

Aug. 7, 1962

W. S. EMMERICH

3,048,736

ARC CHAMBER

Filed April 4, 1960

2 Sheets-Sheet 1

Fig.1.

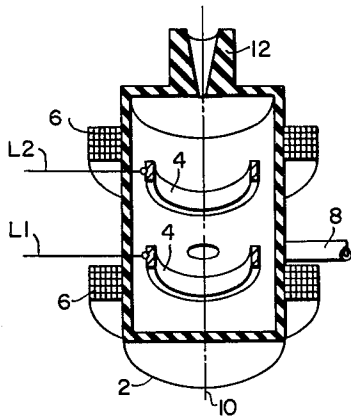


Fig. 2.

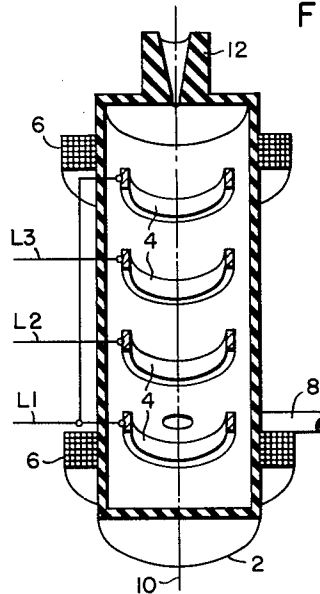
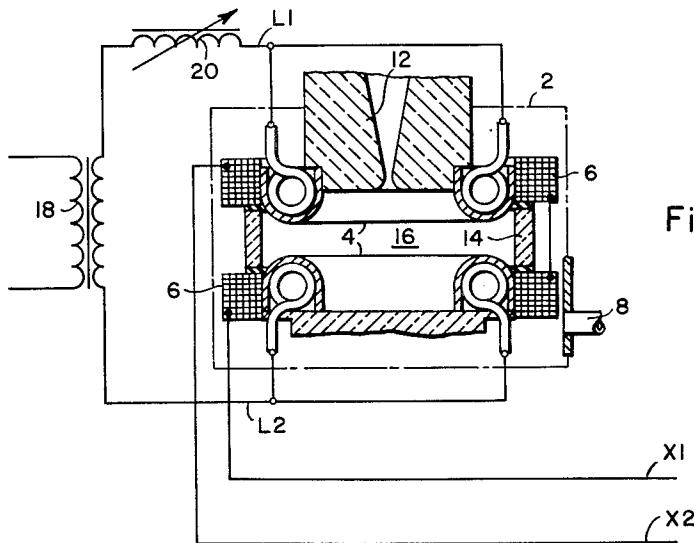


Fig.3.



WITNESSES

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2 Sheets-Sheet 2

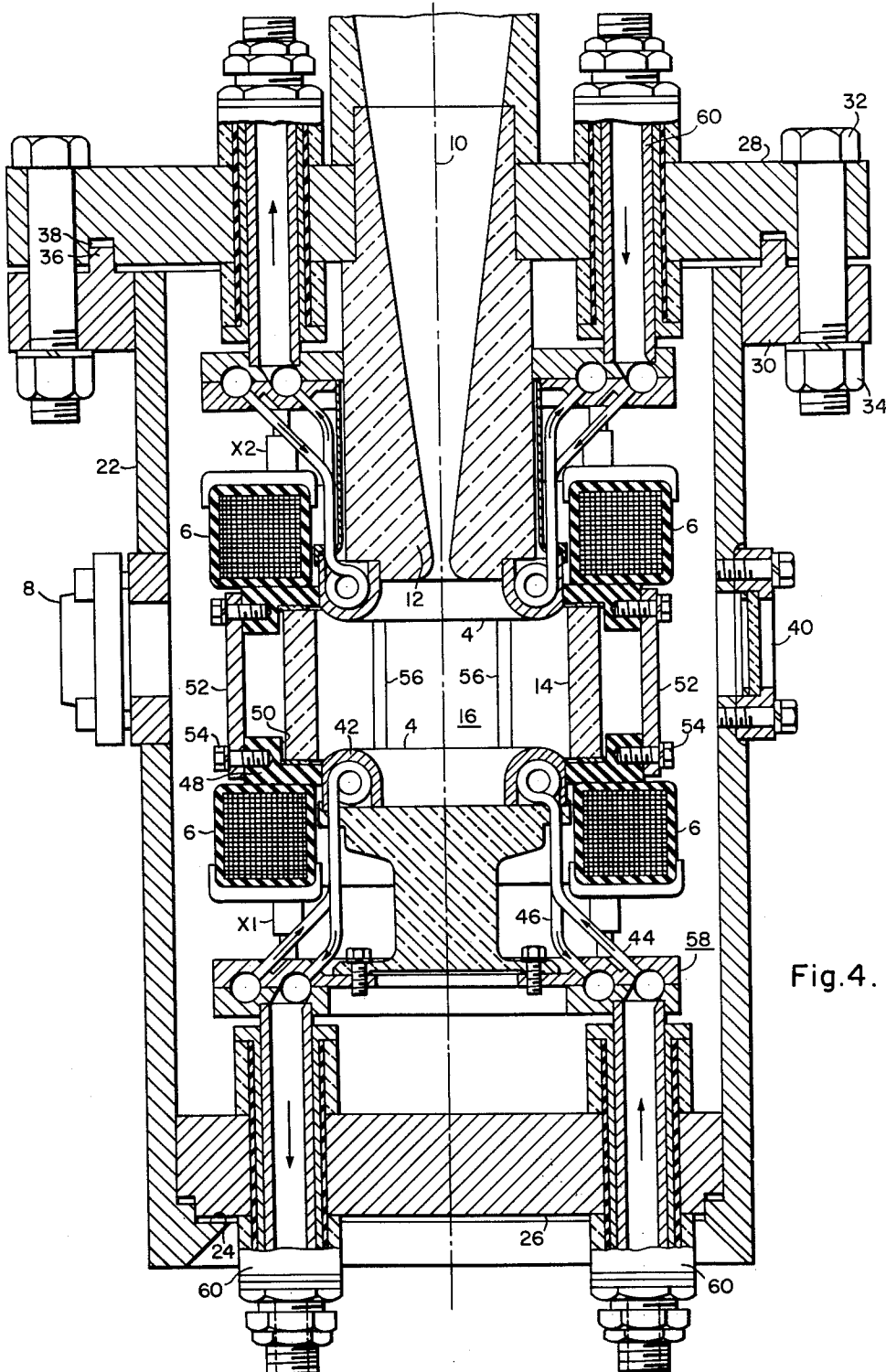


Fig. 4.

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3,048,736

ARC CHAMBER

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Filed Apr. 4, 1960, Ser. No. 19,528

10 Claims. (Cl. 313-161)

The present invention relates generally to arc chambers and more particularly to an arc chamber for heating gas to extremely high temperatures.

Hypersonic aircraft and missiles and their development have been hindered by the lack of adequate test facilities for determining satisfactory configurations and materials prior to their manufacture. Shock tubes and hot shot tunnels, the only facilities now available which can simulate missile reentry conditions, provide test periods so limited in time, in the order to milliseconds, that instrumentation is extremely inaccurate.

A wind tunnel for true air temperatures, density, and velocity simulation of the reentry conditions requires a chamber in which a steady-state pressure is maintained for extended periods. The present invention provides such a chamber wherein gas is heated by an electric arc drawn between ring electrodes placed inside a cylindrical chamber. A magnetic field coil of appropriate configuration is associated with the assembly. Upon start up the cold gas at relatively high pressure with respect to the exit enters between the ring electrodes. The electric arc is forced along the rings by precession due to the action of the magnetic field. The arc is further pushed along the ring electrodes by the entering gas. The rotating arc and the air flow sets up a swirling action in the chamber so that the hottest portion of the heated gas collects along the axis of the cylindrical chamber from where it is removed through a properly placed nozzle.

Accordingly, an object of the present invention is to develop gas velocities, temperature, and pressure conditions for time periods which will simulate the conditions encountered by a body reentering and passing through the earth's atmosphere at speeds in the hypersonic range.

Another object of the present invention is to provide an arc chamber capable of producing a clean flow of gas under steady-state conditions for a hypersonic wind tunnel.

Another object of the present invention is to provide an arc chamber capable of reducing the likelihood of hot spots on the electrodes thereby further reducing possible pollution of the gas.

Another object of the present invention is to provide an arc chamber having a central location which is free from obstruction so that a cleaning action of the stream due to centrifugal acceleration of heavy particles, and the concentration of hottest gas at a central location can take place unhindered and with maximum effectiveness.

Another object of the present invention is to provide an arc chamber wherein there is a relatively high heat dissipation in the arc as compared to losses in the hot spot and in the heating of the chamber walls.

Another object of the present invention is to provide an arc chamber wherein the hottest portion of the heated gas gathers in a central location by means of magnetically directing the arc thereto.

Another object of the present invention is to provide an arc chamber wherein the hottest portion of the heated gas gathers in a central location by means of the flow conditions established by incoming gas to the chamber.

Another object of the present invention is to provide an arc chamber wherein the electric arc tends to be drawn to a central location by the flow of incoming gas.

Another object of the present invention is to provide an arc chamber for use with alternating as well as direct current.

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Further objects and advantages of the present invention will be readily apparent from the following detailed description taken in conjunction with the drawing, in which:

FIGURE 1 is a schematic diagram of an illustrative embodiment of the invention;

FIG. 2 is a schematic diagram of an alternate embodiment of the invention;

FIG. 3 is an electrical schematic diagram of the illustrative embodiment shown in FIG. 1; and

FIG. 4 is a cross-sectional elevation view of the illustrative embodiment shown in FIG. 1 with a jet nozzle for hypersonic wind tunnel purposes.

The principles of the invention are diagrammatically illustrated in FIG. 1, wherein a cross-sectional view of a cylindrical vessel or chamber 2 has mounted therein a pair of ring electrodes 4 which are spaced apart to form an arc gap between them. Magnetic coils 6 are disposed adjacent to the electrodes 4 to provide a radial magnetic field transverse to an electric arc which is sustained between the electrodes 4 by means of the power supply leads L1, L2 connected to the ring electrodes 4. Means are provided for the admission of cool gases under pressure to the chamber 2 and is illustrated as a gas inlet pipe 8 leading to the area between the ring electrodes 4. In operation, the electric arc, while heating the gas, is forced around the electrodes 4 setting up a swirling motion in the chamber 2 so that the hottest portion of the heated gas collects along the axis 10 of the cylindrical chamber 2. Appropriate exit means from the chamber 2 is illustrated as a nozzle 12 which may lead to a previously evacuated wind tunnel and into the test section proper. It is to be understood that the hottest portion of the heated gas is herein meant to exclude the gases within the arc since these gases would, of course, be subjected to the initial heating effect of the ionizing potential.

A hypersonic wind tunnel using an arc chamber utilizing the principles of the present invention depends upon electrically increasing the internal energy of the gas and utilizing Brownian movement to obtain directed kinetic energy for the desired gas velocity. The chamber 2 increases the enthalpy of the gas admitted to the chamber by electrical energy means. The principal advantage of the present invention lies in its ability to produce a clean flow of gas under extremely high pressures and temperatures at steady-state conditions. The absence of electrodes from the central or axis portion of the chamber where the hottest portion of the heated gas will gather reduces the ambient temperature to which the electrodes are exposed. The magnetic field provided by the magnetic coils 6 is positioned to be transverse to the conducting path of the arc so that the arc travels around the ring electrodes 4 inhibiting the formation of hot spots on the electrodes thereby reducing further possible pollution of the gas. In addition, the central or axis portion of the chamber 2 is free from obstruction so that a cleaning action due to centrifugal acceleration of heavy particles, and the concentration of hot gas along the axis can take place unhindered and with maximum effectiveness. The arc itself will be lengthened as it bends toward the axis which in turn establishes a favorable voltage gradient leading to relatively high heat dissipation in the arc.

It is to be noted that the power supply connected across the ring electrodes 4 in FIG. 1 is illustrated to be single phase. When it is desirable, a direct current potential may be used to strike the arc between the electrodes. However, considerable economic advantage is obtained through the use of alternating current power supplies.

FIGURE 2 illustrates an alternate embodiment of my invention utilizing a three phase alternating current source wherein all like parts have been given the same reference characters. An arc capable of increasing the enthalpy of the gas within the chamber 2 will appear across a pair of

the ring electrodes 4 depending upon the phase rotation of the three phase power supply, L1, L2 and L3. The arrangement shown in FIG. 2 provides economic advantages only available through the use of a three phase or multiphase power supply.

FIG. 3 is an electrical schematic diagram for the illustrative embodiment shown in FIGURE 1. The location of the arc chamber 2 is illustrated by the dot-dash line. For purposes of clarity the gas inlet pipe 8 for the admission of gas to the chamber 2 and hence to the area between the electrodes 4 is merely symbolically shown. A cylinder 14 is shown coaxially mounted with the ring electrodes 4 enclosing the area between the ring electrodes 4 to form an envelope 16. The alternating current power leads L1, L2 are shown connected across the ring electrodes 4. A single phase power supply is illustrated as a power transformer 18 having its secondary side serially connected with a reactor 20. The reactor 20 controls the power input to the arc chamber 2. The reactor 20 is adjusted to cause a time phase shift between the voltage and current thereby ensuring a high voltage impressed across the electrodes immediately following current zero. A potential for exciting the magnetic coils 6 is illustrated by the excitation leads X1 and X2.

FIGURE 4 shows an arc chamber utilizing the principles described in connection with the previous figures. Again, for sake of clarity, like components have been given the same reference characters used in the previous figures. The arc chamber 2 is illustrated cylindrical in form comprising a rolled side wall member 22 having annular stepped shoulders 24 at the bottom with a base disc 26 positioned against the shoulders 24 closing the bottom of the arc chamber. A cap 28 secured by means of a clamping ring 30, encloses the other end of the arc chamber. The clamping ring 30 is attached to the side wall member 22 by means of cap bolts 32 and cap nuts 34 peripherally spaced around the clamping ring 30. Locating lugs 36 engaging a groove 38 center the cap 28 on the clamping ring 30. A nozzle block 12 is shown in position extending through the cap 28 to allow removal of the hottest portion of the heated gas. The nozzle block 12 is positioned by the cap 28. The nozzle block 12 may be omitted when desired and the arc chamber may merely have an exhaust tube should the arc chamber be used for applications other than a hypersonic wind tunnel. Any suitable vent or aperture may be disposed on the axis of the chamber. A sight gauge 40 located in the side wall member 22 provides means for observation of the internal workings of the arc chamber 2.

The ring electrodes 4 are coaxially disposed within the chamber 2 and spaced apart to form a spark gap. The ring electrodes 4 have a sparking surface 42 of suitable material such as copper, tungsten, platinum, iridium or other material to minimize ablation and erosion of the electrode due to the intense heat of the hot spot of the arc. The ionized potential appearing across the ring electrodes 4 from the power supply is connected thereacross by means of inlet and outlet connectors 44 and 46. The inlet and outlet connectors 44 and 46 also serve as conduit means for providing a cooling medium to the electrodes as described hereinafter.

The magnetic field coils 6, connected to an excitation potential through the leads X1, X2, are magnetized in an axial direction, each having a north pole on one face and a south pole on the opposite face so that a radial magnetic field will be produced that is transverse to the arc column. As a result the arc column will rotate around the ring electrodes 4 thereby reducing the dwell time and further preventing formation of a critical hot spot on the ring electrodes. It is to be understood, however, that any suitable arrangement of electromagnetic coils or magnets may be used which will produce a magnetic field substantially perpendicular to the arc column.

The incoming cool gas under pressure is admitted to the chamber 2 by means of a flange connection 8 located in the rolled side wall member 22. The cool gas enters the

area between the ring electrodes 4 by passing through a sleeve 14 which is circumferentially disposed with said electrodes 4 and separates the electrodes from the remainder of the chamber 2. The sleeve 14 forms an envelope 16 within the chamber 2. The sleeve 14 may be chosen to have a high factor of reflectivity. Radiant and convection heating within the envelope 16 can be deterrent factors in obtaining even higher air pressures for supersonic speeds since the safe operating temperature of the sidewalls of the envelope 16 can be a limiting factor. However, the high reflectivity of the sleeve member 14 and the tangential openings 56 therethrough will tend to keep the sleeve within safe operating temperature limits through reflection and convection cooling. The streams of incoming gas are tangentially directed to the ring electrodes 4 to assist the magnetic field in rotating the electric arc column.

The sleeve member 14 is positioned around the outer periphery of the ring electrodes 4 by means of circular rings 48 having annular flanges 50. The circular rings 48 are made of an insulating material and abut the outer periphery of the ring electrodes 4. The sleeve member 14 abuts the annular flange 50 thereby completing the enclosure of the envelope 16 wherein the arc heats the gas. Rods 52 peripherally spaced around the circular rings 48 and secured by the bolts 54 strengthen and position the assembly of the envelope 16.

The present invention provides for the cooling of the electrodes 4 by heat exchanger means located within the hollow interior of the ring electrodes 4. A cooling medium, such as water or oil, is introduced to the interior of the ring electrodes by means of the inlet and outlet connectors 44 and 46. The cooling liquid flows in cooling coils embedded within the ring electrodes 4. A manifold 58, having water inlet and outlet passages, connect the power bushings 60 to the inlet and outlet connectors 44 and 46 and hence to the internal recesses of the ring electrodes 4.

In operation, the incoming gas entering the envelope 16 is caught up in a swirling action of the arc which arc is also driven around the electrodes 4 by the tangential direction of the incoming gas with respect to the ring electrodes. The hottest portion of the heated gas locates along the axis 10 of the chamber 2 due to the swirl from whence it is removed by means of an appropriately located aperture or nozzle block 12.

The present invention provides an arc chamber capable of maintaining a steady-state pressure for extended periods. The location of the components within the arc chamber frees the central portion of the chamber from obstructions so that self-cleaning action due to centrifugal removal of heavy particles from the gas stream and the concentration of hot gas along the axis of the chamber due to the swirl can take place unhindered and with maximum efficiency. The electric arc will be lengthened as it is drawn towards the axis by pressure and density gradients in the gas as well as the force from the magnetic field. The longer the arc that is maintained, the greater efficiency in heating the gases in the chamber 2. The longer the arc, the larger the portion of the power that will be put to work heating the gas rather than heating the ring electrodes and the envelope surroundings.

Although this invention has been described with a particular degree of exactness for the purpose of illustration, it is to be understood that the present invention is to include all equivalents, alterations, and modifications within the spirit and scope of the invention.

For instance, the present invention provides an arc chamber that is applicable to magnetohydro dynamic generation of electrical power. The formation of various chemical compounds is possible by use of the heat generated by the electric arc of the type provided by the present invention. Fixation and synthesis can be readily accomplished by means of applying an arc chamber such as described in accordance with the present invention.

I claim as my invention:

1. A chamber for increasing the enthalpy of a gas by electrical energy comprising, a plurality of ring electrodes coaxially disposed within said chamber parallel to each other and spaced apart to form a spark gap; means for connecting an ionizing potential across said electrodes of sufficient magnitude to sustain an arc thereacross; means for admitting gas to said chamber; magnetic means for subjecting said arc to a magnetic field transverse to said arc; and discharge means coaxially disposed to said ring electrodes for removing from said chamber that portion of the gas axially located with respect to said ring electrodes.

2. A chamber for increasing the enthalpy of a gas by electrical energy comprising, a plurality of ring electrodes coaxially disposed within said chamber and spaced apart to form a spark gap; means for connecting an ionizing potential across said electrodes of sufficient magnitude to sustain an arc thereacross; means for connecting a source of gas to said chamber; means circumferentially disposed to said electrodes and between said electrodes and said chamber for forming an envelope of the area between said electrodes; said last-mentioned means having tangential openings for the admission of gas to said envelope; magnetic means for subjecting said arc to a magnetic field transverse to the arc; and exhaust vent means coaxially disposed with said ring electrodes for removing from said chamber the portion of the gas axially located with respect to said ring electrodes.

3. A chamber for increasing the enthalpy of a gas by electrical energy comprising, an exhaust vent within said chamber adapted to accommodate a nozzle; means for admitting gas to said chamber; a first ring electrode fixedly mounted within said chamber and coaxially disposed with said exhaust vent; a second ring electrode fixedly mounted within said chamber and coaxially disposed with said exhaust vent and being parallel to, coaxial with, and spaced from said first electrode; means for sustaining an arc between said ring electrode; and means for providing a magnetic field transverse to said arc.

4. A chamber for increasing the enthalpy of a gas by electrical energy comprising, a pair of ring electrodes coaxially disposed within said chamber and spaced apart to form a spark gap; means for enclosing the area between said ring electrodes thereby forming an envelope therebetween; means for connecting a source of gas to said chamber; means for connecting an ionizing potential across said pair of electrodes of sufficient magnitude to sustain an arc thereacross; said means for enclosing including means peripherally disposed to said ring electrodes for the admission of gas to said envelope tangentially to said ring electrodes; and means disposed along the axis of said chamber for removing from said chamber the hottest portion of the heated gas.

5. A chamber for increasing the enthalpy of a gas by electrical energy comprising, a pair of ring electrodes coaxially disposed within said chamber and spaced apart to form a spark gap; means for enclosing the area between said ring electrodes forming an envelope therebetween; means for connecting a source of gas to said chamber; means for connecting an ionizing potential of sufficient magnitude across said pair of electrodes to strike an arc thereacross; said means for forming an envelope including means peripherally disposed to said ring electrodes for the admission of incoming gas to said envelope and tangentially to said ring electrodes; magnetic means for subjecting said arc to a magnetic field forcing said arc along the ring by precession due to the action of the magnetic field; means disposed along the axis of said chamber and at one end thereof for removing from said chamber the hottest portion of the heated gas axially located with respect to said ring electrodes; said gas within said envelope having a swirling motion

from said means peripherally disposed to said last-mentioned means.

6. A chamber for increasing the enthalpy of a gas by electrical energy comprising, a plurality of ring electrodes coaxially disposed within said chamber and spaced apart to form a plurality of spark gaps; means for connecting an ionizing potential across said electrodes of sufficient magnitude to sustain an arc thereacross; means for admitting gas to said chamber; magnetic means for subjecting said arc to a magnetic field transverse to said arc; and discharge means coaxially disposed to said ring electrodes for removing from said chamber that portion of the gas axially located with respect to said ring electrodes; whereby upon start up the gas being admitted to said chamber being at a higher pressure than the gas being discharged from the chamber.

7. A chamber for increasing the enthalpy of a gas by electrical energy comprising, a plurality of ring electrodes coaxially disposed within said chamber and spaced apart to form a plurality of spark gaps; means for connecting an ionizing potential across said electrodes of sufficient magnitude to sustain an arc thereacross; means for connecting a source of gas to said chamber; means circumferentially disposed to said electrodes and between said electrodes and said chamber for forming an envelope of the area between said electrodes; said last-mentioned means having tangential openings for the admission of gas to said envelope; magnetic means for subjecting said arc to a magnetic field transverse to the arc; and exhaust vent means coaxially disposed with said ring electrodes for removing from said chamber the portion of the gas axially located with respect to said ring electrodes; whereby upon start up the pressure of the gas being admitted to said chamber being greater than the pressure of the gas at the exhaust vent means.

8. A chamber for increasing the enthalpy of a gas by electrical energy comprising, an exhaust vent within said chamber adapted to accommodate a nozzle; means for admitting gas to said chamber; a plurality of ring electrodes disposed within said chamber and spaced apart to form a spark gap between adjacent electrodes; said electrodes coaxially disposed with said exhaust vent and being parallel to, and coaxial with, each other; means for sustaining an arc between said ring electrodes; and means for providing a magnetic field transverse to said arc.

9. A chamber for increasing the enthalpy of a gas by electrical energy comprising, a pair of ring electrodes coaxially disposed within said chamber and spaced apart to form a spark gap; means for enclosing the area between said ring electrodes forming an envelope therebetween; means for connecting a source of gas to said chamber; means for connecting an ionizing potential of sufficient magnitude across said pair of electrodes to strike an arc thereacross; said means for forming an envelope including means for the admission of incoming gas to said envelope; magnetic means for subjecting said arc to a transverse magnetic field forcing said arc along the ring by precession due to the action of the magnetic field; means disposed along the axis of said chamber and at one end thereof for removing from said chamber the hottest portion of the heated gas axially located with respect to said ring electrodes; said magnetic means including a pair of magnetic coils coaxially disposed with respect to said electrodes and within said chamber.

10. A chamber for increasing the enthalpy of a gas by electrical energy comprising, a plurality of ring electrodes coaxially disposed within said chamber and spaced apart to form a plurality of spark gaps; electrical means for connecting an ionizing potential across said electrodes of sufficient magnitude to sustain an arc thereacross; inlet means for connecting a source of gas to said chamber; enclosure means circumferentially disposed to said

electrodes and between said electrodes and said chamber
for forming an envelope of the area between said elec-
trodes; said last-mentioned means having tangential open-
ings for the admission of gas to said envelope; magnetic
means for subjecting said arc to a magnetic field trans-
verse to the arc, said magnetic means including a pair of
magnetic coils disposed about said enclosure means co-
axially with respect to said electrodes and within said
chamber; and exhaust vent means coaxially disposed with
said ring electrodes for removing from said chamber the

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portion of the gas axially located with respect to said ring
electrodes.

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