

[54] **METHOD AND APPARATUS FOR PRODUCING IONS AT ULTRASONIC FREQUENCIES**[75] Inventor: **Robert E. Bolasny**, Boulder, Colo.[73] Assignee: **Scientific Enterprises, Inc.**,
Bloomfield, Colo.[22] Filed: **July 23, 1973**[21] Appl. No.: **381,601****Related U.S. Application Data**

[63] Continuation-in-part of Ser. No. 266,592, June 27, 1972.

[52] U.S. Cl. **328/233; 239/102; 239/3; 239/4; 321/4; 313/63; 315/111**[51] Int. Cl. **B05b 3/14; B05b 5/02**[58] Field of Search **313/63; 315/111; 328/233; 239/34, 102, DIG. 20; 8/15; 321/4**[56] **References Cited****UNITED STATES PATENTS**

3,233,147	2/1966	Ducati	315/111
3,630,441	12/1971	Felici et al.	239/3 X
3,648,929	3/1972	Corbaz	239/102
3,659,151	4/1972	Fabre	239/3 X
3,717,875	2/1973	Arciprete et al.	239/102 X

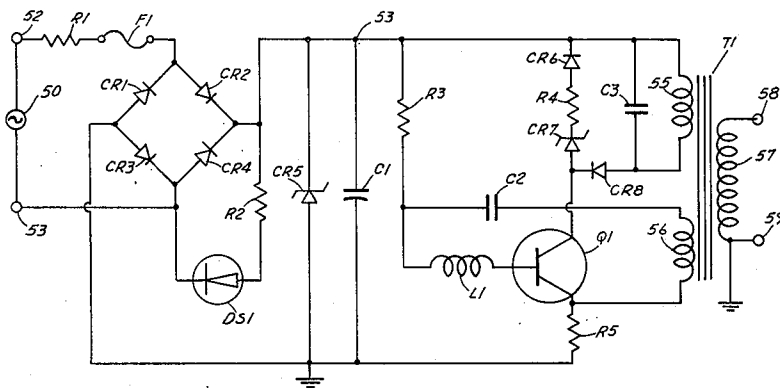
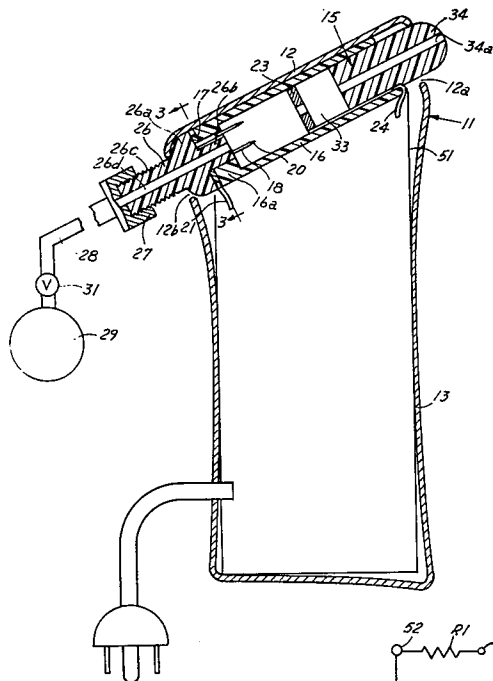
3,780,945	12/1973	Hughes	239/DIG. 20
3,806,029	4/1974	Hughes	239/102 X

Primary Examiner—Alfred L. Brody

Attorney, Agent, or Firm—Ancel W. Lewis, Jr.

[57] **ABSTRACT**

A method and apparatus for producing increased quantities of ions with greater efficiency wherein an electric ion generator produces character-controlled periodic, oscillatory pulses of electric energy having positive and negative components in each cycle of uneven amplitude which are used to generate positive and negative ions in distinct wave fronts or areas in a gas stream. Either the positive or negative pulse components may be used to produce only positive or negative ions. An ultrasonic generator produces vibratory sound wave pulses of ultrasonic sound wave energy in a resonant cavity to pulse the gas, prior to, during or after the ionizing thereof to increase the energy level thereof. The ultrasonic energy sound waves are at approximate multiples of the frequency of the electric energy pulses producing the ions whereby the ultrasonic sound wave pulses hold ions of a similar polarity in the distinct pressure wave fronts or areas.

27 Claims, 12 Drawing Figures

SHEET 1 OF 3

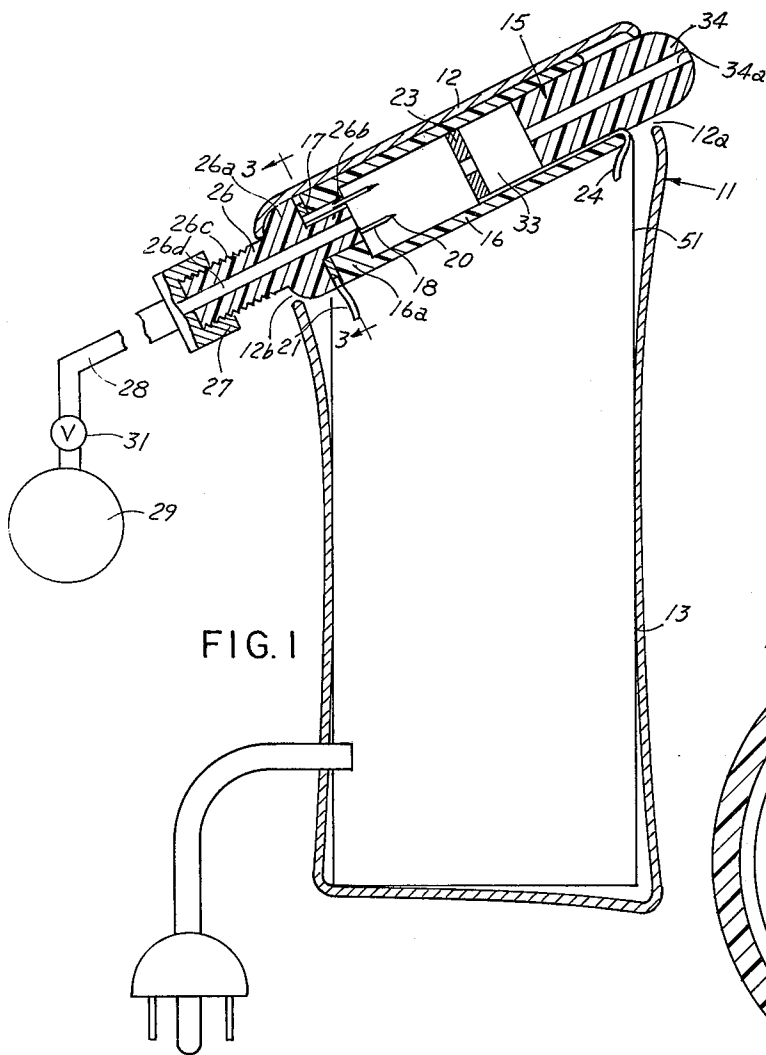


FIG. 1

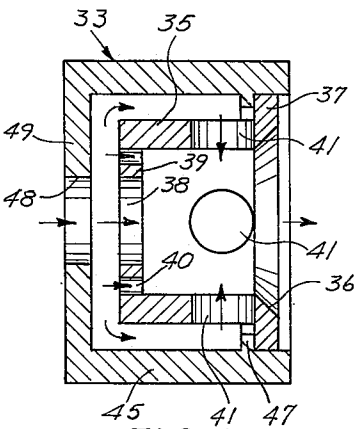


FIG. 2

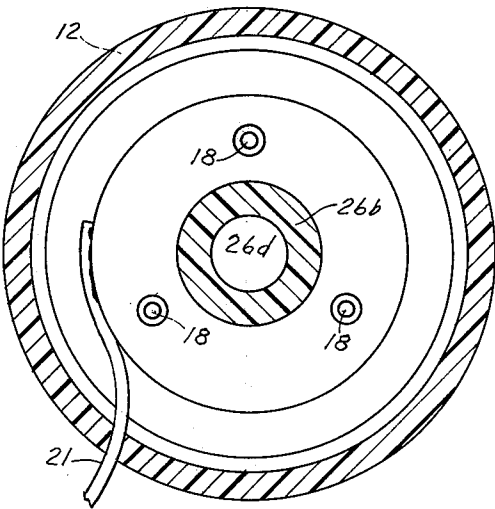


FIG. 3

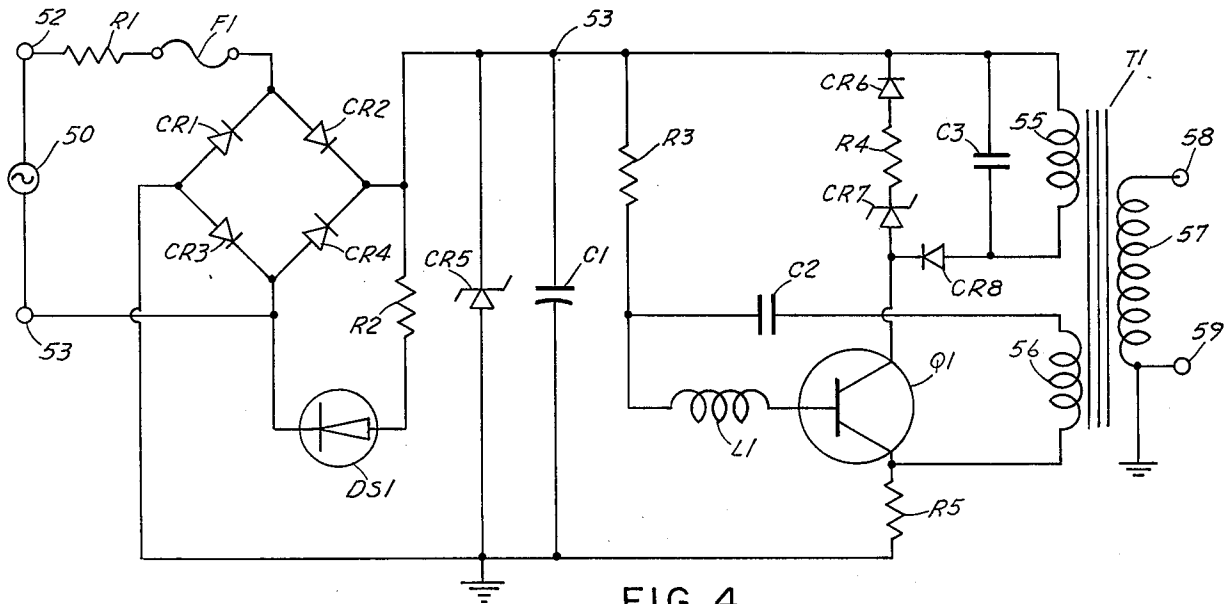


FIG. 4

SHEET 2 OF 3

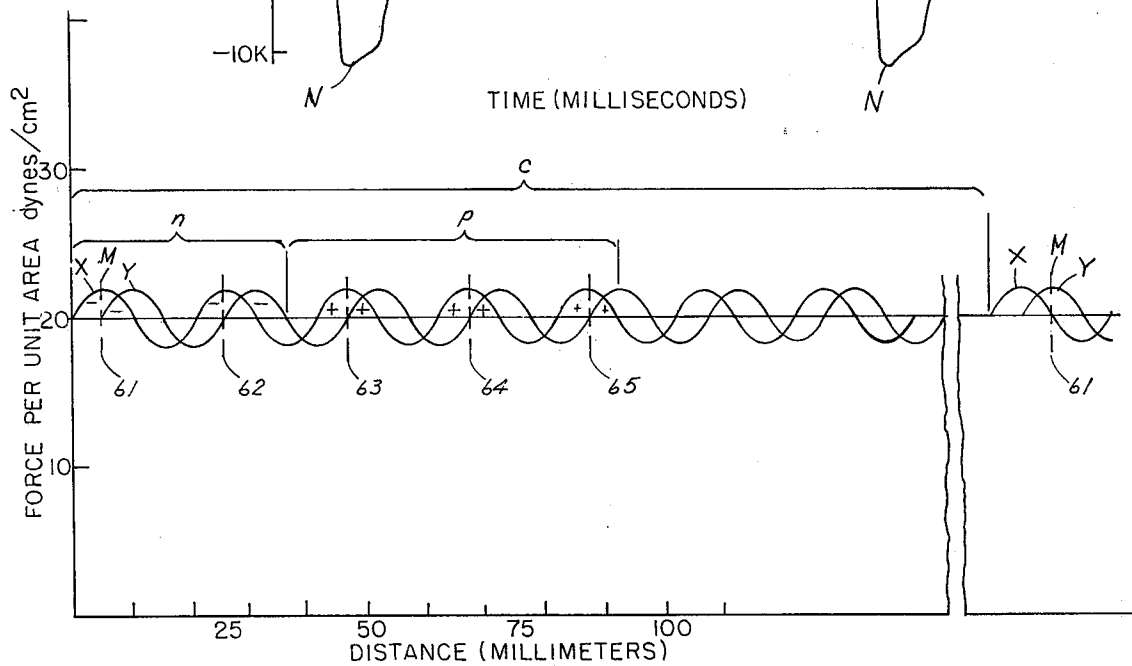
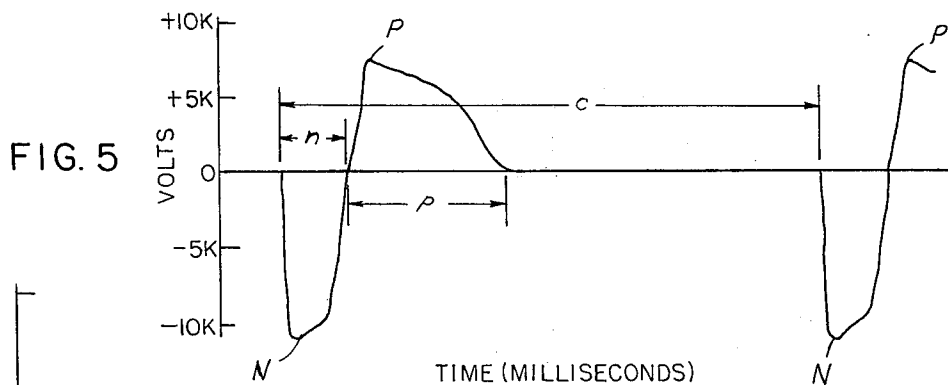


FIG. 6

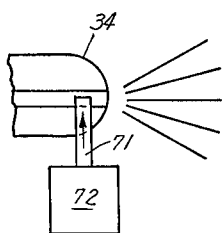


FIG. 8

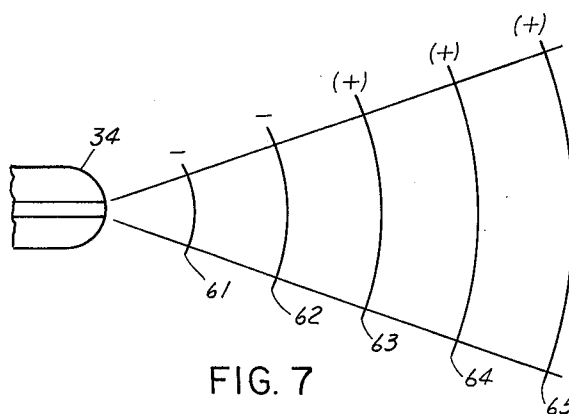


FIG. 7

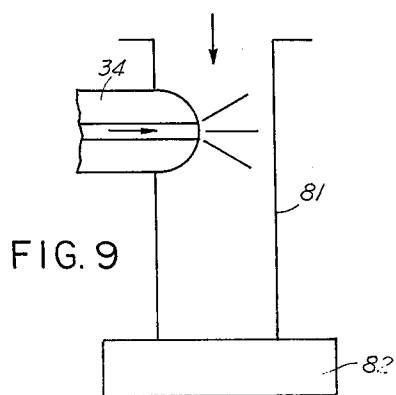


FIG. 9

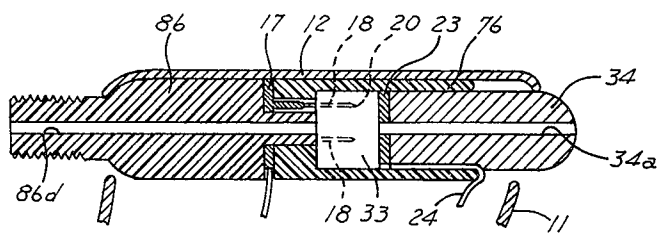


FIG. 10

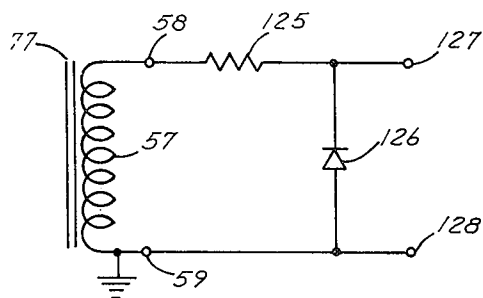


FIG. 12

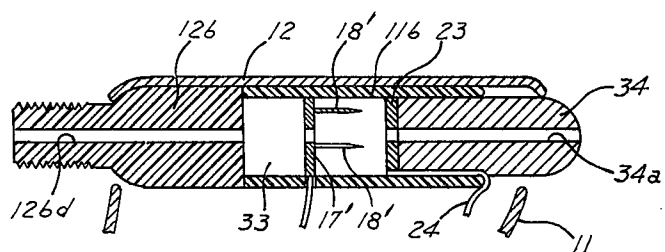


FIG. 11

METHOD AND APPARATUS FOR PRODUCING IONS AT ULTRASONIC FREQUENCIES

This is a continuation-in-part of application, Ser. No. 266,592, filed June 27, 1972.

This invention relates to a novel method and apparatus for producing increased quantities of ions in a body of gas or gas stream at higher energy levels utilizing a combined electric pulse generator to generate ions in a gas and resonant cavity-type ultrasonic sound wave pulse generator for applying vibrating ultrasonic waves to the gas.

Generators for producing ions have a wide range of applications including the control of electrostatic potentials, removal of particulate from surfaces, deposition of powders or aerosols and to a limited extent some attempts have been made to use ions to increase burning of fuel in an internal combustion engine or the like.

Prior art ion generators have relied on high DC voltages in the range of 8,000 to 10,000 volts and sinusoidal waveform AC voltages up to 40,000 volts. This prior art apparatus has been generally bulky in construction, relatively expensive and voltages necessary to generate large quantities of ions generate ozone.

Ultrasonic generators heretofore provided have employed mechanical vibratory reeds, magnetostrictive or piezoelectric devices. So far as known, no prior attempts have been made to utilize a resonant cavity-type ultrasonic sound wave generator to pulse the gas and the types of devices heretofore employed have provided a severe reduction in the amount of ionization principally due to the recombination of positive and negative ions prior to their delivery to point of use.

In my earlier filed application entitled "Method and Apparatus for Generating Ions and Controlling Electrostatic Potentials" there is described a novel ion generator and dispersing apparatus wherein there is generated a character-controlled, oscillatory pulses of electric energy having positive and negative components in each cycle of uneven amplitude which has been found to be highly effective in separating or isolating positive and negative ions into distinct areas.

One specific application for which the present invention is particularly suitable is to remove particulates. A common method of particulate removal is the use of a gas under pressure flowing through a nozzle directed against a surface where cleaning is desired. This method has been effective generally with particulate of 100 micron sizes and larger. Because of the boundary layer, this effectively prevents the high, shear force of the compressed gas from being brought to bear against the particulate. The gas is sometimes ionized in an effort to overcome the electrostatic attraction of particles to the surface, however, this is largely ineffective in removing small particulate (less than 100 microns) because of the boundary layer condition. Moreover, to date, it has not been possible to incorporate an ultrasonic generator which generates sufficient energy in the gas stream to vibrate the particles free of the surface to effectively penetrate the boundary layer.

Accordingly, it is a general object of this invention to provide a novel method and apparatus for producing and delivering ions to the point of use in a highly efficient manner.

Another object of this invention is to provide a novel method and apparatus for producing increased quantities of ions without appreciable recombination in atmospheric air utilizing a combination of electric pulsing

via electrodes and ultrasonic sound wave pulsing of a stream of gas.

Yet a further object of this invention is to generate and deliver increased quantities of ions to the point of use by means of less energy or electric power in smaller and less expensive equipment.

Still a further object of this invention is to provide novel apparatus for producing increased quantities of ions at the point of use characterized by being readily adjustable to different applications, and having no appreciable generation of ozone.

In accordance with the present invention, in a preferred embodiment shown, an electric power source generates a train of periodic, oscillatory positive and negative electric pulses of uneven amplitude which are applied to spaced electrodes in a gas in the form of one or more ionizing points displaced axially from a ground plate in an ionizing chamber through which a stream of gas is passed to generate positive and negative ions. A resonant cavity-type ultrasonic sound wave generator unit pulses the gas with vibratory ultrasonic sound waves prior to, during or after ionization. Either only the positive or negative components of the electric pulses may be used to produce only periodic positive and negative ions. The ultrasonic pulses preferably are in the range of 38 to 58 thousand cycles per second which are multiples of the frequency of the electric pressure and at an inlet pressure from 1/2 to 28 psi which carry the positive and/or negative ions in distinct pressure wave pockets, or areas whereby there is sufficient energy to carry the ions to the point of use such as for example to bring them into intimate contact with a particulate and effectively remove it from a surface, spray paint or increase the efficiency of a burning process and specially the burning process in an internal combustion engine.

Other objects, advantages and capabilities of the present invention will become more apparent as the description proceeds taken in conjunction with the accompanying drawings on which:

FIG. 1 is a cross-sectional view of a hand-held gun embodying features of the present invention;

FIG. 2 is an enlarged cross-sectional view of the ultrasonic generator unit of FIG. 1;

FIG. 3 is a sectional view taken along lines 3—3 of FIG. 1;

FIG. 4 is an electric circuit diagram for the electric ion generator portion of the gun;

FIG. 5 is an output waveform for the circuit diagram of FIG. 4;

FIG. 6 is a diagrammatic view of a waveform illustrating the idealized relationship of pressure and velocity in a resonant cavity for generating ultrasonic energy in a gas stream;

FIG. 7 is a diagrammatic view illustrating spaced waves for the distinct areas of different groups of ions;

FIG. 8 is a diagrammatic view illustrating the application of ions at ultrasonic frequencies to spray a fluid such as paint;

FIG. 9 is a diagrammatic view illustrating the application of ions at ultrasonic frequencies to the air stream leading to a carburetor;

FIG. 10 is a cross-sectional view of another form of gun in which the ionization and ultrasonic pulsing takes place simultaneously;

FIG. 11 is a cross-sectional view of another form of gun in which the ultrasonic pulsing takes place prior to ionization;

FIG. 12 is an electric circuit diagram illustrating the manner of using only one-half the cycle for positive or negative ionization.

Referring now to the drawings in the preferred embodiment shown there is provided an outer casing generally designated by numeral 11 with an upper head portion 12 and a lower hand grip portion 13. A combined ion and ultrasonic generator nozzle assembly generally designated by numeral 15 is mounted in the upper head portion 12 and has end extensions passing through a forward aperture 12a and a rear aperture 12b in the casing.

In general, the nozzle assembly 15 comprises an ionization section at the rear end and an ultrasonic generator section at the forward end so that the gas is first ionized and then pulsed with ultrasonic vibrating sound waves. More specifically, the nozzle assembly 15 has a tubular housing 16 made of a non-conductive material, such as plastic, which forms in an ionizing chamber inside thereof and the ionization section also includes a conductive disc 17 carrying three circumferentially spaced, conductive ionizing electrode pins 18. The pins 18 extend longitudinally through openings in a rear end wall 16a of the housing 16 and each terminate in an ionizing point 20 inside the ionizing chamber. The housing 16 has an axially extending inlet opening in the rear end wall 16a through which the gas stream passes leading into the ionizing chamber. A lead line 21 is connected to disc 17 to apply power from the transformer in the electric power source described hereinafter to pins 18 via disc 17. The ionization section also includes a conductive ground ring 23 with a central axially extending opening located downstream of the pins 18 and has a lead line 24 connected thereto which connects to a ground terminal in the electric power source described hereinafter.

A connector body 26 abuts against the rear end of disc 17 and is coaxially aligned therewith. The connector body 26 has an enlarged intermediate portion 26a inside the casing terminating in a forward end portion 26b of reduced size slidably received in the inlet aperture in the rear end wall 16a of housing 16 together with an externally threaded rear end portion 26c which projects through the rear opening 12b in the casing and receives a fitting 27 to couple a flow line 28 from a source of gas under pressure represented schematically by a tank 29 and control valve 31 in the line to provide a means for supplying a gas under pressure into the ionizing chamber. The connector body has a throughbore 26d which passes the gas under pressure into the ionizing chamber. The rear connector body, disc and pins are separable from the tubular housing and in the assembly the pins are inserted into holes in the rear end wall 16a.

An ultrasonic generator unit 33 is mounted in the downstream end of the housing 16 together with a nozzle head 34 having an inner flow passage 34a located downstream of the ultrasonic generator unit 33. The ground plate 23, ultrasonic generator unit 33 and discharge head 34 having approximately the same external diameter and are sized to be force-fitted into the forward end of the tubular housing 16.

The ultrasonic generator unit 33 shown is of the type described in U.S. Pat. Nos. 3,554,443, 3,581,992 and

3,531,048. Briefly, with particular reference to FIG. 2, the ultrasonic generator unit 33 has an inner cylindrical wall 35 open at its outlet end across a countersink 36 which is surrounded by an annular flange 37. An axial central inlet 38 in end wall 39 is concentric with an imaginary circle containing the centers of eight equally spaced holes 40. Four radial holes 41 in cylindrical wall 35 have coplanar axes spaced 90° from one another. The inner cylindrical wall 35 is mounted in a cell 45 with its flange tightly secured in counterbore 46 against flange 47. Cell 45 has an inlet hole 48 in end wall 49. In the general operation, the gas stream passes through inlet 48 and flows through nozzle inlet 38 and holes 40 and 41 and finally across countersink 36.

The electric circuit board 51 for the electric power for the ionizing section is mounted in the hand grip portion of the casing and supports an electric circuit shown in a diagram form in FIG. 4 which comprises input terminals 52 and 53 to which is applied an AC source, represented at 50, the AC source being typically 115 volt, AC, 50 or 60 Hz. This circuit is generally similar in construction and operation to that of the above-referred to pending application in that it utilizes a blocking oscillator circuit to generate positive and negative pulses, but it is noted that the pulses generated by this circuit are of a reverse polarity. The circuit shown in FIG. 4 comprises rectifiers CR1, CR2, CR3 and CR4 connected in a full wave rectifier bridge and together with a capacitor C1 providing a means for converting the applied AC line voltages to a rectified DC voltage. A current limiting resistor R1 and fuse F1 are connected between the input terminal 52 and one side of the bridge. A series connected resistor R2 and lamp DS1 are connected across rectifier CR4. A zener diode CR5 is connected across capacitor C1. The DC voltage across capacitor C1 between terminal 53 and ground is applied to a blocking oscillator circuit including a NPN transistor Q1 and a pulse transformer T1 having a primary winding 55, feedback winding 56 and a secondary winding 57. The ends of winding 57 define output terminals 58 and 59, the latter terminal 59 being connected to the ground.

A resistor R3 connected to a capacitor C2 charges capacitor C2 from the DC voltage at terminal 53 and provides a bias current to the base electrode of the transistor Q1 via an inductor L1 having a common connection between resistor R3 and capacitor C2. The other side of capacitor C2 is connected to one side of the feedback winding 56. When the transistor Q1 conducts the DC voltage at terminal 53, it is applied across the primary winding 55. This voltage is transformed to the feedback winding 56 causing a current to flow through capacitor C2 and inductor L1 into the base electrode of the transistor which also serves to turn transistor Q1 ON. This operation forms the rise of the negative going driven pulse N shown in FIG. 5. The duration of this driven pulse is determined by several parameters including the magnitude of the DC voltage, the inductance, resistance and capacitance of the pulse transformer T1, the ON resistance and current gain of the transistor Q1, the values of capacitor C2 and the inductance of inductor L1. The principal function of the inductor L1 is to control the rate at which capacitor C2 charges from the regeneration current. When the regeneration current can no longer be sufficiently amplified by transistor Q1 to maintain the increasing primary current required by the pulse transformer, the

pulse transformer reverses its polarity and forms the positive going flyback pulse P as its magnetic field collapses in an attempt to maintain current flow. At this time the transistor Q1 is biased OFF by the charge on the capacitor C2 and the flyback voltage on the feed-back winding.

A series-connected circuit of rectifier CR6, resistor R4 and zener diode CR7 provide a path for current flow during the positive flyback pulse P. The duration and shape of the flyback pulse P is controlled by a capacitor C3 connected across the primary winding 55 and the inductance and stray capacitance of the pulse transformer T1. The relaxation time or time interval designated "P" of the positive flyback pulse P is controlled by the time it takes resistor R3 to discharge the bias voltage on the capacitor C2 and reverse its charge to a voltage where transistor Q1 is again turned ON by bias current flowing into the base electrode. A resistor R5 connected between the collector electrode and ground serves as a part of the source resistance of the DC supply voltage and protects transistor Q1 from excess current. The secondary winding 57 of the transformer has a natural resonant frequency at terminals 58 and 59 and capacitance C3 swamps out this frequency. A diode CR8 connected between the collector electrode and one side of the primary winding 55 prevents reverse current from damaging the transistor during off time. The waveform is periodic in that it repeats itself regularly in time and form, the full cycle time interval being designated c. The waveform is also oscillatory in that it does both positive and negative during each cycle.

The pulses generated in the primary winding 55 are transformed to a higher voltage by the secondary winding 57 and appear at output terminals 58 and 59. The ratio of the duration of the negative driven pulse N designated n and the duration of the positive flyback pulse P designated p is balanced against the ratio of the amplitude of the driven pulse and the amplitude of the flyback pulse to effect an optimum balance of positive and negative ionization at the load while controlling positive and negative corona and eliminating ozone generations. The output amplitude of the negative, driven pulse N is controlled directly by the turns ratio of the primary winding and secondary windings. The negative driven pulse N is in this circuit adjusted for a peak output voltage between 10,000 and 12,000 volts and is illustrated in the waveform of FIG. 5 as about 12,000 volts and the positive flyback pulse P amplitude is adjusted for a positive peak output voltage between 6,000 and 8,000 volts and is illustrated in the waveform of FIG. 5 at about 7,000 volts. The duration of the negative driven pulse is about 0.4 milliseconds and the duration of the positive flyback pulse about 1 millisecond with a full cycle of about 12.5 milliseconds. It has been found that satisfactory results may be obtained with the positive component peak output voltage in the range of 8,000 volts to 20,000 volts and the negative component peak output voltage in the range of about 10,000 volts to 30,000 volts. For the above circuit operating at between 8,000 volts to 10,000 volts and in the range of 0.5 and 2 milliamperes, the power consumption is about 7.5 watts. This is about one-tenth the power of known prior art ionizing devices which produce equal or less ionization.

In the full sequence of operation of the above described apparatus a stream of gas, usually air, under pressure, is delivered from the source 29 through the

inlet passage in connector body 26 and past the ionizing points 20 in the ionizing chamber whereby it is pulsed by oscillatory surges of positive and negative electric energy to generate ions of one polarity or the other. The stream of ionized gas then passes through the ground ring 23 into inlet 48 and through nozzle inlet 38 and axial holes 40 and radial holes 41 and out the nozzle across the countersink 36. The ionized gas flowing through the inlet forms a central core stream of ionized gas in cylinder 35 which contracts to a minimum size in the neighborhood of radial holes 41 and diverges thereafter so that the gas passes through a sculptured converting-diverging nozzle and the core stream of gas is accelerated to an ultrasonic velocity with ultrasonic sound wave vibrations in the range of about 38 to 58 thousand cycles per second depending on air pressure at the inlet which varies from about ½ psi to 28 psi. The pulsing of the stream of gas ionized by specific waveform above described is carried out with the electric pulses being synchronized to sub-multiples of the ultrasonic sound wave pulse frequencies so that peak ultrasonic pulses will occur approximately simultaneously with each electric pulse. While a pulse or sharp breaking waveform provides best results, it is understood that even a sinusoidal waveform may be used with ultrasonic generator and synchronized therewith. The peak ultrasonic pulse picks up and carries or transmits the positive and negative ions in discrete pockets or areas which may be best understood by referring to FIGS. 5, 6 and 7.

An idealized plot of distance (millimeters) along the X axis and force per unit area (dynes per square centimeter) for a 40,000 cycle sound wave is illustrated in FIG. 6 having a sinusoidal pressure wave X, 90° out of phase with a sinusoidal pressure wave Y. The energy level provided by the ultrasonic pulses of the ultrasonic generator unit 33 above described is about twenty dynes per square centimeter. The maximum ultrasonic energy is applied to the ions when the pressure wave X is maximum and the velocity wave Y is zero and at this maximum pressure peak or "node" M represented by a vertical dashed line the ultrasonic generator unit 3 is able to hold the ions in distinct areas or spaced wave fronts.

When the negative pulse N occurs nodes or pressure peaks designated 61 and 62 carry groups of negative ions which are also shown in FIG. 7 as spaced wave fronts 61 and 62 displaced a selected distance from the end of nozzle head 34. When the positive electric pulse P occurs, several nodes or pressure peaks 63, 64 and 65 occur which are also shown as wavefronts in FIG. 7. After the positive pulse P there is a substantial time lapse before the next negative pulse occurs. In this way the present invention prevents the ions of opposite polarity from recombining and the ions are carried at ultrasonic energy levels so that they are more effectively delivered to the point of use such as for example to penetrate barriers and come into intimate contact with a particle to remove it from the surface or the like.

With the ion being held in the pressure nodes of the peak ultrasonic pulse, it is possible to transmit ionization through long lengths of tubing. For example, 20 feet of quarter-inch Tigon or through narrow openings on the order of eleven-thousandths of an inch. The ionization is effectively carried in ambient pressure air for considerable distance (10 feet from a 30 PSI gun)

which makes it a convenient tool for industrial removal of particulate.

Previously, ionization has been used effectively for surface cleaning only in vacuum because of the almost complete loss of energy by the ions hitting air molecules. With the present invention it is possible to bring the end of the nozzle very near a surface (within a sixteenth of an inch) which is nearly in the boundary layer. At this distance it is possible to bring enough energy to bear on the surface that a small amount of the surface can be removed for surface etching and the like. For example, plastic or glass would take on the appearance of being sandblasted. This invention also has application in treating of films prior to printing and in the manufacture of electronic components and the like.

Further with the present invention, it is possible to charge particles of paint or powder used to coat surfaces with considerable amounts of energy, the ultrasonic energy being used as a vehicle for carrying the ionized aerosol and to further disperse particulate. The apparatus for carrying out this method is shown diagrammatically in FIG. 8 to include a tube 71 mounted in the nozzle head 34 and terminating at its upper end in the flow passage. The tube 71 leads to a supply of paint 72 and the paint or the like is drawn up into the flow of ionized and ultrasonically pulsed gas stream so that the paint passes from the nozzle head 34.

The present invention also makes it possible to ionize the air passing through a carburetor and manifold thereby increasing the energy available for burning fuel. The apparatus for carrying out this method is shown diagrammatically in FIG. 9 to include a conduit 81 leading from the air filter (not shown) into the carburetor 82 through which a stream of air is passed. The nozzle head 34 is shown as extending through the wall of the conduit to apply the ions carried at ultrasonic frequencies to the air stream passing from the air filter into the carburetor prior to entry into the combustion chamber. Specifically by ionizing and ultrasonically pulsing the air through a carburetor the energy level of the fuel-air mixture is raised to where the spark plug fires, flame fronts are initiated throughout the fuel-air mixture rather than emanating from the immediate area of the spark plug. This has the effect of burning fuel next to relatively cool walls of the cylinder and in the crack between the cylinder wall and piston. In this application, the combustion is more complete, the amount of unburned hydrocarbons is reduced and the carbon monoxide discharge is reduced and since the burning is carried out at a relatively low temperature, the formation of oxides of nitrogen are reduced.

It is recognized that the ultrasonic sound wave energy may be applied to the gas not only after ionizing the gas using the ionizing and ground electrodes as shown in FIG. 1 through 3, but also during or simultaneous to ionizing and before ionizing with similar results in producing ions at ultrasonic energy levels with the positive and/or negative ions being grouped in distinct areas at increased energy levels.

In an alternative ion generator shown in FIG. 10, the ultrasonic sound wave energy is applied in the ionizing chamber to pulse the gas with ultrasonic wave vibrations and ionize the gas simultaneously. In this form, the connector body 86 with an inlet passage 86a is made to take up the space of the former ionizing chamber and the conductive disc 17 carrying three circumferentially spaced ionizing electrode pins 18 which ex-

tend through openings in the wall at the rear end of a modified housing 76 and each ionizing electrode pin terminates in an ionizing point 20 inside the resonant cavity 33 positioned in housing 76. The ground electrode ring 23 with line 24 is located at the downstream end of the ultrasonic generator unit 33. More specifically, the ionizing points will be circumferentially spaced within the resonant cavity formed by the inner cylindrical wall 38 shown in FIG. 2 where the ultrasonic sound wave energy is generated.

In yet another structural form shown in FIG. 11, the ultrasonic sound wave energy is applied before the ionization of the gas takes place. Here the connecting body 126 and housing 116 are slightly modified from that of FIGS. 1 through 3 with the housing being open ended and the resonant cavity-type ultrasonic sound wave generator 33 placed in the upstream end of the housing 116 ahead of the conductive disc 17' having a smaller orifice which carried the ionizing electrode pins 18' shown as of a shorter form. The housing forms an ionizing chamber around the ionizing electrode pins 18'. The ground disc 23 with lead line 24 is downstream of the ionizing electrode pins 18' and upstream of the nozzle head. In this reverse situation from that shown in FIGS. 1 through 3, the air molecules are grouped or bunched into the high frequency pressure waves and the positive and negative pulsing by the ion generator circuit produces groups of each in distinct areas at increased energy levels as represented in FIG. 7.

Moreover, it is also recognized that for some applications only ions of one polarity may be required. For example, for spray painting as above discussed with reference to FIG. 8, ions of one polarity are usually required. In this case a circuit such as that shown in FIG. 12 may be added to the output of the secondary winding 57 of the transformer to eliminate either the positive or negative electric pulse for each cycle. To this end there is provided a resistor 125 and a unidirectional control element in the form of a diode 126 connected in a series circuit across winding 57 with output or load terminals 127 and 128 being across the diode 126. For one half of the cycles the diode 126 draws no current and the output pulse appearing across the diode at load terminals 127 and 128. However, during the other half of the cycle, the diode 126 conducts and the voltage is dropped across the resistor 125 with no voltage across terminals 127 and 128 so that in effect that portion of the cycle is clipped off. In this way, either the positive or negative component of the pulse may be eliminated from each cycle depending on how the diode is connected so that only one type of ion may be generated by coupling terminal 127 to the electrode having the ionizing point. Moreover, a connected double pole, double throw electric reversing switch could be connected across the diode to reverse the output pulses as desired.

Although the present invention has been described with a certain degree of particularity, it is understood that the present disclosure has been made by way of example and that changes in details of structure may be made without departing from the spirit thereof.

What is claimed is:

1. In a method of producing ions in a gas with greater efficiency and a minimum of ozone, the steps of:
 - providing a stream of gas,
 - applying periodic pulses of electric energy to the stream of gas to generate ions, and

pulsing the stream of gas with ultrasonic sound wave vibrations which are approximate multiples of the frequency of the electric energy to produce groups of the ions in distinct pressure fronts at higher energy levels to increase the energy level thereof.

2. In a method of producing ions in a gas as set forth in claim 1 wherein said pulses are of a single polarity to produce ions of one polarity.

3. In a method of producing ions in a gas as set forth in claim 1 wherein said pulses are oscillatory having positive and negative components to alternately produce positive and negative ions.

4. In a method of producing ions in a gas as set forth in claim 3 wherein said electric energy has positive and negative components of unequal amplitude.

5. In a method of producing ions in a gas as set forth in claim 3 wherein said electric pulses have a positive component peak output voltage in the range of about 8,000 volts to 20,000 volts.

6. In a method of producing ions in a gas as set forth in claim 3 wherein said electric pulses have a negative component in the range of about 10,000 volts to 30,000 volts.

7. In a method of producing ions in a gas as set forth in claim 3 wherein said electric energy is oscillating at a frequency of in the range of about 90 Hz to 1,200 Hz.

8. In a method of producing ions in a gas as set forth in claim 1 wherein the electric energy has a range of current of about 0.5 to 2 milliamperes.

9. In a method of producing ions in a gas as set forth in claim 1 further including the step of producing a stream of gas to be ionized at inlet pressures in the range of about 0.5 psi to 28 psi.

10. In a method of producing ions in a gas as set forth in claim 1 further including the step of introducing particles into the ionized gas stream to form ionized particles in the gas stream.

11. In a method of producing ions in a gas as set forth in claim 1 wherein the pulses of electric energy are applied to the gas prior to the pulsing with ultrasonic sound wave vibrations.

12. In a method of producing ions in a gas as set forth in claim 1 wherein the pulses of electric energy is applied to the gas during the pulsing with ultrasonic sound wave vibrations.

13. In a method of producing ions in a gas as set forth in claim 1 wherein the pulses of electric energy are applied to the gas subsequent to the pulsing with ultrasonic sound wave vibrations.

14. In apparatus for producing ions in a gas with greater efficiency and a minimum of ozone, the combination comprising:

means for providing a stream of gas under pressure, ion generator and dispersing means for applying periodic pulses of electric energy to the stream of gas to produce ions, and

sound wave generator means for pulsing the stream of gas with ultrasonic sound wave vibrations which are approximately multiples of the frequency of the electric energy to generate groups of ions in the stream of gas in distinct pressure fronts at higher energy levels to increase the energy level thereof.

15. In apparatus for producing ions in a gas as set forth in claim 14 wherein said ion generator and dispersing means includes an electric power circuit having means for converting AC power to DC power and a blocking oscillator type electric circuit responsive to

said DC power to generate a negative driven pulse, and a positive flyback pulse in each cycle.

16. In apparatus for producing ions in a gas as set forth in claim 14 wherein said ion generator and dispersing means includes:

tubular housing of a non-conductive material having a gas inlet at one end and a gas outlet at the other end defining an ionizing chamber;

at least one ionizing point at the upstream end of the ionizing chamber to which the electric pulses are applied;

a ground ring for said ionizing point at the downstream end of the ionizing chamber and axially displaced from said ionizing point through which the ionized stream of gas is directed, and

a nozzle head for directing the ionized stream of gas to the point of use.

17. In apparatus for producing ions in a gas as set forth in claim 16 wherein there are plurality of ionizing points at circumferentially spaced intervals in said ionizing chamber.

18. In apparatus for producing ions in a gas as set forth in claim 14 further including means for introducing a gas under pressure into the inlet of said ionizing chamber.

19. In apparatus for producing ions in a gas as set forth in claim 14 wherein said sound wave generator means is of the resonant cavity-type.

20. In apparatus for producing ions in a gas as set forth in claim 5 wherein said sound wave generator means includes;

an inner cylindrical wall open at its outlet end across a countersink surrounded by an annular flange, the cylindrical wall having an end wall with an axial inlet concentric with an imaginary circle containing the centers of a plurality of spaced axial holes and further having radial holes in the sides thereof with coplanar axis spaced at about 90 degrees, and a cell surrounding the inner cylindrical wall with the flange secured along the inside thereof to form an axially extending outer cavity, the cell having an inlet coaxially aligned with the inlet and outlet of the inner cylindrical wall whereby to produce a core stream of ionized gas flow forming a sculptured convergingdiverging nozzle adjacent said radial holes at the outlet end of said cylindrical wall which accelerates the core stream to ultrasonic speeds.

21. In apparatus for producing ions in a gas as set forth in claim 14 wherein said ion generator and dispersing means includes an electric generator circuit for producing periodic oscillatory pulses of electric energy having alternating positive and negative pulse components and a uni-directional control circuit for eliminating one of said positive and negative pulse components to produce ions of only one polarity.

22. In apparatus for producing ions in a gas as set forth in claim 21 wherein said uni-directional control circuit is a diode and resistor connected across the output of the electric generator circuit.

23. In apparatus for producing ions in a gas as set forth in claim 14 wherein said ion generator and dispersing means includes an electric generator circuit for producing pulses of electric energy and an ionizing electrode and a ground electrode spaced from the ionizing electrode in an ionizing chamber through which

the gas passes and said sound wave generator means is in the form of a resonant cavity.

24. In apparatus for producing ions in a gas as set forth in claim 23 wherein said ionizing chamber and resonant cavity are in a coaxial alinement and in flow communication with one another.

25. In apparatus for producing ions in a gas as set forth in claim 23 wherein said ionizing chamber and resonant cavity are coextensive in length for ultrasonic

pulsing during ionization.

26. In apparatus for producing ions in a gas as set forth in claim 23 wherein said ionizing chamber is upstream of said resonant cavity.

27. In apparatus for producing ions in a gas as set forth in claim 23 wherein said ionizing chamber is downstream of said resonant cavity.

* * * * *

10

15

20

25

30

35

40

45

50

55

60

65

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,878,469 Dated April 15, 1975

Inventor(s) Robert E. Bolasny

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Claim 20, line 2, cancel "5" and substitute --14--

Signed and Sealed this

second Day of December 1975

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,878,469 Dated April 15, 1975

Inventor(s) Robert E. Bolasny

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 7, line 44, delete "ehe" and insert --the--

Column 9, line 13, delete "gasas" and insert --gas as--

line 29, delete "milliaperes" and insert

--milliamperes--

Line 51, correct the spelling of "efficiency"

Column 10, line 46, delete "convergingdiverging" and insert

--converging-diverging--

Column 11, line 4, delete "claiam" and insert --claim--

Signed and Sealed this

thirtieth Day of September 1975

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks