome panel box and reset the electrical controls.

There are some known alternatives available for cooling enclosures such as electrical and electronic control panel boxes. One alternative is simply to permit the panel box to cool by radiation and convection without the aid of any type cooling system; but such presents the problems discussed above. Another alternative is simply to open the door of the box and direct a fan onto the controls for a period of time to achieve the cooling; but such allows dirt and dust to enter the box, opens the box to the hazards of splashing oil and water, breaks the seal to the atmosphere in sealed or substantially sealed boxes, and in some instances is considered a violation of codes and/or plant rules. A further alternative is to create a freon type refrigerator around the enclosure by fixing cooling coils to the enclosure and then providing a layer of insulation on those coils to maintain a reasonable degree of efficiency for the cooling system; even though such a system is effective, it is quite expensive in that a separate compressor unit and evaporator unit must be provided to supply the cooling coils with refrigerant and the system is relatively bulky, heavy and complicated.

The cooling system of this invention incorporates a vortex tube to create the refrigerated or cold air for sealed, substantially sealed, or unsealed enclosures. Basically, a vortex tube is a device having no moving parts which, when fed with compressed air, emits a stream of cold air from one end and a stream of hot air from the other end. That is, the vortex tube converts an ordinary supply of compressed air into two air flow streams, one hot and one cold. Enough temperature difference may be produced to freeze water at one end of the vortex tube while boiling it at the other end of the vortex tube, and the proportions of hot air and cold air flows and their temperatures can be varied over a wide range. In operation, the compressed air first enters nozzles which inject it tangentially into a vortex generation chamber, that chamber being positioned intermediate the hot end and the cold end of the vortex tube but closer to the cold end than the hot end. The vortex so created moves through the vortex tube toward the hot end of the tube. Swirling air near the inner surface of the tube becomes hot as the flow proceeds toward the hot end outlet, and hot air leaves through a restriction at the hot end. However, the restriction at the hot end imposes enough back pressure on the vortex to force some of the air to the center of the tube and back through the tube toward the cold end. This air becomes very cold as it passes back through the vortex tube and, after passing back through the vortex chamber, leaves the tube through the cold outlet. Generally, almost any capacity cooling requirement can be met with a vortex tube or a series of vortex tubes, and the heating and cooling effects can be produced using almost any gas. Typical vortex tubes are illustrated in Fulton patents U.S. Pat. No. 3,173,273 and U.S. Pat. No. 3,208,229.

The specific problems of the prior art recited above in connection with enclosures, and particularly in connection with enclosures adapted to house electrical or electronic controls or other types of electrical equipment, are overcome with the unique cooling system of this invention. This cooling system makes use of a vortex tube, the cold tube portion of the vortex tube being ducted into the enclosure and the hot tube portion of the vortex tube being ducted to the atmosphere. In preferred form a high pressure air inlet valve is interconnected with the vortex tube's generator, the inlet valve being controlled by a thermostat adapted to sense the temperature within the enclosure. An exhaust structure is provided to

discharge enclosure air and hot tube air to the atmosphere, the exhaust structure being interconnected with the enclosure as well as with the hot tube. The exhaust structure admixes air exhausted from the enclosure and air exhausted from the hot tube prior to discharging the combined flows. The exhaust structure includes an aspirator for admixing the enclosure air and the hot tube air, and a single pressure relief type outlet valve for exhausting the admixed air to the atmosphere.

In operation, the thermostat senses the temperature inside the enclosure and causes the inlet valve to open when that temperature exceeds a predetermined level. The open inlet valve admits high pressure air to the vortex tube where, through the well known action of the vortex tube, a cold air flow is developed in the cold tube toward the enclosure and a hot air flow is developed in the hot tube toward the exhaust structure. As the cold air flow is admitted into the enclosure, the air in the enclosure is driven out of the enclosure and at least part is piped to the exhaust structure where it is admixed with the hot air flow from the hot tube. Thereafter, the mixed flow of enclosure air exhaust and hot tube air exhaust are discharged to the atmosphere through the single relief type outlet valve. When the inside of the enclosure is cooled to the desired temperature level as sensed by the thermostat, the inlet valve is closed, cold air flow into the enclosure ceases, and the exhaust relief valve reseals the entire enclosure in the case of sealed and substantially sealed enclosures.

Thus, the vortex tube cooling system of this invention provides true standby protection for the inside of an enclosure in that it operates only when the enclosure interior exceeds a high temperature regulated by the thermostatic setting. Further, the enclosure cannot be overcooled in that the system is automatically shut off when the inside of the enclosure reaches a low temperature regulated by the thermostatic setting. In use with electrical equipment enclosures, the vortex tube cooling system of this invention is capable of dissipating resistive heat generated within the enclosures as well as heat imparted to the enclosures due to their hot surroundings or environment.

The novel vortex tube cooling system of this invention provides a number of advantages over those systems known to the prior art. The aspirator part of the exhaust structure serves to aid in removing displaced air from the enclosure thereby increasing the efficiency of the system, serves to lower the temperature of the final exhaust by mixing displaced enclosure air with hot tube air thereby promoting personal safety and comfort of those working near the system, and requires only one outlet valve for exhaust air from the enclosure and the hot tube. Further, and particularly when a substantially sealed or sealed enclosure is used, the single relief type outlet valve of the exhaust structure readily permits the sealed or substantially sealed character of the enclosure to be maintained and permits a slight positive pressure to be maintained in the enclosure during operation to insure that the enclosure remains substantially sealed against splashing liquids or dirt or dust. Further, electrical connection or electrical control is not required for the cooling system as, in the preferred structural form, it is self-contained in a single housing and operates on air pressure only. Further, because the cooling system is a standby type of cooling system in the sense that it only operates to discharge refrigerated air when called on to do so by the thermostat, several such cooling systems with an aggregate capacity substantially larger than the available compressed air capacity may be installed and serviced by the same compressor since simultaneous operation of several coolers is statistically unlikely. Further, when the exhausted enclosure air is passed over the hot tube section of the vortex tube prior to being admixed with the hot tube air in the preferred structural embodiment, the hot tube is externally cooled (since the enclosure exhaust air is always cooler than the hot tube air) and this improves the performance of the vortex tube. Further, the preferred structural embodiment is such that only a single hole in the enclosure need be provided to install the vortex tube cooling system.

Other objectives and advantages will be more apparent from the following detailed description taken in conjunction with the drawings in which:

FIG. 1 illustrates a use of the vortex tube cooling system of this invention in combination with a substantially sealed enclosure shown as a panel box for electrical controls:

FIG. 2 is a cross-sectional view taken along line 2—2 of FIG. 1;

FIG. 3 is a cross-sectional view of the base block for the inlet valve, thermostat and vortex tube but with all components removed, the view being taken along the same plane as is shown for the assembled base block in FIG. 2;

FIG. 4 is a cross-sectional view taken along line 4—4 of FIG. 3;

FIG. 5 is a cross-sectional view taken generally along line 5—5 of FIG. 4;

FIG. 6 is a cross-sectional view of the exhaust block with the outlet valve and vortex tube removed, the view being taken along the same plane as is shown for the assembled exhaust block in FIG. 2; and

FIG. 7 is a cross-sectional view taken along line 7—7 of FIG. 2.

As illustrated in FIG. 1, the vortex tube cooling system 10 is combined with an enclosure 11 adapted to be substantially sealed to the atmosphere. The enclosure 11 may be any type of box, case, room, or the like, where it is either necessary or desirable to maintain the area substantially sealed to the surrounding atmospheric environment. The enclosure 11 may likewise be a sealed or an unsealed enclosure. As illustrated in FIG. 1, the substantially sealed enclosure 11 is in the form of a panel box adapted to receive a series of electrical controls, not shown, such as would be used for the control of electric motors. The enclosure or panel box 11 has a front door 12 hinged as at 13 to the box casing 14 to permit opening and closing as desired to service the electrical components therein. The door 12 is adapted to be closed into a substantially sealed relation with the casing 14 of the panel box 11, and may be provided with a latch or lock 15 to maintain that closed attitude.

The vortex tube cooling system 10 is mounted on top 17 of the panel box 11. The cooling system 10 basically comprises air inlet valve 21, vortex tube 22, thermostat 23, and exhaust apparatus 24. These elements are all mounted to a housing 25 that is defined by base block 26, sleeve 27 and cap 28. It is preferred that the cooling system 10 be mounted on top 17 of the panel box 11 as the thermostat 23 is then disposed in that area of the box's inner environment to sense the warmest air in the box, and this also permits the warmest air in the box to be the first expelled from the box through the cooling system.

The cooling system 10 requires only a single hole 31 in the top 17 of the box 11 for mounting thereto, the bottom end of the base block 26 extending through that hole. The base block 26 is provided with an annular seat 32 adapted to receive a flanged ring 33, the ring providing a seat for sealing structure in the form of O-ring 34. After the housing 25 is positioned in a vertical attitude on the top 17 of the box 11, a lock ring 35 is threaded on threads 36 cut onto the neck 37 of the base block 26, thereby clamping the housing 25 in fixed position with the box between the flanged ring 33 and the lock ring and thereby also providing a sealed joint. It will be noted that only the single hole 31 is required in top 17 of box 11 to mount the cooling system. Refrigerated air from cooling system 10 flows into the box through the block 26 in hole 31 and displaced enclosure air exhausts from the box through the block 26 in hole 31. Further, the box 11 remains sealed to the outside atmosphere through use of O-ring 34 after the cooling system 10 is mounted to the box.

The cold tube portion 41 of the vortex tube 22 extends down into the box 11 (when the system 10 is mounted to the box 11) while the hot tube portion 42 of the vortex tube extends up into the housing 25. The cold tube portion 41 connects with a length of flexible tubing 43 inside of the box, the cold end of the cold tube having threads 44 to mount the flexible tubing, see FIG. 2. The flexible tubing or ducting 43

preferably is of a length sufficient to extend down into the bottom area 45 of the box 11, and preferably is positioned so that it is free of kinks and so that its free end 46 faces upward near the bottom 47 of the box. Alternatively, the tubing or ducting 43 may be directed to any area of the box 11 that requires concentrated cooling or no tubing may be used at all if desired. Under usual circumstances the tubing 43 is preferably directed into the bottom area 45 of the panel box 11, with its free end 46 directed upward, so as to direct the refrigerated or cooled air into the bottom of the panel box to aid in forcing the enclosure air toward the top where it can be exhausted through the housing 25. Use of this tubing 43 avoids stratification of the air in the box 11 and assures more even cooling of the entire box.

The thermostat 23 carried by the housing 25 also extends down into the panel box 11 when the system 10 is mounted to the box. When the system 10 is mounted to the top 17 of the box 11 as shown in FIG. 1, the thermostat's bell 40 is thereby positioned in that part of the box where the hottest temperatures are found.

The housing 25 includes the base block 26 on which is mounted the tubular sleeve 27, the bottom end of the sleeve being carried on annular seat 51 turned into top surface 52 of the base block. The top end of the sleeve 27 is closed off by cover 28. The tubular sleeve 27 is divided into two chambers 53, 54 by an intermediate wall 55 fixed to the inside wall of the sleeve. The cover 28 is fixed to the sleeve 27 by at least one bolt 56 extending from the cover through chamber 54 and into threaded engagement with wall 55. The top chamber 54 is provided with a series of ports 57 in sleeve 27 radially disposed around the sleeve and located adjacent the top surface 58 of the intermediate wall 55. The top chamber 54 acts as an exhaust chamber and is closed to the atmosphere except through ports 57. It will be noted that because the exhaust ports 57 are so closely positioned to top surface 58 of intermediate wall 55 that the exhaust chamber is maintained free of water if the system is used in an outdoors environment.

When refrigerated air is introduced into the box 11, and particularly where the box is substantially sealed or sealed as is box 11, there is a need to exhaust an equal volume of air from the box to avoid pressure buildup therein. As mentioned, the box's exhaust air is displaced and directed out through housing 25 as the refrigerated or cold air is injected into the box through housing 25. The displaced enclosure air is exhausted through bores 59 in base block 26, see FIGS. 4 and 5. These bores 59 extend longitudinally through the base block 26 from the bottom face 61 through to the top face 52, thereby communicating at one end with the inside of box 11 and at the other end with holding chamber 53. Thus, chamber 53 is only accessible through ports or bores 59 and exhaust apparatus 24.

It will be particularly noted that when the enclosure air exhaust is ducted through the ports or bores 59 into holding chamber 53 that it surrounds the hot tube portion 42 of the vortex tube 22. This aids in increasing the efficiency of the vortex tube's operation because the enclosure's exhaust air is usually at a lower temperature than the hot tube's exhaust air, thereby tending to cool the hot tube. Once the box's exhaust air reaches the holding chamber 53 it is directed into the exhaust chamber 54 through exhaust apparatus 24. As mentioned, the exhaust apparatus 24 admixes the enclosure's air exhaust and the hot tube's air exhaust, and this admixed air flow is directed to exhaust chamber 54 prior to discharge to the atmosphere surrounding the housing 25 through ports 57. The exhaust chamber 54 acts to modulate the air blast tendency that the admixed air flow may have as it is exhausted from the exhaust structure 24 so as to promote a safer environment for those working around the cooling system 10.

The base block 26 of the housing 25 is suitably bored, in addition to bores 59, to mount a poppet valve 21, the vortex tube 22, and the thermostat 23. As shown in FIGS. 2-4, a stepped valve-thermostat bore 64 and a stepped vortex tube bore 65 are positioned longitudinally in the housing 25 and parallel

one to the other. These bores 64, 65 are interconnected one with the other through transfer port 66. The bore 64 is internally threaded at its top and bottom as at 69, 70, respectively. The bore 65 is only internally threaded at its bottom as at 79. Air inlet 67 is also bored into base block 26 but is positioned transverse to the housing axis. Inlet bore 67 communicates with upper portion of bore 64 where air inlet valve 21 is mounted and is provided with threads 68 to receive a suitable air hose fitting, not shown, for attaching the system 10 to a compressed air source, not shown.

The thermostat 23 is a wax pellet 71 type thermostat and comprises a hollow pin holder 72 threaded into axial alignment with bore 64 from the bottom face 61 of the base block 26. The pin holder 72 includes a closed well 73 mounted to the bottom thereof which receives the wax plug 71, the well being of a cross-sectional area substantially greater than the cross-section defined by pin 74 received in holder 72. A rubber diaphragm 75 is positioned on top the wax plug 71, the diaphragm being clamped in position between arms 62 of well 73 and feet 63 of holder 72. A rubber plug 77 fills flared bottom 60 of holder 72, the plug being of decreasing cross-sectional area from its base surface to its top surface 89 which supports pin 74. The bell 40 is mounted in good heat conducting relation to the well 73, the bell having a series of holes 76 on its upper shoulder. The holes 76 in the bell 40 function to permit the enclosure air to completely surround the bell and circulate through it for better temperature sensing; the bell thereby functions to increase the sensitivity of the thermostat 23.

The temperature sensed by the bell 40 is transmitted by conduction to the well 73 and, hence, to the wax plug 71. The wax plug 71 is of a wax particularly designed to expand very slowly outside of a limited temperature range but very rapidly within that limited range. Upon the wax plug being exposed to that very limited temperature range (the wax being selected to provide a limited temperature range at which it is desired to begin and stop cooling of the inside of the box) the wax plug expands or contracts quite rapidly. Because the cross-sectional area ratio between the top surface 89 of the rubber plug 77 and the wax plug 71 may be on the order of 20-1, when the wax plug begins its rapid expansion such is transmitted through the rubber diaphragm 75 to the pin and causes the pin to rise relative to the holder 72 when the temperature is rising. In other words, and for example, if the wax plug 71 increases in height approximately one-hundredth of an inch, the pin will move up in height approximately two-tenths of an inch. Such rising of the pin 74 causes the air inlet valve 21 to open as will be subsequently described. The principles of this type thermostat are well known to the art, and form no part of this invention apart from the combination herein described. A typical type of thermostat useful with this invention which embodies the principle described above is Vernatherm made by American Standard Corp. Of course, the wax pellet type thermostat is only one of several types of thermostats that can be used with the cooling system of this invention.

The inlet air valve 21 cooperates with air inlet 67 and is particularly illustrated in FIG. 2. The pin 74 of the thermostat 23 extends axially into feed bore 81 portion of bore 64. Feed bore 81 is provided with a seat 82 on its upper end adapted to cooperate with a first poppet valve head 83. The poppet valve head 83 is located in poppet bore portion 87 of bore 64 and has an annular surface 84 adapted to cooperate with the valve seat 82. The head 83 is provided with an annular groove 85 that receives an O-ring 86, the O-ring also cooperating with the valve seat 82 when the valve is in the closed attitude (see FIG. 2) to provide an airtight seal and prevent leakage from the high pressure air source into vortex tube 22.

The poppet valve head 83 is slidably received in cap 80 which is threadedly engaged with and mounted in the top end of bore 64. O-ring 78 is disposed between cap 80 and bore 64 adjacent the upper end to prevent air leakage from poppet bore portion 87 of bore 64 into holding chamber 53. A compression spring 88 is interposed between the bottom of cap 80

and the valve head 83, and continuously urges the valve head toward the valve seat 82. Hence, and in operation, as the temperature inside the box 11 rises into the limited temperature range the pin 74 forces the valve head 83 off its seat and admits compressed air through poppet bore portion 87 of bore 64 into feed bore portion 81 of bore 64 from which the compressed air is directed into transfer bore 66 toward vortex tube bore 65. As the temperature inside the box 11 falls into the limited temperature range, the spring 88 forces head 83 onto seat 82 and pushes pin 74 down against top surface 82 of rubber plug 75.

It is preferred that the inlet valve 21 structure be of that type urged closed by the forces generated by inlet pressure, i.e., a negative valve; the valve 21 described above is of this type. As the thermostat 23 attempts to open the valve 21 it must overcome not only the spring 88 force but also the air pressure force tending to hold the valve closed. Once the valve head 83 starts to rise the air pressure force rapidly diminishes and the valve is caused to "pop" open. On closing, the reverse is true and the valve tends to snap closed when the valve head 83 approaches the seat 82. These effects give a nonmodulating type valve 21 which tends to be either fully open or fully closed because it is unstable in the throttling situation. This type of valve 21 is advantageous in this cooling system 10 for two reasons, namely, (a) throttling is thermodynamically wasteful and denies vortex tube 22 the opportunity to convert all the available energy in the compressed air into refrigeration, and (b) the system 10 is intended as a standby device to operate only when temperatures exceed a high limit and to stop when temperatures drop below a low limit (a modulating valve would tend to seek some steady state inlet air flow which would balance the cooling effect with the temperature sensed by the thermostat 23, and thus defeating the standby characteristic of the system).

The vortex tube 22 is located in bore 65 of base block 26. The vortex tube 22 includes a generator 91 which defines an annular chamber 92 in combination with bore 65, the annular chamber 92 being open to transfer bore 66. As shown, the generator 91 is molded nylon. Annular chamber 92 communicates with a vortex chamber 94 through nozzles 93. Hot tube 42 with integral flange 96 is received in the top part of bore 65, the flange being seated on rim 97 in bore 65 and against face 103 of generator 91. Flange 96 aids in defining one side of the nozzles 93 and annular chamber 92. Taper sleeve 104 is press fit into that end of hot tube 42 adjacent generator face 103. An O-ring is pressed on seat 100 defined in the bore 65 between the flange 96 and the hot tube 42 outer surface to prevent air leakage from the annular chamber 92 into the holding chamber 53. Cold tube 41 is slipped over tubular extension 98 integral with generator 91. Threaded collar 101 is formed integral with cold tube 41. The hot tube 42, the cold tube 41 and the generator 91 are maintained in assembled relation by the cold tube and collar structure 41, 101 being threaded into the bottom end 79 of bore 65 until the assembled components of the vortex tube are abutted against or seated on rim 97 of the bore 65. Collar 101 is shaped so as to press an O-ring 102 between itself and the sides of bore 65 to assure an airtight seal at that point. The functioning of a vortex tube and specific structural details of a vortex tube are particularly set out in Fulton patents U.S. Pat. No. 3,173,273 and U.S. Pat. No. 3,208,229.

The exhaust and admix apparatus 24 is illustrated in FIGS. 2 and 6, 7. The top end of the hot tube 42 is threaded to admix or aspirator block 111. The aspirator block 111 is characterized by a nozzle 115 and four aspirator inlet ports 113 for enclosure air exhaust, all of which intersect at 114. The nozzle 115 is of a substantially smaller diameter than the hot tube 42 diameter and is axially aligned with the hot tube. The four ports 113, of course, open into the holding chamber 53 and are transversely positioned relative to nozzle 115. The aspirator block 111 extends from the holding chamber 53 into the exhaust chamber 54, the block being held in position relative to wall 55 through flange 116 provided on the outside of the

block. The flange 116 abuts the top 58 of the wall 55 as the block 111 is threaded onto the top of hot tube 42 into final position.

The discharge throat 117 of the aspirator block 111 is of substantially the same diameter as the diameter of the hot tube 42 and is positioned in the exhaust chamber 54. The discharge throat 117 of the nozzle 115 is closed by a cap-shaped or pressure relief type poppet exhaust valve 118 that operates automatically in response to the combined enclosure air exhaust and hot tube air exhaust. The poppet or pressure relief type valve 118 includes valve means in the form of an inverted cup 119 to which a sealing disc 121 is fixed, the valve 118 being adapted to close and seal the throat 117 to chamber 54 and, hence, the outside environment surrounding the system 10. The cup 119 is provided with ports 122 radially disposed relative to the throat 117 for discharging the admixed air flow from throat 117 into the chamber 54. An annular ledge 123 near the rim of the cup 119 cooperates with control means in the form of a compression spring 124 interposed between that ledge and the underside of the cap 28 to continuously urge the exhaust valve 118 into sealing and closing relation with the aspirator block 111, thereby automatically maintaining the throat 117 closed to the atmosphere except when the cooling system 10 is operating. It will be particularly noted, therefore, that the inside of the box 11 is sealed from the outside atmosphere surrounding the box because of the O-ring 34 restrained by flange ring 33 about the bottom of the block 26, because of the exhaust structure's valve 118 over nozzle throat 117, and because of the poppet valve head 83 associated with the inlet air.

In operation, the temperature of the inside of the box 11 is sensed by bell 40 and transmitted to the wax plug 71 of the thermostat 23. When the temperature inside the box 11 reaches that limited temperature range of the wax plug 71 which causes it to expand rapidly, the wax plug does so expand and the pin 74 is forced upwardly which causes the poppet valve head 83 to move off the inlet valve seat 82. When the poppet valve 21 opens, compressed air proceeds through inlet port 67, bore 64 and transfer bore 66 into the annular chamber 92 of the generator 91 which surrounds the vortex chamber 94. Typically, such compressed air may be at about 100 p.s.i.g.

As the high pressure air in the annular chamber 92 is introduced into the vortex chamber 94 through inwardly directed tangential nozzles 93 it is accelerated and forced to spin at a very high angular velocity. The vortex chamber 94 has two outlets, one at each end of the vortex tube 22, and all of the air initially travels toward the hot tube end since this outlet of the vortex chamber is of a greater diameter. As the vortex of spinning air is directed from the vortex chamber 94 into the hot tube 42, the spinning air occupies only a volume that is close to the inside surface of the hot tube. As the spinning air travels up the hot tube 42, it grows hot and at the end thereof the restriction or nozzle 115 allows part of the air to escape; this escaping air is heated substantially relative to the incoming high pressure air through transverse bore 66. The restriction or nozzle 115 also imposes a back pressure on the travelling, spinning column of air and causes an unexhausted portion to turn inward toward the center of the hot tube 42 and be driven back through the center thereof while still spinning at high speeds. As the air travels back through the center of the hot tube 42 it passes through the center of vortex chamber 94, into the cold tube, and into the panel box 11; by the time it passes through the generator into the cold tube 41 it has become very cold. Basically, and from a theoretical standpoint, the BTUs of heating imparted by the vortex tube to the hot exhaust air approximately equals the BTU's of cooling imparted to the cold exhaust air.

As the refrigerated air passes from the cold tube 41 it is directed through the flexible tubing 43 and out into the inside of box 11. The refrigerated air causes the air in box 11 to be vented through the bores 59 of base block 26 into the holding chamber 53. From the holding chamber 53 the enclosure air

exhaust is aspirated with the hot air from the hot tube 42 by admixture at point 114 in aspirator block 111, all exhaust air (from both box 11 and from hot tube 42) thereby being exhausted through exhaust apparatus 24. All air then leaves the exhaust apparatus 24 through throat 117 in block 111 and poppet valve 118, the cap 119 of the poppet valve only opening when the pressure in throat 117 of the aspirator block 111 exceeds the predetermined or control level set by spring 124.

Overcooling cannot occur since the wax plug 71 in thermostat 23 retracts to its normal volume upon cooling, thereby permitting the pin 74 to retract through the urging of spring 88 when the temperature inside the box 11 drops back below that temperature range to which wax plug 71 is most sensitive. This, of course, permits inlet poppet valve 83 to close which stops the flow of compressed air to vortex tube 22 until the temperature inside the box rises once again.

Having described in detail the preferred embodiment of our invention, what we desire to claim and protect by Letters Patent is:

1. A cooling system particularly useful with sealed, substantially sealed or unsealed enclosures comprising

a vortex tube that creates a cold air flow and a hot air flow from use of compressed air, said vortex tube including a hot tube and a cold tube with a generator disposed between said hot and cold tubes, and said cold tube being adapted for connection with the enclosure and said generator being adapted for connection with a compressed air source,

exhaust structure connected with said system for exhausting enclosure air and hot tube air to the atmosphere surrounding said system, and

admix structure operatively connected with said exhaust structure to admix the hot tube air exhaust with the enclosure air exhaust and, thereafter, discharge the combined exhaust to the atmosphere.

2. A cooling system as set forth in claim 1 including

an air inlet valve connected between said vortex tube and the compressed air source, and

a thermostat associated with said air inlet valve, said thermostat being adapted to sense the temperature within the enclosure, to cause said inlet valve to open when the enclosure temperature exceeds a desirable level, and to cause said inlet valve to close when the enclosure temperature has been cooled to a desirable level, said system thereby functioning as a cooling device which operates on compressed air to provide refrigerated air to the inside of the enclosure when same requires cooling.

3. A cooling system as set forth in claim 2 wherein said cooling system is mounted relative to an enclosure so that said thermostat senses the temperature of the air adjacent the top of said enclosure, and including

ducting connected with said cold tube, the open end of said ducting being disposed in proximity to the bottom of said enclosure.

4. A cooling system as set forth in claim 1 wherein said admix structure includes

an aspirator connected with said hot tube, said aspirator being supplied with hot air exhaust from said hot tube, and

porting adapted to connect said aspirator with an enclosure, the combined air exhaust of hot tube air and enclosure air being admixed by said aspirator.

5. A cooling system as set forth in claim 4 including

a housing which carries said vortex tube and said exhaust structure in operating relation, said housing including structure that defines a holding chamber which substantially surrounds at least a portion of said hot tube, said porting connecting the enclosure with said holding chamber, and the inlet port to said aspirator for the enclosure air exhaust being located in said holding chamber.

6. A cooling system as set forth in claim 5 wherein said housing includes

a base block which defines a bore within which said vortex tube is mounted, and

wherein said porting includes at least one exhaust bore defined in said base block that extends from an exposed face of said base block and connects with said holding chamber, the exposed face of said base block being presented to the inside of an enclosure upon assembly therewith.

7. A cooling system as set forth in claim 4 wherein said exhaust structure includes

an outlet valve associated with the exhaust throat of said aspirator, the head of said outlet valve being normally urged closed against the exhaust throat of said aspirator and being opened only when the pressure therein achieves a predetermined level.

8. A cooling system as set forth in claim 7 including structure that defines an exhaust chamber, said outlet valve being positioned in said exhaust chamber so that said exhaust chamber initially receives the combined exhaust air flows from said aspirator, and said exhaust chamber having ports by which the combined exhaust air flows from said hot tube and the enclosure are discharged to the atmosphere.

9. A cooling system as set forth in claim 1 wherein said system is adapted to be connected with an enclosure through a single hole defined in the enclosure and comprising

sealing structure associated with said system so as to seal the interior of the enclosure from the atmosphere through said hole once said system is mounted in operating relation with the enclosure.

10. A cooling system particularly useful with sealed, substantially sealed, or unsealed enclosures, said cooling system being operable to provide refrigerated air to an enclosure, comprising

a vortex tube that operates to create a cold air flow and a hot air flow from use of a compressed inlet air flow, said vortex tube including a hot tube and a cold tube with a generator disposed between said hot and said cold tubes, and said cold tube being adapted for connection with the enclosure and said generator being adapted for connection with a compressed air source,

exhaust structure connected with said system for exhausting enclosure air and for exhausting hot tube air to the atmosphere surrounding said system,

valve means interconnected with said exhaust structure for cooperation with at least one of the enclosure air exhaust and the hot tube air exhaust, and

control means interconnected with said valve means and adapted to open and close said valve means automatically, said valve means being automatically opened by said control means to exhaust that one air exhaust through said exhaust structure to the atmosphere when said vortex tube is operating and being automatically closed by said control means to maintain said exhaust structure closed to the atmosphere surrounding said system as to that one air exhaust when said vortex tube is not operating.

11. A cooling system as set forth in claim 10 wherein said valve means and said control means are in the form of a spring loaded pressure relief type valve.

12. A cooling system as set forth in claim 10 wherein said valve means is also interconnected with said exhaust structure for cooperation with the other of the hot tube air exhaust and the enclosure air exhaust, said valve means being automatically opened by said control means to exhaust that other air exhaust through said exhaust structure to the atmosphere when said vortex tube is operating and being automatically closed by said valve means to maintain said exhaust structure closed to the atmosphere surrounding said system as to that other air exhaust when said vortex tube is not operating.

13. A cooling system as set forth in claim 12 wherein said valve means and said control means are in the form of at least one spring loaded pressure relief type valve.

14. A cooling system as set forth in claim 12 including admix structure operatively connected with said exhaust structure to admix the hot tube air exhaust with the enclosure air exhaust and, thereafter, discharge the combined exhaust to the atmosphere.

15. A cooling system as set forth in claim 14 wherein said valve means and said control means are in the form of a pressure relief type valve, the admixed enclosure air exhaust and hot tube air exhaust being exhausted to the atmosphere through said valve.

16. A cooling system as set forth in claim 15 including a housing that defines an exhaust chamber, said valve being positioned in said exhaust chamber so that said exhaust chamber initially receives the admixed exhaust air flow, and said exhaust chamber having ports by which the combined exhaust air flow is discharged to the atmosphere.

17. A cooling system as set forth in claim 12 including an air inlet valve connected between said vortex tube and the compressed air source, and a thermostat associated with said air inlet valve, said thermostat being adapted to sense the temperature within the enclosure, to allow said inlet valve to open when the enclosure temperature exceeds a desirable level, and to allow said inlet valve to close when the enclosed temperature has been cooled to a desirable level, said system thereby functioning as a cooling system which operates only when the enclosure requires cooling.

18. A cooling system as set forth in claim 10 wherein said system is structured so that same can be connected in mounted relation with the enclosure through utilization of a single hole in that enclosure, the refrigerated air passing from the vortex tube into the enclosure through that hole and the enclosure air exhaust passing out from the enclosure through that hole.

19. A cooling system as set forth in claim 12 wherein said

system is structured so that same can be connected in mounted relation with the enclosure through utilization of a single hole in that enclosure, the refrigerated air passing from the vortex tube into the enclosure through that hole and the enclosure air exhaust passing out from the enclosure through that hole.

20. A cooling system as set forth in claim 19 including sealing structure associated with said system so as to close the interior of the enclosure through the hole from the atmosphere once said system is mounted in operating relation with the enclosure.

21. A cooling system as set forth in claim 20 wherein said valve means and control means are in the form of at least one spring loaded pressure relief type valve.

22. A cooling system as set forth in claim 21 including an air inlet valve connected between said vortex tube and the compressed air source, said inlet air valve being of the non-modulating type, and

a thermostat associated with said air inlet valve, said thermostat including a sensor adapted to sense the temperature within the enclosure and mechanical structure interconnected with said sensor that is adapted to open said inlet valve automatically when the enclosure temperature exceeds a desirable level and to close said inlet valve automatically when the enclosure temperature has been cooled to a desirable level, said system thereby functioning as a cooling device which operates on compressed air only to provide refrigerated air to the inside of the enclosure when same requires cooling.

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