SEARCH ROOM

July 7, 1970 M. GOURDINE 3,519,855

ELECTROGASDYNAMIC SYSTEMS

Filed March 3, 1965 2 Sheets-Sheet 1

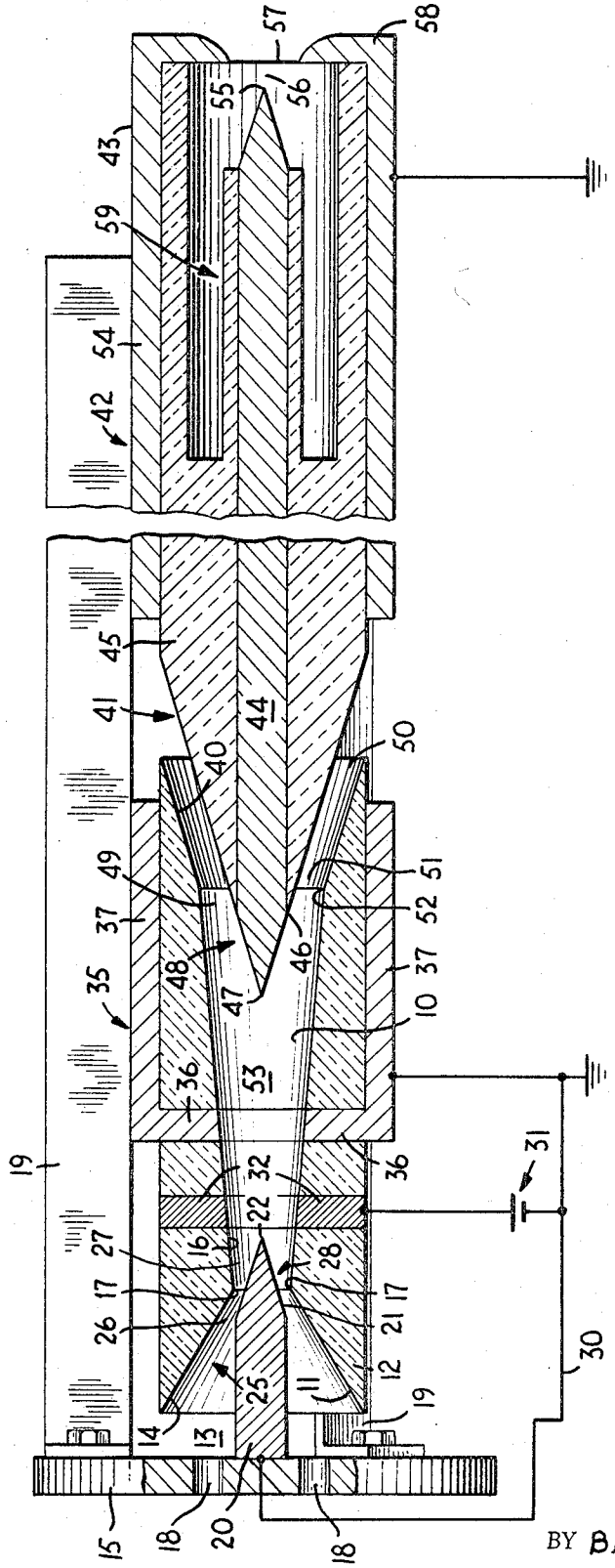


FIG. 1

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ELECTROGASDYNAMIC SYSTEMS

Filed March 3, 1965 2 Sheets-Sheet 2

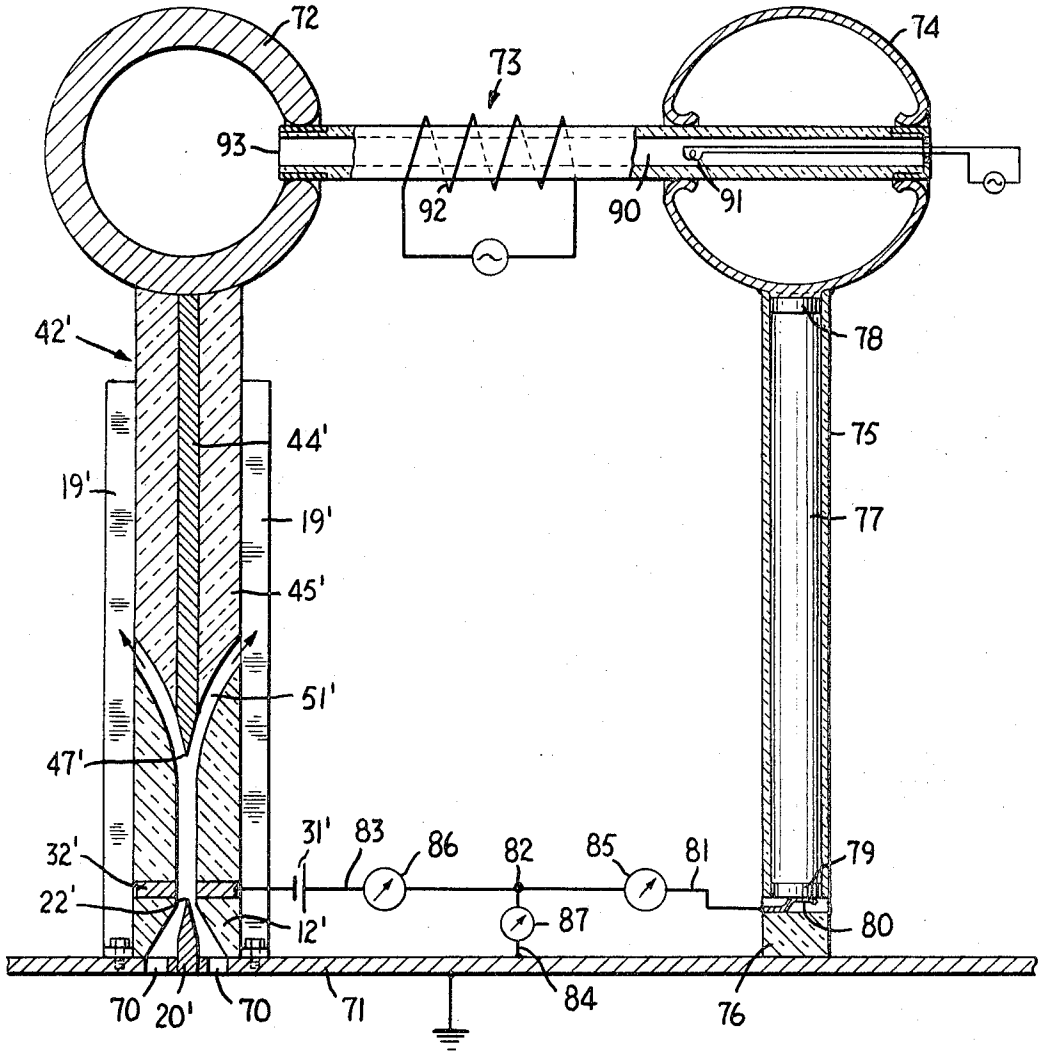


FIG. 2

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United States Patent Office 3,519,855
Patented July 7, 1970

3,519,855

ELECTROGASDYNAMIC SYSTEMS

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Int. Cl. H02n 3/00
U.S. Cl. 310—10 23 Claims

ABSTRACT OF THE DISCLOSURE

An electrogasdynamic apparatus operating on a gaseous stream containing a condensable constituent, in which the apparatus includes a dielectric convergent-divergent nozzle section defining a flow channel. A forwardly tapering plug electrode is disposed in the flow channel at the throat of the dielectric nozzle to define thereby a rapidly diverging annular flow configuration adjacent the tapering portion of the plug. Generally surrounding the channel and flush with the divergent portion of the nozzle boundary is an attractor electrode. An ionizing potential source is connected between the plug and attractor electrodes to establish in the channel a transverse ionizing field which ionizes condensed particles of the constituent formed during rapid expansion in the nozzle section. Slightly downstream of the attractor electrode is a shield electrode of which a portion is exposed to the interior of the flow channel to establish a downstream potential terminus for a longitudinal electric field set up between it and a collector electrode disposed to collect charges carried downstream from the shield electrode.

This invention relates to electrogasdynamic energy conversion means for converting fluid potential and/or kinetic energy into high voltage electricity usable for various applications as, say, to produce electron beam radiation, or X-ray beam radiation or to induce chemical or nuclear reactions in plastics, metals, foods, gases, etc.

In U.S. Pat. No. 2,638,555 to Marks, it is proposed to condense fluid on molecular ions and grow charged colloids around those ions in order to reduce ion mobility in an electrogasdynamic converter. In accordance with one aspect of this invention, another technique is utilized for lowering the mobility of ions through the fluid. Specifically, I have discovered that, by providing the fluid both with multi-molecular particles (which may be, say, of colloidal size) and with ions existing in the fluid medium around those particles, the mobility of the ions through the fluid is reduced orders of magnitude, even though the particles are completely or substantially uncharged. The particles may be introduced by condensing part of the fluid into, say droplets during expansion through a nozzle.

Other aspects of this invention relate to or carry forward the teachings of my copending application Ser. No. 389,360, filed Aug. 13, 1964. In that application, I have disclosed that, with ions of reduced mobility in the fluid, only one stage is necessary in the electrogasdynamic (EGD) converter. That is, it is not necessary to incorporate more than one corona electrode, attractor electrode, and collector electrode in the EGD converter.

In accordance with an aspect of the present invention, a simplified design results when the corona electrode is of a shape to form a plug nozzle, and the collector electrode is of a shape to form a flow diffuser. Thus, the corona and collector electrodes each forms an annular passage for the flow, without obstructing the flow. In fact, they help establish and guide the flow.

An object of the invention is to provide electrogasdynamic systems far more compact than prior art systems of that sort.

Another object of this invention is to provide means for

exposing gases to a high frequency high voltage electric discharge capable of inducing chemical reactions, as, for example, the production of ozone in oxygen and the cracking of long chain hydrocarbon molecules. Those gases can then be used to process the surface of plastic or metals.

Other objects of the invention as well as the advantages thereof will become apparent from the following description when read in conjunction with the accompanying drawings in which:

FIG. 1 is a cross-sectional view, schematically illustrating an exemplary embodiment of the invention; and

FIG. 2 is a cross-sectional view schematically illustrating an incorporation of the FIG. 1 device in a larger overall system.

Referring to the FIG. 1 device, an axial flow path or channel **10** for a gaseous ionizable working fluid is enclosed by the inner wall **11** of a flow tube **12** of "Mylar," boron nitride or other suitable dielectric material. The tube wall **11** conforms to a surface of revolution. High pressure fluid is introduced at subsonic or sonic speed into channel **10** at inlet **13**. Downstream from the inlet, the wall **11** has a conically tapered convergent section **14** followed by a divergent section **16**, the two sections meeting at a junction **17**.

Inserted in inlet **13** is a plug **20** of copper or other conductive metal. The left hand end of the plug is cylindrical. From a starting point upstream of junction **17**, plug **20** is progressively reduced in diameter by a conical taper **21** which is convergent in the downstream direction, and which axially overlaps with portions of the convergent and divergent sections **14** and **16** of wall **11**. The plug taper **21** terminates at a point **22** disposed downstream of junction **17** and providing a corona electrode.

The wall **12** and the plug **20** form between them an annular nozzle passage **25** for the fluid flow channel **10**. The nozzle passage has an upstream convergent section **26** a downstream divergent section **27** and a throat **28** disposed between those two sections **26** and **27** at the junction **17** of the sections **14** and **16** of wall **11**. Plug **20** is of large enough diameter at junction **17** to render the radial dimension of throat **28** substantially less than that plug diameter. Such small radial dimension of the throat and the conical taper of plug **20** permit the nozzle divergent section **27** to expand rapidly downstream even though the inner wall **11** of flow tube **12** has a relatively low divergence within wall section **16**. Hence, despite the small divergence of that wall section, the plug nozzle formed by plug **20** and wall **11** is well adapted to accelerate input fluid to supersonic speed within a short axial distance after the fluid has passed through the throat of the nozzle.

As is evident, the plug **20** is a multi-function element in that it both provides (with wall **11**) a supersonic plug nozzle and, at point **22**, a corona electrode.

The corona electrode **22** is grounded by lead **30** and is connected to the negative terminal of an ionizing voltage source **31** (in some applications the positive terminal may be used instead). The positive terminal of source **31** is connected to an annular attractor electrode **32** incorporated in tube **12** so that the inner surface of the electrode is flush with the tube inner wall **11** and is adjacent to but in radially spaced relation from the corona electrode **22**. In operation, the voltage source **31** develops between the electrodes **22** and **32** an electric ionizing field productive of a negative point corona discharge from the corona electrode. The discharge ionizes the fluid which has been accelerated to supersonic speed by the described nozzle.

Downstream of the ionizing field, the ionized fluid produces electrical charge effects which might distort that field or otherwise affect it adversely. For this reason, in the FIG. 1 device, the ionizing field is electrically isolated from those charge effects by a grounded shield electrode **35** disposed downstream of the ionizing electrodes **22** and

32. As shown, the shield elecrode is comprised of an annular inturned radial flange portion 36 extending from the outside to the inside of tube 12 to terminate in an inner surface flush with the tube wall 11. Flange portion 36 is one of the channel electrodes that directly affects the axial distribution pattern of field potential in the channel region. In its relation to the channel, electrode 36 is analogous to the suppressor grid in a pentode.

At its outside margin, flange portion 36 is joined to a cylindrical sheath portion 37 forming another part of electrode 35 and surrounding the EGD converter section of tube 12 which is downstream of that flange portion 36.

The electrical effects of the shield electrode 35 are (1) to establish at the axial location of flange portion 36 a node of ground value in the mentioned axial field potential distribution pattern, and (2) to establish by sheath portion 37 a ground potential barrier zone preventing escape from tube 12 to the exterior thereof of stray electric fields.

At the outlet of tube 12, the wall 11 has a divergent conical taper 40. Disposed within and in radially spaced relation from taper 40 and extending upstream of that taper is the head 41 of an insulator-conductor structure 42 coaxial with tube 12 and extending away therefrom to an outer end 43. The structure 42 is comprised of a central conductor 44 jacketed by a dielectric casing 45. Head 41 has a conical taper 46 such that the surface of the head converges in the upstream direction to form the upstream end of conductor 44 into a pointed tip 47 providing a collector electrode. Mechanically speaking, the tapered head 41 is a supersonic flow diffuser plug forming with the inner wall 11 of tube 12 a supersonic flow diffuser nozzle 48 for fluid in channel 10. Nozzle 48 has an annular convergent section 49, a conically flaring annular divergent section 50 and an annular throat 51 at the upstream termination 52 of conical taper 40. The nozzle provides for the fluid an exit passage within which the fluid is reduced from supersonic to sonic or subsonic speed.

As indicated by FIG. 1, collector electrode 47 is within sheath portion 37 of shield electrode 35, and that sheath portion and conductor 44 axially overlap. Hence, the shield electrode reduces leakage to the exterior of the FIG. 1 device of stray fields from the collector electrode 47 and the conductor 44.

The channel section 53 between electrodes 36 and 47 is the EGD converter section within which the kinetic energy of the fluid is converted into electrical energy. With L being the axial length of that section and D its means diameter, the section should have a L/D or aspect ratio of at least 5.0 for resons explained in my aforementioned copending application. The shown divergence of wall 11 over the length of section 53 reduces friction losses in the channel and also reduces losses caused by diffusion of ions to the wall (or the stagnant boundary layer adjacent thereto) by the radial space charge induced electric field.

Rightward (FIG. 1) of nozzle 48, the dielectric casing of tubular structure 42 is enclosed by a grounded cylindrical outer conductor 54. The structure 42 is thus a shielded coaxial conductor. To the right of head 41, structure 42 can be flexible and of any convenient length. Conductor 54, among other functions, prevents the escape to the exterior of structure 42 of stray electric fields.

At the outer end 43 of structure 42, the central conductor 44 tapers to a point to form a cathode electrode 55 spaced by a vacuum gap 56 from a thin metallic window electrode 57 constituted of a material suitable for passing electrons or producing a shower of X-rays as desired. If desired, vacuum gap 56 can be of adjustable size. The cathode electrode 55 can be caused to emit electrons either by thermonic emission or by field emission.

Anode electric 57 is mechanically and electrically joined with an inturned annular radial flange 58 forming a part of and terminating the right hand end of the shielding conductor 54. An annular recess 59 is formed as shown in the portion of the dielectric casing 45 which surrounds the section of conductor 44 leading up to cathode 55. The purpose of recess 59 is to prevent electric breakdown along the surface of the insulation 45.

The several structural components of the FIG. 1 device may be supported by any appropriate conventional exterior frame. Thus, for example, plug 20 may be concentrically supported by a circular metal plate 15 perforated around the plug by apertures 18 permitting passage of the fluid through the plate to inlet 13, and tube 12 and structure 42 may be supported by three axial dielectric fins 19 spaced around the FIG. 1 device at 120° intervals, each of the fins being rigidly fastened at its left hand to the rim of the mentioned plate, and each of the fins along its length being in contact with and fastened to the sheath 37 of tube 12 and the sheath 54 of insulator-conductor structure 42.

The FIG. 1 device operates as follows. A gaseous ionizable working fluid comprised at least in part of a condensable constituent (which is initially in gaseous form) is supplied at high pressure to the inlet 13 of flow tube 12. Examples of suitable working fluids are steam and air saturated or nearly so with water vapor.

From inlet 13, the fluid passes through the plug nozzle 25 to be accelerated thereby to supersonic speed. During the expansion of fluid in the nozzle, a part or all of the condensable constituent condenses into multimolecular particles which are entrained in the surrounding still-gaseous fluid medium, and which are in the form of, say, droplets which may subsequently freeze as the temperature drops in the plug nozzle. The particles may conveniently be (but need not necessarily be) of colloidal size and are charge-neutral particles in that they are not initially charged and do not acquire a charge by merger therewith of ions formed in the fluid outside the particles. In certain applications, the particles may be entrained in the fluid before it enters flow tube 12 and may be, say, particles of fly ash.

After the described particles have been formed, the negative point corona discharge from corona electrode 22 produces negative molecular ions in the still-gaseous fluid medium surrounding the particles. While those ions do not charge the particles, the mobility of the negative molecular ions is greatly reduced by the presence in the flow of the mentioned particles. Hence, the motion of the body of the fluid sweeps the ions downstream past the attractor electrode 32 and the channel shield electrode 36 into the EGD converter section 53 of the channel 10. The reduction by the uncharged particles in the mobility of the ions serves to produce a good low-loss coupling between the ions and the non-ionized gaseous body of the fluid, and, moreover, to reduce the tendency of the ions to be driven to or near the tube wall by the radial space charge induced electric field.

As the ions approach collector electrode 47, the negative charges on the ions are neutralized by positive charges drawn out of the collector electrode. Because of the loss therefrom of positive charges, the collector electrode 47 and the conductor 44 become progressively more negatively charged to build up an electric field which tends to repel the ions from the collector, and which causes some slip between the ions and the body of the fluid. Such slip is, however, minimized because of the reduction in ion mobility caused by the presence in the fluid of the mentioned entrained particles. When the ion-repelling field between collector electrode 47 and grounded channel electrode 46 has built up, the flowing fluid does work within EGD section 53 in moving the negative ions against that field. Hence, a conversion of the kinetic energy of the fluid into electrical energy is effected in section 53.

Inasmuch as conductor 44 is initially open circuited at its right-hand end by vacuum gap 56, and inasmuch as conductor 44 is separated by a dielectric filled space from the grounded electrode 50, conductor 44 is adapted to accumulate charge in the same way as a condenser

plate is adapted to do so. Hence, the negative charge on collector electrode **47** and conductor **44** progressively increases until the potential on the conductor is very great, e.g., —100,000 volts. Because charge can accumulate, as described, on the elements **47** and **44**, the FIG. 1 device is self-starting in the sense that no external voltage source is needed to initiate or maintain the ion-repelling field developed by the collector electrode. As described, conversion of the kinetic energy of the fluid into electrical energy takes place because the body of the fluid does work in sweeping the ions downstream (in converter section **53**) against the force exerted by the ion-repelling field emanating from collector electrode **47** and extending between that electrode and electrode **36**

Once the conductor **44** has accumulated thereon a large enough negative charge and potential, the cathode **55** begins to emit electrons which flow to the relatively positive window electrode **57**. In dependence on the design of the latter electrode, some of the electrons may pass through it or the bombardment of electrode **57** by the electrons may cause that electrode to emit X-rays. The current provided by the flow of electrons from cathode **55** to anode **57** is returned through shield electrode **54** to ground.

If the discharge device **55–57** is replaced by an impedance high enough to reduce to a low or negligible value the current which can flow from the right hand end of conductor **44** to ground, then the negative charge and potential on elements **44** and **47** accumulates to a value such that a high frequency high voltage spark flashes back from the colector electrode **47** through the converter section **53** to gruonded channel electrode **36**. Such high frequency high voltage spark may be used to induce chemical reactions in the gas or fluid passing through the converter section. Thus, for example, the spark may be utilized to produce ozone from oxygen or to produce free radicals and excited molecules. Instead of generating the described spark at the collector electrode, the spark may be generated at point **55** of conductor **44** by replacing vacuum gap **56** by a gap occupied by a gaseous or fluid medium and by replacing window electrode **57** by a conventional grounded electrode.

A working example of the FIG. 1 device is as follows:

Quantity—	Value
Working fluid	Water saturated air.
Channel length	3×10^{-2} m.
Channel mean diameter	2×10^{-3} m.
Flow Mach number	1.5–2.
Ion mobolity	10^{-5}–10^{-6} m.^{2} v.$^{-1}$ sec.$^{-1}$
Corona current	5×10^{-5} amp.
Corona voltage	4×10^{3} volt.
Corona power	2×10^{-1} watt.
Output voltage	Up to 120,000 volts.
Output current	Up to 2×10^{-5} amp.
Output power	Up to 2 watts.

FIG. 2 shows the incorporation in a high voltage discharge system of an electrogasdynamic converter which is substantially the same as that of FIG. 1 except that the elements **35**, **50** and **55–58** of the FIG. 1 device are omitted in the FIG. 2 device. Because of the similarity between the two devices, the components of the FIG. 2 converter aer designated by the same reference numerals as their FIG. 1 counterparts but are distinguished therefrom by the use of prime superscripts for the reference numerals.

In the FIG. 2 ssytem, fluid enters the electrogasdynamic converter through orifices **70** in a metal stand **71** on which the converter is mounted. The central conductor **44'** of the insulator-conductor column **42'** is electrically connected at its outer end to a smooth polished hollow metallic charge-accumulator sphere **72** mounted on the column. Spaced from sphere **72** by a gap **73** is a second smooth polished hollow metallic charge-accumulator sphere **74** mounted on a hollow glass column **75** upstanding from a solid cylindrical insulating base **76** on stand **71**. A neon tube **77** having upper and lower terminals **78** and **79** is inserted in glass column **75** so that upper terminal **78** contacts sphere **74** and lower terminal **79** contacts a resilient conductive leaf spring **80** mounted on the upper surface of base **76**. Spring **80** is connected through lead **81**, junction **82** and lead **83** to the positive terminal or ionizing voltage source **31'**, and the same spring is connected through lead **81**, junction **82**, lead **84**, stand **71** and plug **20'** to the corona electrode **22'**. Ammeters **85**, **86**, and **87** are inserted into leads **81**, **83** and **84**, respectively.

The electrogasdynamic converter of FIG. 2 operates like the FIG. 1 device to develop a positive charge on the conductor **44'**. That charge is stored by the accumulator sphere **72** until the potential on the sphere is great enough to produce a spark discharge across gap **73** between the spheres **72** and **74**. The current accompanying the discharge is conducted through the neon tube **77** so as to cause emanation from the tube of a flash of light which is visible through glass column **75**. Thereafter, the current returns by way of circuit **81–84** to the electrogasdynamic converter. With continuing operation, a succession of spark discharges and light flashes are produced in the described manner.

The spark gap load between the two smooth polished spheres **72** and **74** can be replaced by a load provided by a beam tube **90**. In the beam tube, electrons are produced by a hot filament **91**, and they are focused by means of an applied magnetic field generated by a suitably energized coil **92**. By proper selection of the metal target **93** at the left hand end of the beam tube, either electrons or X-rays may be sprayed into the sphere **72**. In the case of X-rays, the sphere **72** should be thick enough to prevent dangerous radiation from being sprayed into the room.

The FIG. 2 system is ideally suited for demonstrating the principles of electrogasdynamic energy conversion in educational institutions because it is safe and has high versatility. It can produce from compressed air, Freon or other gasse either AC or DC electricty, electron beams, X-ray beams or chemical reactions in the working fluid itself.

Theabove described embodiments being exemplary only, it is to be understood that additions thereto, modifications thereof or omissions therefrom can be made without departing from the spirit of the invention, and that the invention comprehends embodiments differing in form and/or detail from those specifically disclosed. For example, the invention is of application when the fluid flow in the EGD converter section is subsonic or sonic as well as when it is supersonic. Moreover, the invention is of application when the field developed by the collector electrode is ion-attracting so that the electrical energy of the collector field is converted into increased kinetic and/or potential energy of the fluid. The ions in the fluid need not be molecular but (in certain instances) may be atomic. An energy converter of a configuration according to the invention and, also, components of that converter are usable with liquid as well as gaseous working fluid although gaseous fluids are preferred.

Accordingly, the invention is not to be considered as limited save as is consonant with the recitals of the following claims.

I claim:

1. The electrogasdynamic method comprising, flowing in a flow path an ionizable working fluid at least partly comprised of a condensable constituent initially in gaseous form, expanding said fluid to accelerate it to supersonic speed and to condense said constituent into multimolecular particles entrained in said fluid, applying to said expanded fluid an electric field having terminal points in a region of the flow path in which flow is supersonic, by which a preponderance of unipolar ions are produced in the fluid medium around said condensed particles, and

applying to said ionized fluid an electric field productive of ion slip in said fluid.

2. Apparatus comprising, dielectric flow tube means for an ionizable working fluid, plug electrode means received in said flow tube means in radially spaced relation from the inner wall thereof to be separated therefrom by an annular supersonic nozzle passage having an upstream convergent section, a downstream divergent section and a throat between said sections, the dimension in the radial direction of said plug means being greater at said throat than the radial throat dimension of said passage, said plug means being convergent in shape in the downstream direction for said fluid to terminate downstream of said throat in a point providing corona electrode means, attractor electrode means exposed to the working fluid at the inner wall of the downstream divergent section and located to establish between it and the corona electrode means a fluid-ionizing electric field transversely of the flow when an electric potential is applied between said attractor and said corona electrode means.

3. Apparatus in accordance with claim 2, in which: said electrode at the inner wall of the downstream divergent section is located slightly downstream of the corona electrode means.

4. Apparatus comprising, dielectric flow tube means for an ionizable working fluid, ionizing electrode means disposed in an upstream portion of said flow tube means and adapted to render said fluid ionized, and conductive shield electrode means exposed to the flow tube interior to establish a shielding potential therein and having a portion on the outside of said dielectric flow tube means downstream of said ionizing electrode means to substantially eliminate any longitudinal electric field on the outside of said flow tube means.

5. Apparatus comprising, fluid flow guide means definite of a flow path for an ionizable working fluid, ionizing electrode means and collector electrode means spaced from each other along said path in the flow direction thereof to be upstream and downstream, respectively, relative to each other, said first and second named electrode means being productive respectively, of an ionizing field for said fluid and of a field inducing ion slip in the ionized fluid, said two fields creating a voltage distribution pattern along said path, and shield electrode means disposed along said path between said ionizing and collector electrode means and connected in circuit with each thereof to produce a node in said distribution pattern.

6. The electrogasdynamic method comprising, flowing in a flow path an ionizable working fluid, ionizing said fluid in an upstream portion of said path by an ionizing field, and electrically isolating by a shielding potential said upsteram portion and said ionizing field and from the electrical charge effects produced by said ionized fluid downstream of said upstream portion.

7. Apparatus comprising, flow tube means for an ionizable working fluid, means in an upstream portion or said tube means to ionize said fluid, and flow diffuser means disposed in a downstream portion of said tube means in radially spaced relation from the inner wall thereof to provide exit passage means for said fluid between said wall and diffuser means, said diffuser means being convergent to a point in the upstream direction, and said diffuser means being comprised of dielectric casing means and of central conductor means jacketed by said casing means and providing collector electrode means at said point.

8. Apparatus comprising, flow tube means for an ionizable working fluid, means in an upstream portion of said tube means to ionize said fluid, and insulator-conductor means downstream of said ionizing means and having an outer end away from said tube means and a flow diffuser head radially spaced from the inner wall of said tube means to provide exit passage means for said fluid between said wall and head, said insulator-conductor means being comprised of dielectric casing means and of central conductor means jacketed by said casing means and extending between said head and end, and said central conductor means providing collector electrode means at said head.

9. Apparatus as in claim 8 further comprising, outer conductor means disposed on the outside of said casing means to render said insulator-conductor means a plural conductor means.

10. Apparatus as in claim 8 further comprising, first discharge electrode means at said outer end and coupled through said central conductor means with said collector electrode means, second discharge electrode means spaced from said first discharge electrode means by a gap bridgeable by a discharge of electric current induced by electric charge conducted by said central conductor means from said collector electrode means to said first discharge electrode means, and means coupled to said second discharge electrode means to provide a return path for said current.

11. Apparatus as in claim 8 further comprising, hollow charge-accumulator means coupled through said central conductor means to said collector electrode means.

12. Apparatus comprising, electrogasdynamic means operable to convert the kinetic energy of a moving working fluid into electrical energy in the form of high voltage electrical charge, first hollow charge-accumulator means coupled to said converter means to store said electrical charge, second hollow charge-accumulator means spaced from said first means by a gap bridgeable by a discharge of electric current induced by said stored charge, and means coupled between said second means and said converter means to provide a return path to said converter means for said current.

13. Apparatus as in claim 12 further comprising, beam tube load means disposed in said gap between said first and second hollow charge-accumulator means.

14. The electrogasdynamic method comprising, supplying to an ionizing zone a flow of a gaseous ionizable working fluid having charge-neutral multi-molecular particles entrained therein, applying to said fluid in said zone an ionizing electric field by which molecular ions are produced in the gaseous medium of said fluid which surrounds said particles, said particles remaining uncharged by said ions, and the mobility of said ions in said fluid reduced by said particles, and applying to said ionized fluid an electric field which is productive of ion slip in said fluid in the flow direction thereof, and which effects an energy conversion between the kinetic energy of said fluid and electrical energy.

15. A method as in claim 14 in which said last named electric field is an ion-repelling field so as to render said energy conversion one in which said kinetic energy is converted into electrical energy.

16. Apparatus comprising, fluid flow guide means definitive of a flow path for an ionizable working fluid, multiple electrode means and collector electrode means spaced from each other along said path to be upstream and downstream respectively, relative to each other, said multiple electrode means including electrode means to ionize fluid in said path, and circuit means including capacitance means electrically connected between said muultiple electrode means and said collector electrode means, said circuit means providing for accumulation of a charge potential between said multiple electrode means and collector electrode means, and means providing a gap bridgeable by an electrical discharge induced by said accumulated potential, said gap being in a return path for current from said collector electrode means to said multiple electrode means.

17. Apparatus as in claim 16 in which said gap is a gap through said path between said collector electrode means and multiple electrode means for a spark discharge from said collector electrode means.

18. Apparatus comprising flow tube means for an ionizable working fluid, ionizing electrode means disposed in an upstream portion of said flow tube means and adapted

to render said fluid ionized, shield electrode means on the outside of said flow tube means downstream of said ionizing electrode means, and collector electrode means disposed in said flow tube means downstream of said ionizing electrode means and adapted to apply to said ionized fluid an electric field productive of ion slip in said fluid, said collector electrode means being in overlapping relation in the flow direction with said shield electrode means.

19. Electrogasdynamic method, comprising the steps of:

flowing in a flow path a working fluid at least partly comprised of a condensable constituent initially in gaseou form;

expanding said fluid to accelerate it to supersonic speed and to condense said constituent into multi-molecular particles entrained in said fluid;

simultaneously applying to said fluid during expansion an ionizing electric field having terminal points in a region of the flow path in which flow is supersonic by which a predominance of unipolar ions are produced in the fluid to serve as nuclei for said condensed particles; and

maintaining in the flow path downstream of said ionizing electric field a longitudinal electric field created by ionization of the flow.

20. Electrogasdynamic apparatus, comprising:

flow tube means for an ionizable working fluid, said flow tube means including an upstream convergent section and a dielectric downstream divergent section defining therebetween a nozzle throat for the supersonic expansion of the fluid;

corona electrode means exposed to the fluid to have an electrical discharge portion thereof located downstream of the throat; and

attractor electrode means located in said dielectric divergent portion and exposed to the interior of the flow tube means to establish between it and the discharge portion of said corona electrode means an electrical discharge field effective to simultaneously ionize said fluid during its expansion in the divergent section, said attractor electrode means being electrically isolated in said flow tube means by the dielectric portions of the divergent section upstream and downstream thereof to maintain in said downstream divergent portion a longitudinal electric field attributable to the space charge created by ionization of the fluid.

21. Apparatus according to claim **20**, in which:

the corona electrode means is radially spaced from the inner wall of the flow tube means; and

the attractor electrode means is in the form of an annular ring disposed slightly downstream from the emitting portion of the corona electrode means and is substantially flush with the inner wall of the divergent portion of the nozzle.

22. An electrogasdynamic apparatus comprising:

dielectric flow tube means defining a flow path for an ionizable stream of gas;

electrical discharge electrode means disposed in an upstream portion of said flow tube means to produce a preponderance of unipolar charges in the stream,

potential source means for exciting the electrical discharge electrode means,

a collector electrode disposed downstream of the ionizing electrode means and exposed to the ionized flow to neutralize electrical charges carried downstream by the stream;

said collector electrode means and dielectric flow tube means being effective to establish in the stream a longitudinal charge-repelling electric field; and

electrical current indicating means coupled to the collector electrode to provide an indication of the rate at which charges are neutralized.

23. Apparatus comprising:

means defining a flow tube for an ionizable working fluid and including an upstream convergent section and a downstream divergent section defining therebetween a nozzle throat for the supersonic expansion of a gas, the downstream section providing a dielectric flow boundary over a portion of its axial extent;

corona electrode means comprising a member supported upstream of the nozzle throat and extending therethrough, the member tapering in a forward direction to terminate in an electrical discharge tip downstream of the throat; and

attractor electrode means located in said divergent portion adjacent the dielectric boundary and exposed to the interior of the flow tube to establish between the attractor electrode and the discharge tip an electrical discharge field effective to ionize the gas during its flow through the divergent section.

References Cited

UNITED STATES PATENTS

3,225,225	12/1965	Wattendorf et al.	310—6

FOREIGN PATENTS

842,689	3/1939	France.
958,214	5/1964	Great Britain.

DAVID X. SLINEY, Primary Examiner

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,519,850 Dated July 7, 1970

Inventor(s) Meredith Gourdine

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

Column 3, line 49, "means" should be --mean--;
line 51, "resons" should be --reasons--;

Column 5, line 30, "colector" should be --collector--;
line 31, "gruonded" should be --grounded--;
line 63, "aer" should be --are--;
line 67, "ssytem" should be --system--;

Column 6, line 8, "or" should be --of--;
line 41, "gasse" should be --gases--;
line 41, "electricty" should be --electricity--;
line 44, "theabove" should be --The above--;

Column 7, lines 35 and 36 "definite" should be --definitive--;
line 52, "upsteram" should be --upstream--;

Column 8, line 43, after "fluid" insert --being--;
line 60, "muultiple" should be --multiple--;

Column 9, line 13, "gaseou" should be --gaseous--.

SIGNED AND SEALED
NOV 24 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents