

[54] GAS COOLING AND DRYING SYSTEM FOR CORONA DISCHARGE OZONE GENERATING UNIT 3,750,556 8/1973 Duke et al. 98/2.11

[75] Inventors: Ronald A. Schultz, Berkeley; Robert I. Tenney, Deerfield, both of Ill.

[73] Assignee: Ozone Incorporated, Deerfield, Ill.

[22] Filed: Aug. 19, 1974

[21] Appl. No.: 498,845

[52] U.S. Cl. 250/533; 62/5; 250/536; 250/541

[51] Int. Cl. C01b 13/12; F25b 9/02

[58] Field of Search 55/17; 62/5; 250/533, 541; 250/536-538

[56] References Cited

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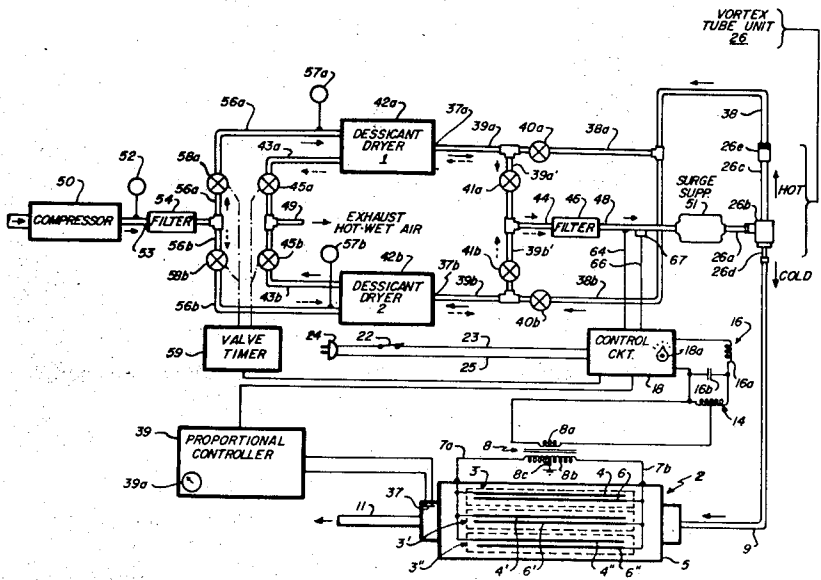
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Primary Examiner—John H. Mack
Assistant Examiner—Aaron Weisstuch
Attorney, Agent, or Firm—Wallenstein, Spangenberg, Hattis & Strampel

[57] ABSTRACT

A unique combination of one and preferably a pair of gas drying units for drying oxygen containing gas to be ozonized and a corona discharge ozone generating unit is provided by a vortex tube unit having an inlet for receiving dried air to be ozonized, a cool air outlet carrying the slow moving molecules of the gas to the inlet of the ozone generating unit and a warm air outlet connected through passageways extending to openings in the drying units for circulating warm air for drying saturated gas drying units. Where two drying units are provided, the air to be dried and ozonized is preferably alternately automatically fed to the inputs of the two drying units, and the warm air outlet of the vortex tube unit is alternately fed through the air drying unit so the drying unit which at a given instant is not receiving air to be dried is itself being dried by warm de-moisturizing air.

7 Claims, 6 Drawing Figures



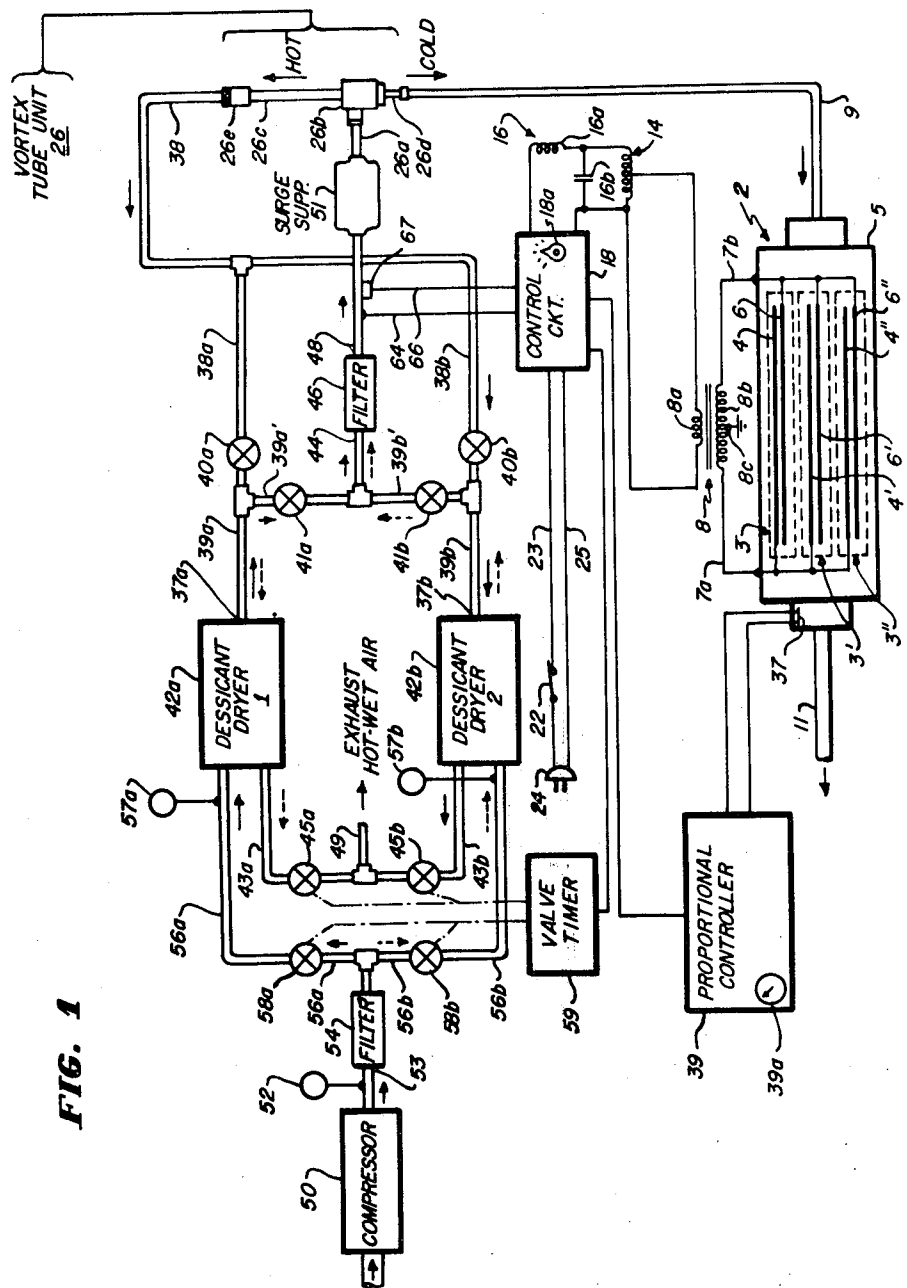


FIG. 1

FIG. 2

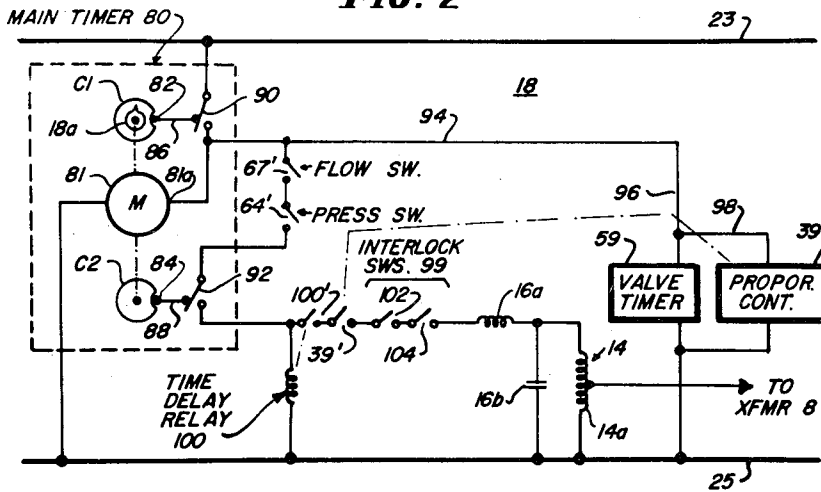
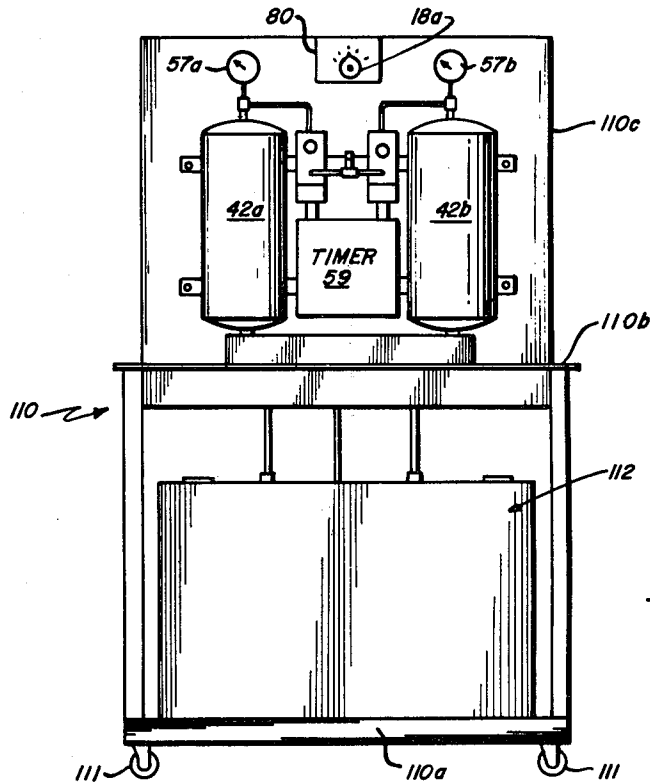


FIG. 3

FIG. 4

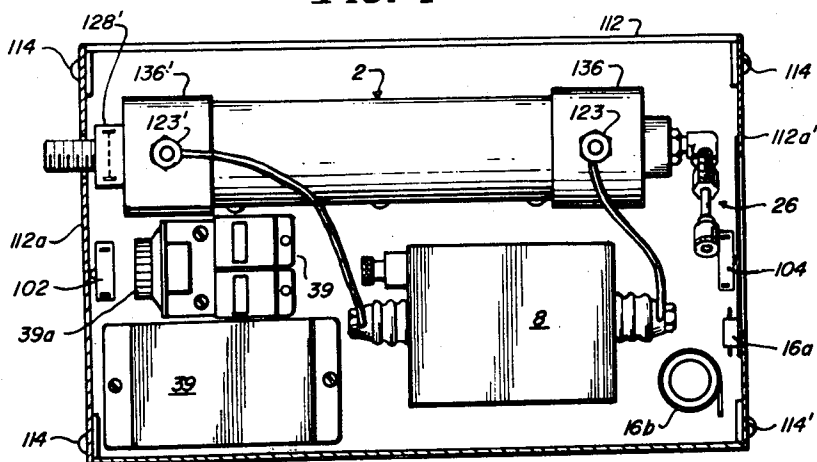


FIG. 5

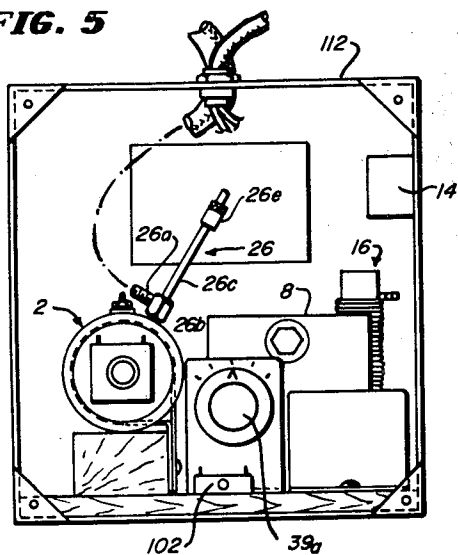
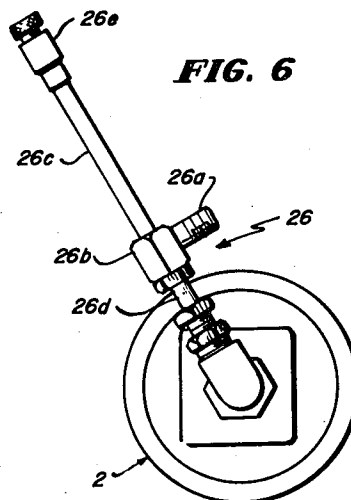


FIG. 6



GAS COOLING AND DRYING SYSTEM FOR CORONA DISCHARGE OZONE GENERATING UNIT

BACKGROUND OF THE INVENTION

Ozone is produced by passing oxygen or a mixture of gases containing oxygen, such as air, through the corona existing between pairs of electrodes which are separated by an air gap and a dielectric shield and which are connected to a high voltage source. This corona evolves heat, only a fraction of which (about 34 kilocalories per gram mol) is required for the formation of ozone. If the excess heat is not dissipated, the temperature of the effluent gases, the electrodes, dielectric shield and housing is elevated. This leads to decomposition of a portion of the ozone which is approximately 100°C breaks down almost as soon as it is formed. The higher the temperature the more rapidly does the ozone decompose. The heat may also cause the resistive properties of the dielectric shields utilized to change so that they perforate, causing short circuits within the electrode array.

In the past, a portion of the heat produced by the ozonation process was dissipated by enlarging the electrode surface area in respect to the length of the corona filled air gap. This creates problems of warping with resulting short circuits. Others have sought to cool the electrodes by passing a refrigerant such as water or brine through and/or over them. Aqueous refrigerants cannot be used within the corona area so are confined to use within the electrode structure. This calls for enlarging the physical size of the cooled electrode and requires that one side of the electrical circuit be grounded, thereby preventing the use of center tap grounded transformer windings to reduce the magnitude of the voltages with respect to ground present in the equipment involved.

The dielectric shield generally used between the electrodes of an ozone generating unit is made of a glass or similar material which can be readily cracked or punctured when excessive stresses are applied thereto by hot spots or wide variations in temperature of the air moving over different portions thereof. Cracking or puncturing of the dielectric shield will destroy the insulating qualities thereof and cause arcing and destruction thereof. Hot spots can be caused by an unequal distribution of the electric field due to variations in the spacing between the electrodes, and wide extremes of temperature of the air moving over the dielectric shield can be caused by uncontrolled air inlet temperatures and ozonation. It may be that while it has been proposed to pre-cool air to be ozonized in an ozone generating device, as for example disclosed in U.S. Pat. No. 3,024,185 to Fleck, such pre-cooling has not been commercially utilized to any significant extent because it increases the possibility of undesired temperature ranges of the air flowing over the dielectric shields. Thus, most commercial ozone generating units utilize grounded water-cooled jackets surrounding the outermost electrodes thereof which result in expensive bulky equipment which in many cases does not adequately cool portions of the ozone cooling generating unit remote from the cooling jackets.

The air to be ozonized should be dry to prevent insulation breakdown and to prevent the formation of nitric acid which might corrode the electrodes. The air should also be free of oil and other combustibles. It is

common, therefore, to pass air to be ozonized through filters and an air drying unit, which is generally a unit containing a desiccant material which absorbs moisture. When this desiccant material becomes saturated, it is necessary to dry the same. In some cases, a pair of such drying units are utilized, one of which is used at a given time for drying the air fed to the ozone generating unit and the other of which may be dried by passing warm air therethrough obtained by passing ambient air through a heater and circulating the same through the drying unit in any suitable way.

To summarize some of the deficiencies of prior ozone generating systems, they were generally of relatively bulky construction and, therefore, not particularly suitable for the manufacture of portable ozone generating equipment, were relatively expensive to manufacture, and in many cases were relatively unreliable due to pitting or breaking of the dielectric shields used therein. Moreover, they frequently required the presence of an operator to check temperatures in the system and to watch the condition of the air drying units so the operator could switch over from a saturated drying unit to a previously dried drying unit to insure the feeding of dry air to the ozone generating unit.

SUMMARY OF THE INVENTION

The present invention represents a substantial improvement over the prior art by reducing the cost of the ozone generating equipment and the size thereof and its dependence on the use of a circulating coolant liquid so it can, where desired, be mounted on a portable cart where it can be moved easily to point where its use is desired and be placed into operation merely by connecting it to a source of electric power and a source of air to be ozonized under pressure. Moreover, in accordance with the preferred aspect of the invention, the equipment is automatically controlled in a manner which insures its reliable operation even in the absence of operating personnel.

In accordance with one of the features of the present invention, there is provided a unique application of a device known as a vortex tube unit which is a relatively very compact T-shaped structure comprising an inlet tube, a warm air outlet tube and a cool air outlet tube, all joining an air rotating chamber which separates faster moving molecules from the slower and cooler moving molecules and directs the faster moving molecules to the warm air outlet tube and the slower moving molecules to the cool air outlet tube. By suitably controlling the ratio of the molecules collected by the cool and warm air outlet tubes a suitable temperature differential is obtained in the air leaving the warm and cool air outlet tubes. For example, where 10 percent -30 percent of the air passing into the vortex tube unit is collected by the warm outlet tube, the temperature of the air therein can be from 220°-310°F hotter than the remaining 70 percent -90 percent of the air introduced into the unit which passes out of the cool air outlet tube at a temperature below about 50°F. These temperature examples assume an input air temperature to the vortex tube unit in the range of from 90° to 119°F. The cool air flowing from the cool air outlet tube of the vortex tube unit is fed to the input of a corona discharge ozone generating unit, and the warm air flowing from the warm air outlet tube of the vortex tube unit is fed to a gas drying unit not in use for de-moisturizing the same. There is thus no need for bulky, costly water jackets

and air heaters heretofore used in most commercial ozone generating systems.

In accordance with a specific aspect of the invention, timer controlled valves are provided to direct the flow of the air to be ozonized into one of the gas drying units and the warm air of the warm air outlet tube of the vortex tube unit to another air drying unit and to periodically switch the flow of these air streams therebetween, so the presence of an operator is made unnecessary.

The above and other advantages and features of the invention will become apparent upon making reference to the specification to follow, the drawings and the claims.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram showing the various paths of flow and the means for drying, cooling and ozonizing the air in accordance with the present invention;

FIG. 2 is a circuit diagram of the control circuit portion of the air drying, cooling and ozonizing system of FIG. 1;

FIG. 3 is a view of a portable cart carrying all of the apparatus shown in FIG. 1, except for the air compressor;

FIG. 4 is a horizontal sectional view through the housing shown in the bottom portion of the cart shown in FIG. 3 in which housing the ozone generating unit, high voltage transformer and associated electrical apparatus is housed;

FIG. 5 is an end view of the housing shown in FIG. 4 with an end panel removed; and

FIG. 6 illustrates the connection of the vortex tube unit to the ozone generating unit shown in smaller scale in FIG. 5;

DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

In FIG. 1 is shown the air drying, cooling and ozonizing system of the invention which includes a corona discharge ozone generating unit 2 having three ozone generating tube assemblies 3, 3' and 3'' banded together in a common bundle and supported within a cylindrical casing 5 made of a suitable molded insulating material like poly vinyl chloride. (The design of the ozone generating unit 2 illustrated in the drawing is a joint invention of Romuald Slipiec and the present co-inventor Ronald Schultz.) The ozone generating tube assemblies 3, 3' and 3'' respectively have pairs of electrodes 4-6, 4'-6' and 4''-6'' separated by insulating tubes (not shown in FIG. 1) made of dielectric material like glass. The corresponding electrodes of the various ozone generating tube assemblies are connected to conductors 7a and 7b respectively extending to the opposite ends of the secondary winding 8b of a high voltage transformer 8. Because of the method of cooling of the ozone generating unit 2, the secondary winding 8b of the transformer 8 has a grounded center tap 8c which reduces voltages with respect to ground to one half that which would be present in the absence of such a ground, to reduce insulating requirements and the hazards of the system in comparison to the conventional method of cooling ozone generating units by grounded water cooled jackets.

The primary winding 8a of the high voltage transformer 8 is shown connected to an adjustable autotransformer 14 whose input is connected to a suitable filter circuit 16 including an inductor 16a and a capaci-

tor 16b, and a control circuit 18 to be described in detail and shown in FIG. 2 which controls the feeding of energizing voltage to the autotransformer 14. The control circuit may control 110 to 220 volts AC appearing on input power lines 23-25. A manually operable on-off switch 22 may be associated with one of the lines 23 extending to a power plug 24 for controlling the feeding of electric power to the entire system shown in FIG. 1.

One of the important aspects of novelty of the air drying, cooling and ozonizing system shown in FIG. 1 is the unique application of the vortex tube unit 26 which has not heretofore been considered for use as an air cooling or heating means for any purpose associated with ozone generating devices, let alone in the specific manner shown in FIG. 1 and now to be described. The vortex tube unit 26 has an inlet conduit 26a extending to the head portion 26b where the inlet air is caused to flow in a circular path in a manner wherein the higher speed air molecules are collected by a warm air outlet conduit 26c and the slower moving molecules are collected by a cool air outlet conduit 26d. The size of an aperture at the end of the warm air outlet conduit 26c is controlled by suitable adjustable means 26e. The adjustment of this aperture size varies the ratio of the relatively high and low speed molecules reaching the warm and cool air outlet conduits 26c and 26d, thereby varying the relative temperatures of the air flowing in these conduits.

In one successful operating ozone generating system, the following exemplary conditions were present:

inlet air pressure to vortex tube unit 26 - 80 psi.

flow rate of inlet air - 10 cfm

flow rate of air exiting from cool air conduit 26d - 8 cfm

temperature of air exiting from cool air outlet conduit 26d - 44°F

Pressure of air exiting from cool air conduit 26c - 10 psi.

flow rate of air exiting from warm air outlet conduit 26c - 2 cfm.

The temperature of the air exiting from the cool air outlet conduit 26d of the vortex tube unit 26 which is connected to the conduit 9 extending to the inlet of the ozone generating unit 2 should be kept within certain limits to assure both the effective operation of the ozone generating unit 2 and prevent destruction of the dielectric tubes to be described which separate the various pairs of electrodes 4-6, 4'-6' and 4''-6''. The dielectric tubes to be described are made of a glass or other similarly frangible material which can crack when subjected to stresses caused, for example, by wide temperature differentials between the ends thereof. As previously indicated, the main purpose of the cooling of the air passing into the ozone generating unit 2 is to keep the temperature conditions within the unit sufficiently low that the ozone will not immediately dissociate upon being formed between the electrodes of the unit. It is most desirable, therefore, that the temperature of the incoming air fed to the ozone generating unit does not exceed about 50°F for most effective results. The temperature of the air entering the ozone generating unit 2 has a lower limit from the standpoint of avoiding extremes of temperatures within the unit which might damage the dielectric tubes referred to. In the equipment being described this lower limit is desirably of the order of magnitude of about 25°F.

The speed of the inlet air through the ozone generating unit is also an important factor since the speed of movement also effects the rate of cooling which the air involved achieves within the ozone generating unit. In ozone generating units of the capacity with which the present invention has its most important application (i.e., ozone generating units capable of generating in the range of from 2 to 500 grams of ozone per cubic foot of air), the air flow rate is desirably in the range of from 1.3 to 1.5 cubic feet per minute per square foot of electrode surface area.

Since the actual temperature conditions within the ozone generating unit are not always predictable, to insure that the temperature conditions within the unit do not reach damaging levels or levels where the ozone will readily disassociate and therefore cause the unit to operate inefficiently, there is most preferably provided means for varying the average on time of the ozone generating unit to limit the average amount of heat generated within the unit caused by the ozone formation process as previously described. In the most preferred form of the system illustrated, this is accomplished by utilizing a temperature responsive means 37 placed at the outlet end of the ozone generating unit 2 to sense the temperature conditions of the ozonized air flowing from this unit. When the temperature of this air reaches an undesirably high level which would cause ozone dissociate or dielectric tube damaging extremes of temperature within the unit, a control unit 39 is rendered operable to disconnect the voltage to the high voltage transformer 8 either on a continuous basis until the temperature conditions referred to drop to a desired level or by varying the relative repetitive on and off periods during which voltage is applied to the transformer 8. In the latter case, the control unit 39 may be a conventional proportional controller which has a temperature set point manual control knob 39a which sets a particular control temperature. When the temperature of the air exiting from the ozone generating unit 2 is at the control temperature, a 50 percent duty cycle could be provided where energizing voltages to the high voltage transformer are alternately switched on and off over equal periods of time. When the temperature of the outlet air exceeds the set limit of the proportional controller by progressively increasing amounts, the proportion of time in each control cycle the voltage applied to the high voltage transformer becomes progressively less than 50 percent. On the other hand, when the temperature of the air exiting the ozone generating unit 2 progressively decreases from the set point temperature, the proportion of the on period of each control cycle progressively increases from 50 percent. In one exemplary proportional controller, the controller operated at a frequency of 5 cycles per minute, and provided a set point at 90°F where continuous off and continuous on conditions respectively for temperatures ½° above and below the set point temperature.

The portion of the air flow and control system just described which automatically limits the outlet temperature of the ozone generating unit is a sole invention of the applicant Robert Tenney.

The warm air produced by the vortex tube unit 26 is uniquely used in the air flow and control system shown in FIG. 1 to maintain the air to be ozonized in a dry condition. Moist air in the ozone generating unit undesirably greatly reduces the efficiency of the ozone generating process and can create short circuit conditions

within the ozone generating unit. To this end, the warm air outlet conduit 26c of the vortex tube unit 26 is connected to a conduit 38 leading to a pair of branch conduits 38a and 38b in which a pair of one way pressure responsive valves 40a and 40b are located for selectively opening or closing the associated branch lines. Each of these valves is open when the pressure on the side thereof nearest the warm air outlet conduit 26c of the vortex tube unit 26 is higher than the pressure on the opposite side thereof and is closed when the pressure on the side thereof nearest the warm air outlet conduit 26c of the vortex tube unit 26 is equal to or less than the pressure on the opposite side thereof.

The branch conduits 38a and 38b respectively join a pair of passageways extending between openings 37a and 37b in a pair of dryer units 42a and 42b and a common conduit 44 extending or connected to the inlet of the vortex tube unit 26. The latter passageways are formed by conduit sections 39a-39a' and 39b-39b' extending to the common conduit 44. One way pressure responsive valves 41a and 41b are respectively located in the conduit section 39a' and 39b'. Branch conduits 38a and 38b intersect the juncture of the conduit sections 39a-39a' and 39b-39b' respectively. Each of the pressure responsive valves 41a and 41b is open when the pressures on the side thereof nearest the associated dryer is higher than the pressure on the opposite sides thereof and is closed when the pressure on the sides of the valves 41a and 41b nearest the associated dryer is equal to or less than the pressure on the opposite side thereof. The conduit 44 is connected to the inlet side of vortex tube unit 26 by a filter 46 which filters non-gaseous substances from the air, a conduit 48, and a surge suppressor 51 which eliminates or reduces sudden substantial pressure changes occurring in the input thereto.

Associated with the conduit 48 adjacent the suppressor 51 and the inlet of the vortex tube unit 26 are a pair of control elements which respond to the pressure and the flow rate of the air flowing in the conduit 48. Thus, a pressure responsive switch (not shown in FIG. 1) is electrically connected by conductor means 64 to the control circuit 18. The pressure responsive switch prevents the control circuit 18 from connecting the power lines 23 and 25 to the autotransformer 14 until the pressure within the conduit 48 reaches a given desired value which will insure proper operation of the vortex tube unit 26. Conductor means 66 extends between a flow rate unit 67 attached to the conduit 48 and the control circuit 18. The flow rate unit includes contacts, not shown in FIG. 1, which operate when the flow rate reaches a given desired value. It is also undesirable to permit the ozone generating unit to be operable unless air is flowing therethrough at a desired minimum rate. Thus, when both proper pressure and flow rate conditions exist, the control circuit 18 is conditioned to interconnect the power lines 23 and 25 with the autotransformer 14, provided the timer and delay means to be described forming part of the control circuit 18 have been rendered operable.

The dryers 42a and 42b each provide for the flow in one direction or the other therethrough of air to be dried and ozonized or warm air for drying the interior thereof. The dryers 42a and 42b may be conventional dryers which include dessicant materials which absorb moisture and which become saturated and need to be dried in order to be once again effective to perform a

moisture absorbing function. The openings 37a and 37b in the dryers 42a and 42b each act in one mode of operation of the associated dryer as an exitway for dried air and in another mode of operation thereof as an entryway for warm de-moisturizing air from the warm outlet conduit 26c of the vortex tube unit 26. When the opening 37a or 37b of the dryer 42a or 42b acts as an exitway for dried air, the pressure thereof will effect closure of the valve 40a or 40b in the associated conduit branch line 38a or 38b, and the opening of the valve 41a or 41b in the branch conduit 39a' or 39b'. At any one time, only the dryer 42a or 42b will receive air to be dried, and thus at any given moment of operation of the system the opening 37a or 37b of one of the dryer units 42a or 42b will be connected to the inlet of the vortex tube unit 26 while the other of same will be connected to the warm air outlet conduit 26c of the vortex tube unit 26. Thus, while one of the dryers is being used for drying air being fed therethrough, the other dryer is automatically being de-moisturized by warm air fed thereto from the vortex tube unit 26.

The source of air to be ozonized initially passes through a compressor 50, which may be part of a permanent installation in a given plant in which the ozonizing operation is to be performed. The compressor delivers at the output thereof air at a suitable pressure (for example, 90 lbs. per square inch) as measured by a suitable pressure meter 52 associated therewith. The source of air under pressure is then fed through a conduit 53 to a suitable filter 54 which removes most of the non-gaseous material carried in the air. The air leaving the filter 54 then flows to one of two conduits 56a or 56b in which are located timer controlled solenoid valves 58a or 58b. The conduits 56a-56b extend respectively to the inputs of the dryer units 42a and 42b at which pressure meters 57a or 57b may be located. The warm de-moisturizing air passing through the dryers 42a or 42b at any given moment leaves the associated dryer through an exit conduit 43a or 43b in which is located a timer controlled solenoid valve 45a or 45b. The conduits 43a and 43b join a common conduit 49 extending to a discharge point for moist air. An electrically operated timer 59 controlled by the control circuit 18 operates the pairs of solenoid valves 45a-45b and 58a-58b so that only one of the valve pairs 45a-58b or 45b-58a are open at one time, so that air to be dried flows through one of the dryers while the other dryer receives warm de-moisturizing air from the warm air outlet conduit 26c of the vortex tube unit 26.

In accordance with a sole invention of co-inventor Robert Tenney, upon closure of the main power switch 22 to initiate energization of the system illustrated in FIG. 1, the control circuit 18, which may include another timer to be described, initially energizes the valve timer 59 to effect opening of one of the valve pairs 45b-58a or 45a-58b, while keeping the connection between power lines 23-25 temporarily decoupled from the auto-transformer 14. This enables dry air to flush through the ozone generating unit 2 to eliminate moisture which may have previously gained access thereto before voltage is applied thereto. After a given time delay, like five minutes or so, the control circuit 18 then connects power lines 23 and 25 to the autotransformer 14 which energizes the high voltage transformer 8 to start an ozone generating operation within the ozone generating unit 2. The control circuit 18 preferably also includes a timer which is adjusted by a control knob

18a which must be rotated from its home position to enable the control circuit 18 to energize the various electrical devices connected thereto and after a selected time period is returned to home position to de-energize all of the devices. The timer portion of the control circuit 18 is most advantageously so designed that the voltage on the power lines 23-25 will be disconnected from the autotransformer 14 a given period (like five minutes or so) ahead of the time when the valve timer 59 is de-energized to close off the solenoid operated valves 45a-45b and 58a-58b, so the dry air flushes through the ozone generating unit 2 after termination of the corona discharge therein.

Refer now to FIG. 2 which shows an exemplary and preferred control circuit 18. This control circuit includes a main timer 80 having an electric motor 81 with one terminal connected to power line 25 and the other terminal connected to cam operated contacts 90, in turn, connected to power line 23. The movable part of the cam operated contacts 90 is connected to a cam follower 86 which rides on the periphery of a cam C1 having a narrow depression 82. When the cam C1 is in its initial or home position, the cam follower 86 rides within the depression 82 to open the contacts 90 de-energizing the motor 81. The shaft of the cam C1 is turned by the aforementioned manually operable control knob 18a which is rotated from its home position in one direction to a degree depending upon the length the ozone generator unit 2 is to be operated. (Cam C1 is rotatable manually in only this direction to set the timer to the desired timing period.) The shaft of the motor 81 is coupled to the shaft of the cam C1 by suitable gearing so that cam C1 is rotated one revolution for the maximum timing period of the timer. The motor 81 operates the cam C1 in the opposite direction to return the depression 82 thereof to the point where the follower 86 falls therein, resulting in opening of the contacts 90 and de-energization of the timer motor 81. Any rotation of the cam C1 from its home position will cause the cam follower 86 to ride upon the raised portion of the cam surface to close the contacts 90.

Cam C1 is ganged to a second cam C2 which has a 5 minute longer depression 84. A cam follower 88 carrying the movable part of cam operated contacts 92 rides on the periphery of the cam C2. When the cam follower 88 rides in the depression 84, the cam operated contacts 92 are open and when it rides on the raised portion of the cam C2 the cam operated contacts 92 are closed. Since the depression 84 of cam C2 is longer by 5 minutes than the very narrow depression 82 of the cam C1, the contacts 92 will close 5 minutes before the contacts 90 as these cams approach their home position where the timer 80 becomes de-energized.

A power bus 94 extends the juncture of electric motor 81 and the cam operated contacts 90, on the one hand, and branch lines 96 and 98 respectively extending to one of the terminals of the valve timer 59 and the proportional controller 39 whose opposite terminals are connected to the other power line 25. Thus, the valve timer 59 and the proportional controller 39 are energized as long as the motor 81 is energized, that is until the cam C1 returns to its home position where the depression 82 thereof receives the follower 86 which then opens the contacts 90 and de-energizes the timer motor 81.

Another branch circuit extends between the power bus 94 and power line 25 and includes a series connec-

tion of the aforementioned pressure responsive switch 64', which closes when a given pressure level is reached in conduit 48 connected to the input of the vortex tube unit 26, a flow rate responsive switch 67' which closes when the air flow in the conduit 48 reaches a given flow rate, contacts 92 and timer delay relay 100.

The autotransformer 14 is located in a branch circuit 99 of the control circuit 18 in parallel with the timer delay relay 100. This branch circuit extends from the power line 25 through the autotransformer winding 14a and filter inductor 16a, contacts 102 and 104 which are interlock switches on panels forming the housing in which a high voltage transformer is located, contacts 39' which are alternately opened and closed by the proportional controller 39 as previously described, and time delay relay contacts 100' of the time delay relay 100. Thus, it can be seen, that the autotransformer winding 14 and the high voltage transformer 8 coupled thereto as shown in FIG. 1 will receive energizing voltage in accordance with the duty cycle determined by the proportional controller 39 beginning 5 minutes after initiation of energization of the main timer 80. The energization of the autotransformer 14 terminates 5 minutes before the timer returns to its home position.

FIGS. 3-6 illustrate the most advantageous form for the ozone generating system of the present invention which is compact, portable and inexpensive in comparison to prior ozone generating systems of similar capacity. As best shown in FIG. 3, all the components shown in FIG. 1, except the compressor 50, are carried on a portable cart 110 on which is supported a metal housing 112 containing, among other things, the ozone generating unit 2, the vortex tube unit 26, the high voltage transformer 8, filter 16 and the autotransformer 14. The cart 110 has an upper shelf 110b from which upwardly extends along the center portion thereof a mounting panel 100c on which may be mounted other portions of the air flow and control system as shown in FIG. 1, such as the dryer units 42a-42b, timer operated valves 45a-45b and 58a-58b, main timer 80 and the other valves 40a-41a and 40b-41b and associated conduits, filter 46 and suppressor 51.

An exemplary positioning of the various elements within the housing 112 are shown in FIGS. 4-6. FIG. 4 illustrates the interlock switches 102 and 104 are normally closed when the end panels 112a and 112a' of the housing 112 are closed and which open when the associated panels are removed from the housing 112 by loosening of screws 114 and 114'.

It should be apparent that the preferred ozone generating system including the various control features therefore previously described result in an exceedingly reliable, compact and economical automatically controlled ozone generating system which can be mounted on a portable cart where desired, so that the equipment can be readily moved to a desired location in a plant.

It should be understood that numerous modifications may be made in the most preferred form of the invention described without deviating from the broader aspects of the present invention.

We claim:

1. In combination, a corona discharge ozone generating unit; means for cooling the corona discharge ozone generating unit comprising a vortex tube unit for receiving gas to be ozonized at a first inlet and separating the high energy gas molecules from the low energy gas molecules therein and delivering the resultant relative-

ly cool gas molecules to a cool gas outlet thereof and the relatively warm gas molecules to a warm gas outlet thereof; a main inlet for an oxygen containing gas to be ozonized; a drying unit providing for the flow in one direction or the other therethrough of gas to be dried and ozonized and including means for absorbing moisture from the gas flowing therethrough which must be periodically dried with warm gas, said gas drying unit having a first inlet at one end into which oxygen containing gas to be dried is to pass into the unit, an outlet for a de-moisturizing gas from which outlet drying gas passes from the unit, and an opening from which dried oxygen containing gas can exit from the unit or drying warm gas can enter the unit; conduit means forming a first passageway interconnecting said main inlet and said first inlet of said drying unit; valve means in said first passageway for selectively opening and closing said first passageway; conduit means forming a second passageway extending between said outlet for de-moisturizing gas of said drying unit and a discharge point therefor; second valve means for said second passageway for selectively opening or closing the same; conduit means forming a third passageway extending between said opening in said drying unit from which dried oxygen containing gas can exit and said inlet of said vortex tube unit; third valve means for said third passageways for closing off the associated passageway leading to said inlet of said vortex tube unit when the opening of the associated drying unit acts as an entryway for de-moisturizing gas and for opening the same when the opening of the associated drying unit is to act as an exitway for dried oxygen containing gas; conduit means forming a fourth passageway extending from the warm air outlet of said vortex tube unit to a point of said third passageway on the side of said third valve means nearest said opening in said drying unit; fourth valve means for said fourth passageway for closing off the associated passageway when the opening in the associated drying unit is to act as an exitway for dried gas to be ozonized and for opening the associated passageway when the opening of said drying unit acts as an entryway for de-moisturizing gas; and conduit means extending between the cool gas outlet of said vortex tube unit and the inlet to said ozone generating unit for feeding sufficient quantities of cold gas through said ozone generating unit to generate the required amount of ozone and to cool the surfaces within said ozone generating unit so that the temperature of the ozone produced does not reach an elevated temperature at which ozone substantially dissociates.

2. An ozone generating system comprising a main inlet for an oxygen containing gas to be ozonized, a first and a second drying unit each providing for the flow in one direction or the other therethrough of gas to be dried and including saturable means for absorbing moisture from the gas flowing therethrough which saturable means must be periodically dried with conduit means forming a pair of passageways respectively connecting said main inlet to inlets for gas to be ozonized of said first and second drying units; a first pair of valve means respectively for said first pair of passageways for selectively opening one or the other of said first pair of passageways; conduit means forming a second pair of passageways respectively extending between outlets for exiting de-moisturizing warm air therefrom of said first and second drying units and a discharge point therefor; a second pair of valve means respectively for said sec-

ond pair of passageways for selectively opening one or the other of said second pair of passageways; a corona discharge ozone generating unit; and means for cooling the corona discharge ozone generating unit and supplying warm de-moisturizing air to said gas drying units comprising a vortex tube unit for receiving air at a first inlet and separating the high energy gas molecules from the low energy gas molecules therein and delivering the resultant relatively cool gas molecules to a cool gas outlet thereof and relatively warm gas molecules to a warm gas outlet thereof; conduit means forming a third pair of passageways respectively extending between openings in said drying units and said inlet of said vortex tube unit, from which dried oxygen containing gas exits or drying warm gas enters the units; a third pair of valve means respectively for said third pair of passageways each for closing off the associated passageways leading to said inlet of said vortex tube unit when the opening of the associated drying unit is to act as an entryway for de-moisturizing gas and for opening the same when the opening of the associated drying unit is to act as an exitway for dried oxygen containing gas; conduit means forming a fourth pair of passageways extending from the warm air outlet of said vortex tube unit respectively to points of said third pair of passageways on the side of said third valve means nearest said openings in said drying units; a fourth pair of valve means respectively for said fourth pair of passageways each for closing off the associated passageways when the opening in the associated drying unit is to act as an exitway for dried gases and for opening the associated passageway when the opening of the associated drying unit acts as an entryway for de-moisturizing gas; and conduit means extending between the cold gas outlet of said vortex tube unit and the inlet to said ozone generating unit for feeding sufficient quantities of cool gas through said ozone generating unit to generate the required amount of ozone and to cool the surfaces within said ozone generating unit so that the temperature of the ozone produced does not reach the elevated temperature at which ozone substantially dissociates.

3. The ozone generating system of claim 2 wherein there is provided timer means for automatically periodically effecting the alternately opening and closing of said first, second, third and fourth pair of valve means so the oxygen containing gas to be ozonized is alternately automatically fed to the inlet of said drying units, said opening of the drying unit receiving oxygen gas to be ozonized is connected to the inlet of the vortex tube unit, said opening of the other drying unit is connected to the warm gas outlet of said vortex tube unit, and said outlet for de-moisturizing gas of the latter drying unit is coupled to said discharge point.

4. The ozone generating system of claim 3 wherein said third and fourth pair of valve means are one way valves operated by the pressure differentials present in said third and fourth pairs of passageways by the flow paths determined by said first pair of valve means.

5. In combination, a corona discharge ozone generating unit; means for cooling the corona discharge ozone generating unit comprising a vortex tube unit for receiving gas to be ozonized at a first inlet and separating the high energy gas molecules from the low energy gas molecules therein and delivering the resultant relatively cool gas molecules to a cool gas outlet thereof and the relatively warm gas molecules to a warm gas outlet thereof; a main inlet for an oxygen containing

gas to be ozonized; a drying unit providing for the flow therethrough of gas to be dried and ozonized and including means for absorbing moisture from the gas flowing therethrough which must be periodically dried with gas, said gas drying unit having inlet means at which oxygen containing gas to be dried and warm de-moisturizing gas are to pass into the unit, outlet means from which de-moisturizing gas passes from the unit and the dried oxygen containing gas can exit from the unit; conduit means forming passageway means interconnecting said main inlet and said inlet means of said drying unit; valve means in said passageway means for selectively opening and closing the same; conduit means forming passageway means extending between said outlet means for de-moisturizing gas and a discharge point therefor; valve means for the last mentioned passageway means for selectively opening or closing the same; conduit means forming passageway means extending between said outlet means from which dried oxygen containing gas can exit from the drying unit and said inlet of said vortex tube unit; valve means for the last mentioned passageway means for selectively opening and closing the same; conduit means forming a passageway mean extending from the warm air outlet of said vortex tube unit to said inlet means for de-moisturizing gas; valve means for the last mentioned passageway means for selectively opening and closing the same; and conduit means extending between the cool gas outlet of said vortex tube unit and the inlet to said ozone generating unit for feeding sufficient quantities of cold gas through said ozone generating unit to generate the required amount of ozone and to cool the surfaces within said ozone generating unit so that the temperature of the ozone produced does not reach an elevated temperature at which ozone substantially dissociates.

6. An ozone generating system comprising a main inlet for an oxygen containing gas to be ozonized, a first and a second drying unit each providing for the flow of gas to be dried and including saturable means for absorbing moisture from the gas flowing therethrough which saturable means must be periodically dried with a de-moisturizing gas; conduit means forming a first pair of passageways respectively connecting said main inlet to respective inlets for gas to be ozonized of said first and second drying units; a first pair of valve means respectively for said first pair of passageways for selectively opening one or the other of said first pair of passageways; conduit means forming a second pair of passageways respectively extending between outlets for exiting de-moisturizing warm air from said first and second drying units and a discharge point therefor; a second pair of valve means respectively for said second pair of passageways for selectively opening one or the other of said second pair of passageways; a corona discharge ozone generating unit; and means for cooling the corona discharge ozone generating unit and supplying warm de-moisturizing air to said gas drying units comprising a vortex tube unit for receiving air at a first inlet and separating the high energy gas molecules from the low energy gas molecules therein and delivering the resultant relatively cool gas molecules to a cool gas outlet thereof and relatively warm gas molecules to a warm gas outlet thereof, conduit means forming a third pair of passageways respectively extending between openings in said drying units and said inlet of said vortex tube unit, from which openings dried oxygen contain-

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ing gas can exit the drying units, a third pair of valve means respectively for said third pair of passageways each for selectively opening or closing the associated passageways, conduit means forming a fourth pair of passageways interconnecting respectively the warm air outlet of said vortex tube unit and openings in said drying units; a fourth pair of valve means respectively for said fourth pair of passageways each for selectively opening and closing the associated passageways, and conduit means extending between the cold gas outlet of said vortex tube unit and the inlet to said ozone generating unit for feeding sufficient quantities of cool gas through said ozone generating unit to generate the required amount of ozone and to cool the surfaces within said ozone generating unit so that the temperature of the ozone produced does not reach the elevated tem-

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perature at which ozone substantially dissociates.

7. The ozone generating system of claim 6 wherein there is provided timer means for automatically periodically effecting the alternately opening and closing of said first, second, third and fourth pair of valve means so the oxygen containing gas to be ozonized is alternately automatically fed to the inlet of said drying units, said opening of the drying unit from which dried oxygen gas to be ozonized passes is connected to the inlet of the vortex tube unit, said opening of the other drying unit into which de-moisturizing gas is to pass into the drying unit is connected to the warm gas outlet of said vortex tube unit, and said outlet for de-moisturizing gas of the latter drying unit is coupled to said discharge point.

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