

[54] CONTROL SYSTEM FOR CORONA
DISCHARGE OZONE GENERATING UNIT

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250/533; 250/537; 250/538; 250/541
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[58] Field of Search 250/532-541

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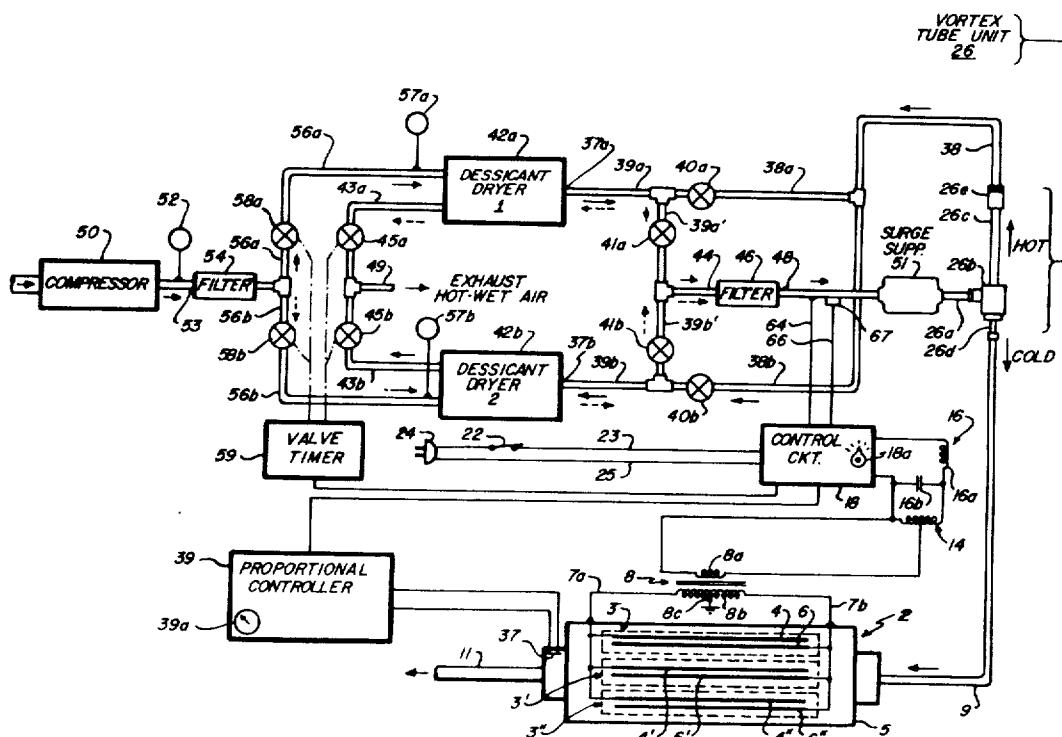
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Hattis & Strampel

[57] ABSTRACT

A control system for an ozone generating system includes a temperature responsive portion which is responsive to the temperature of the ozonized gas by interrupting the coupling of high voltage to the electrodes of an ozone generating unit when the temperature of the ozonized gas reaches a level below the temperature at which said ozonized gas rapidly dissociates, the circulation of the gas to be ozonized through said unit continuing during the interruption of high voltage, and a timer sequencing portion for automatically initiating circulation of air through the ozone generating unit a given predetermined period prior to the coupling of high voltage to the electrodes of the ozone generating unit and for automatically terminating the coupling of high voltage to said electrodes of the ozone generating unit a given period prior to termination of air circulation when ozonization is to be terminated.

11 Claims, 6 Drawing Figures



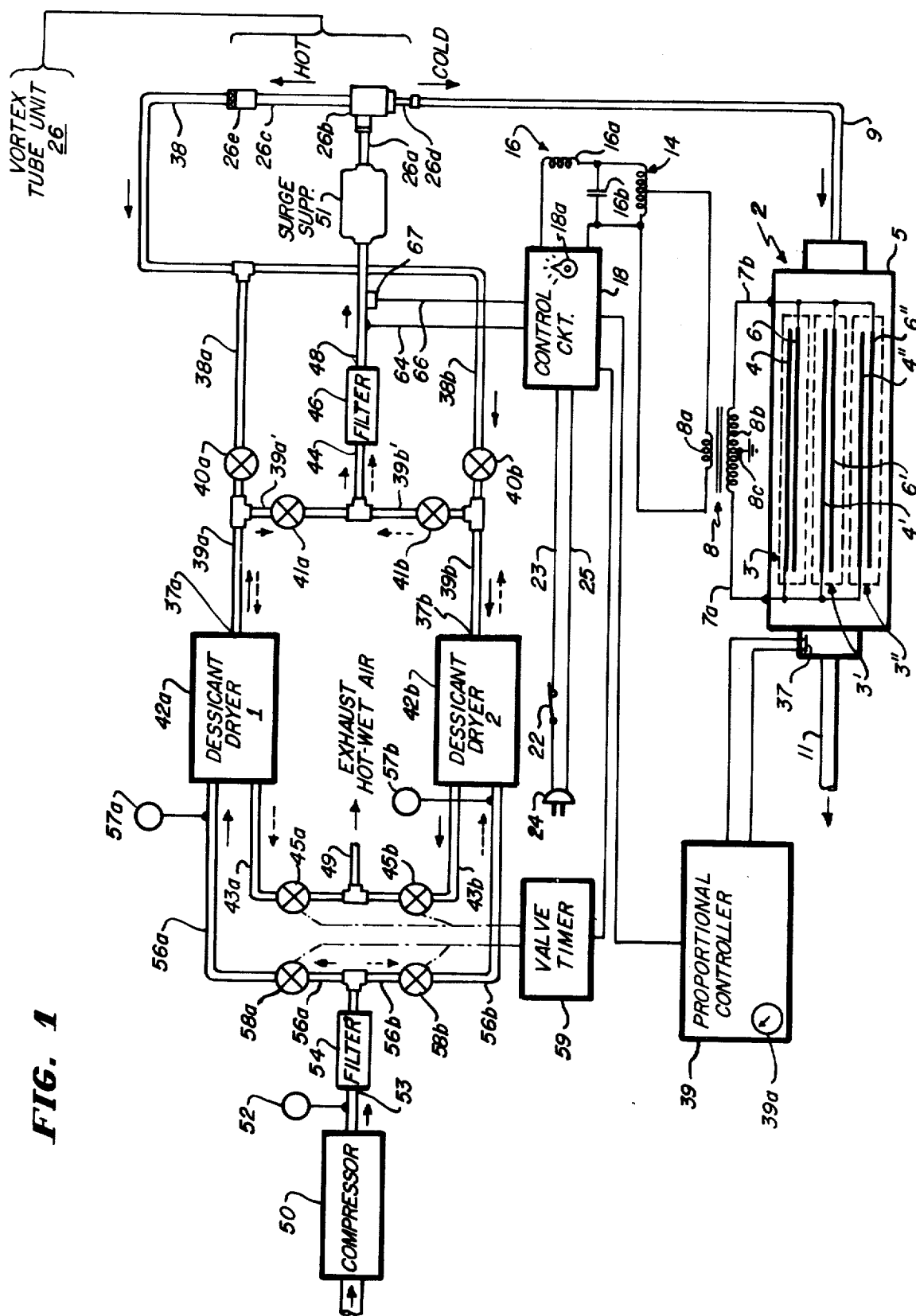


FIG. 1

FIG. 2

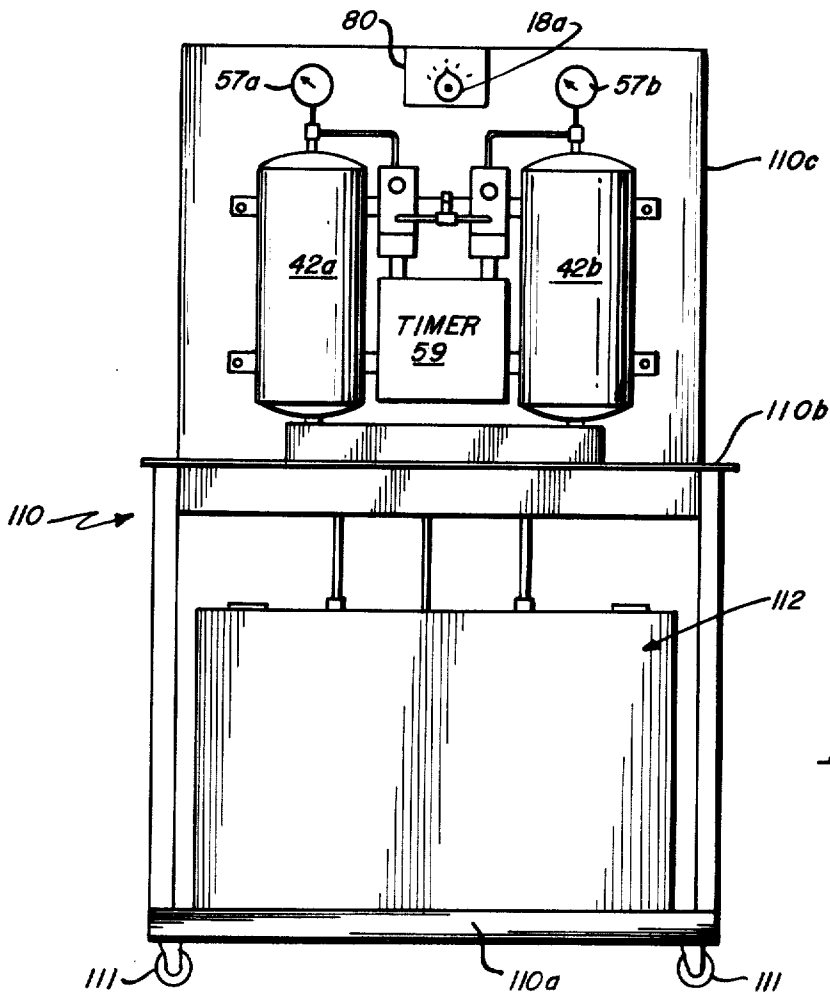
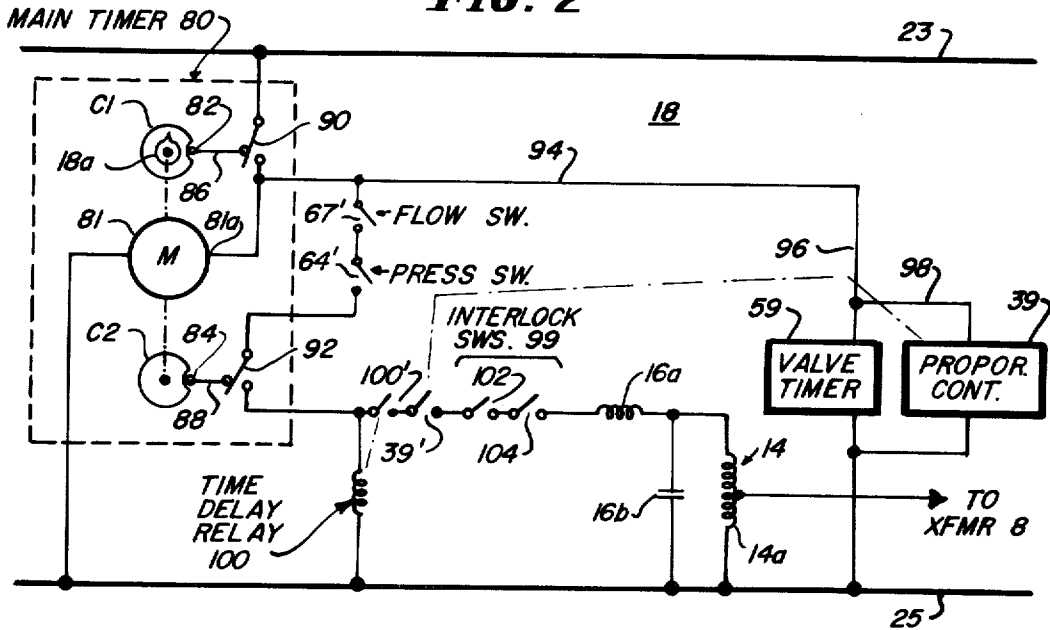


FIG. 3

FIG. 4

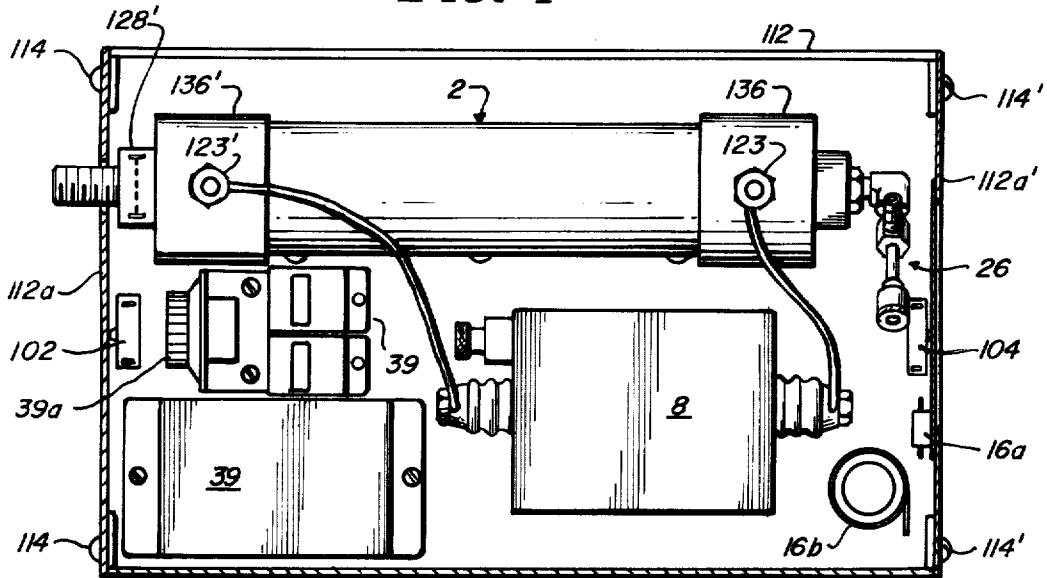


FIG. 5

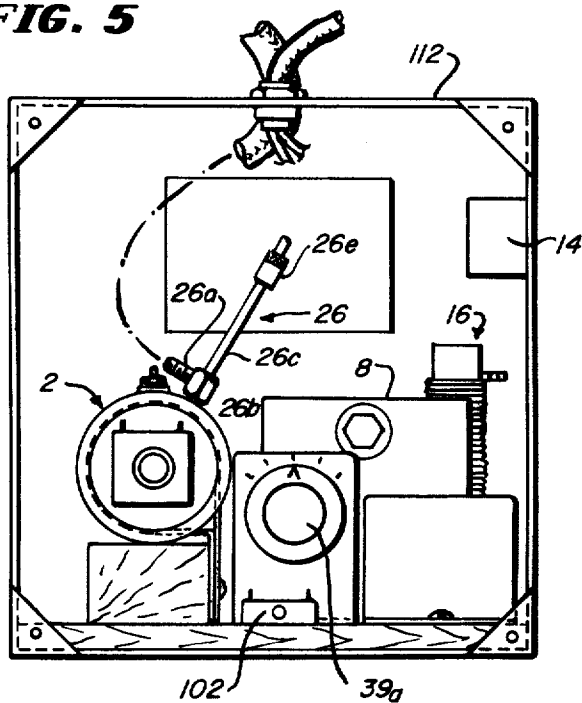
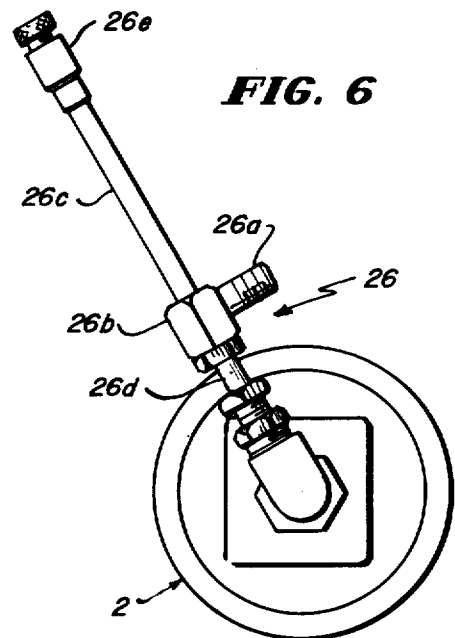


FIG. 6



CONTROL SYSTEM FOR CORONA DISCHARGE OZONE GENERATING UNIT

BACKGROUND OF THE INVENTION

This invention relates to ozone generating equipment wherein 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 AC voltage. 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 at 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 generating unit remote from the cooling jackets.

Prior ozone generating systems require the presence of an operator to start the same into operation, switch over from a saturated air drying unit to one which has been dried out and therefore is ready to receive air to

be ozonized, and to check the temperatures of the air in the system to avoid the destruction of the equipment by excessive temperatures which may be developed in the ozone generating unit.

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

In accordance with one of the features of the invention, overheating of both the ozone generating unit and the ozonized air is prevented by providing means responsive to the temperature of the ozonized gas, and control means responsive to the temperature responsive means for at least temporarily terminating the operation of the ozone generating unit when the temperature of the ozonized gas reaches a level (like about 90°F) below the temperature at which the gas rapidly dissociates, which is generally a temperature of about 150°F. This termination of operation of the ozone generating unit is most advantageously achieved by interrupting the coupling of high voltage to the electrodes of the ozone generating unit so the circulation of the gas to be ozonized continues during the temporary interruption of the high voltage. This has the advantage of purging the equipment of any ozone which could be destructive to various surfaces in the ozone generating unit if circulation of the air to be ozonized were to be terminated before the system is flushed, and also preventing overheating of the dielectric tubes of the ozone generating unit where the flow of air to be ozonized through the ozone generating unit is used to cool the surfaces thereof which are heated by the corona discharge and the release of heat during the ozonation process.

The means for terminating the coupling of high voltage to the electrodes of the ozone generating unit is most advantageously achieved with a proportional controller which may be of conventional design with means for setting a temperature at which the controller alternately establishes and interrupts the presence of high voltage across the electrodes at a duty cycle to maintain a given temperature within the control range thereof. This duty cycle is preferably about 75 percent.

In accordance with another feature of the invention, an automatic control circuit is provided for the ozone generating system which, when the equipment is initially turned on, permits the air circulating means to circulate air through the ozone generating unit a given predetermined period before high voltage is automatically connected to the ozone generating unit. This insures the drying out of the system before application of voltage, which, if applied when there is moisture still accumulated in the system, could result in arcing and damage to the dielectric shields of the ozone generating unit. In accordance with a related feature of the invention, the automatic control circuit also insures when

the equipment is to be turned off that the high voltage is first disconnected from the electrodes of the ozone generating unit before air circulation is terminated, so that ozone is purged from the system and portions of the ozone generating unit which have been heated up can be cooled by the passage of air through the ozone generating unit.

In accordance with another aspect of the invention, the air circulated through the ozone generating unit is pre-cooled by a vortex tube unit which separates relatively fast and slow moving molecules and directs the relatively high speed moving molecules to a warm air outlet and directs the relatively slow moving molecules to a cool air outlet, thereby providing air flows of two widely different temperatures. The cooler air is circulated through the ozone generating unit. The proper operation of a vortex tube unit requires that the pressure of the gas at the inlet side thereof be at least a given pressure to enable the unit properly to separate out the molecules in the proper proportion to achieve an air temperature at the cool air outlet thereof to effect the desired amount of cooling within the ozone generating unit. Additionally, while the vortex tube unit may receive gas at a proper minimum pressure, blockage of air flow through the ozone generating unit would interrupt proper cooling of the ozone generating unit even though the pressure at the inlet to the vortex tube unit has reached or exceeded a desired limit. In accordance with this feature of the invention, there is provided a control circuit which automatically disconnects the feeding of high voltage to the electrodes of the ozone generating unit when the pressure of the air at the inlet to the vortex tube unit drops below a given level and also when the air flow rate drops below a given level.

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 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

FIG. 1 shows an ozone generating unit 2 having three dielectric tube and electrode 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 drawings is a joint invention of Romuald Slipiec and the present co-inventor Ronald Schultz.) The dielectric tube and electrode assemblies 3, 3' and 3'' respectively have pairs of electrodes 4-6, 4'-6' and 4''-6'' separated by insulating tubes (not shown) made of a 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 capacitor 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 or 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 which is a joint invention of myself and Ronald Schultz 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 24 - 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 - 45°F
- pressure of air exiting from warm 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 preventing destruction of the dielectric tubes which separate the various pairs of electrodes 4-6, 4'-6' and 4''-6''. The dielectric tubes 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 disassociate 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 the 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 100 grams of ozone per cubic feet 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, in accordance with one of the features of the present invention there is 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 approaches an undesirably high level which would cause ozone disassociation 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 or control temperature range. When the temperature of the air exiting from the ozone generating unit 2 is within this range, a given

duty cycle is provided where energizing voltage to the high voltage transformer is alternately switched on and off over given relative proportions of time depending upon the given conditions. When the temperature of the outlet air exceeds the upper limit of this range, the controller continuously interrupts the coupling of high voltage to the electrodes, and below this temperature the controller couples the high voltage to the electrodes during progressively increasing percentages of each cycle until the lower limit of the control range is reached where the voltage is continuously coupled to the electrodes. In one exemplary proportional controller, it operated at a frequency of 5 cycles per minute, was adjusted to provide a control range of 1°F and a full off temperature of 90°F. Below this temperature, the duty cycle progressively increased to 100 percent at 80°F. A duty cycle of about 75 percent on time each cycle is preferred. This duty cycle is achieved by varying the magnitude of the high voltage and/or the flow rate.

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 pressure 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.

In accordance with another feature of the invention, associated with the conduit 48 adjacent to 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 an output 50a 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 5 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 5 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 between 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 connection 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 having rollers 111. The cart is shown as having a lower shelf 110a 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 110c on which may be mounted other portions of the air flow and control sys-

tem 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 which are normally closed when the end panels 112a and 112a' of the housing 112 are closed and which open when the associated panels 112a and 112a' 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.

I claim:

1. In an ozone generating system including a corona discharge ozone generating unit for ozonizing an oxygen containing gas, the ozonized gas rapidly dissociating at temperatures above a given value, the ozone generating unit including at least one pair of electrodes to be connected to the terminals of a high voltage source and a heat damageable dielectric tube between said electrodes, a source of ozone producing high voltage to be operably connected to said electrodes and means for circulating the oxygen containing gas to be ozonized through said corona discharge generating unit, the improvement in means for controlling the operation of the ozone generating system, said means comprising temperature responsive means responsive to the temperature of the ozonized gas, and control means responsive to said temperature responsive means for interrupting the coupling of said ozone producing high voltage to said electrodes of the ozone generating unit when the temperature of the ozonized gas reaches a level below the temperature at which said ozonized gas rapidly dissociates, the circulation of the gas to be ozonized through said unit continuing during said interruption of the high voltage.

2. The ozone generating system of claim 1 wherein said control means interrupts the coupling of said ozone producing high voltage to said electrodes of said ozone generating unit when the temperature of the ozonized gas reaches a level of at least about 90°F.

3. The ozone generating system of claim 1 wherein said control means includes a proportional controller with means for setting a temperature at which the controller alternately establishes and interrupts the presence of said ozone producing high voltage across said electrodes.

4. The ozone generating system of claim 1 wherein there is provided means for cooling the gas to be ozonized to aid in preventing the build-up of dielectric shield damaging temperatures in the ozone generating unit and the temperature at which the ozonized gas rapidly dissociates.

5. The ozone generating system of claim 1 wherein there is provided gas flow rate responsive means and means for preventing the coupling of high voltage to

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said electrodes of the ozone generating unit until the flow rate reaches a given value.

6. The ozone generating system of claim 5 wherein there is provided 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, said cool gas outlet being connected to the inlet of the ozone generating unit, said vortex tube unit requiring gas of at least a given pressure to be operable and there is provided pressure responsive means responsive to the pressure of the gas to be ozonized being fed to the inlet of said vortex tube unit and means for preventing the coupling of high voltage to said electrodes of the ozone generating unit until the pressure reaches said given pressure.

7. An ozone generating system including a corona discharge ozone generating unit for ozonizing an oxygen containing gas, the ozonized gas rapidly dissociating at temperatures above a given value, the ozone generating unit including at least one pair of electrodes to be connected to the terminals of a high voltage source and a heat damageable dielectric tube between said electrodes, a source of ozone producing high voltage to be operably connected to said electrodes and means for circulating the oxygen containing gas to be ozonized through said corona discharge generating unit, drying means for drying the gas to be ozonized, and control means for first automatically initiating operation of said circulating and drying means a given predetermined period prior to the coupling of said ozone producing high voltage to said electrodes of the ozone generating unit and then to couple said ozone producing high voltage to said electrodes of the ozone generating unit in order to substantially insure the drying out of the ozone generating unit before the high voltage is fed thereto.

8. The ozone generating system of claim 7 wherein there is provided timer controlled means for terminating the coupling of said high voltage to said electrodes of the ozone generating unit a given period prior to termination of the operation of said circulating means to prevent overheating of the ozone generating unit and retention of ozone in the unit.

9. An ozone generating system including a corona discharge ozone generating unit for ozonizing an oxy-

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gen containing gas, the ozonized gas rapidly dissociating at temperatures above a given value, the ozone generating unit including at least one pair of electrodes to be connected to the terminals of a high voltage source and a heat damageable dielectric tube between said electrodes, a source of ozone producing high voltage to be operably connected to said electrodes and means for circulating the oxygen containing gas to be ozonized through said corona discharge generating unit, and timer controlled means for terminating the coupling of said high voltage to said electrodes of the ozone generating unit a given period prior to termination of the operation of said circulating means to prevent overheating of the ozone generating unit and retention of ozone in the unit.

10. The ozone generating system of claim 9 wherein there is provided timer controlled means for automatically initiating the coupling of said high voltage to said electrodes of the ozone generating unit a given period after initiation of operation of said circulating means.

11. In an ozone generating system including a corona discharge ozone generating unit for ozonizing an oxygen containing gas, the ozonized gas rapidly dissociating at temperatures above a given value, the ozone generating unit including at least one pair of electrodes to be connected to the terminals of a high voltage source and a heat damageable dielectric tube between said electrodes, a source of ozone producing high voltage to be operably connected to said electrodes and means for circulating the oxygen containing gas to be ozonized through said corona discharge generating unit, the improvement coupling 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, said cool gas outlet being connected to the inlet of the ozone generating unit, said vortex tube unit requiring gas of at least a given pressure to be operable, and there is provided pressure responsive means responsive to the pressure of the gas to be ozonized being fed to the inlet of said vortex tube unit, and means for preventing the coupling of said ozone producing high voltage to said electrodes of the ozone generating unit until the pressure reaches said given pressure.

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