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APPARATUS FOR CREATING EXTREMELY HIGH TEMPERATURES

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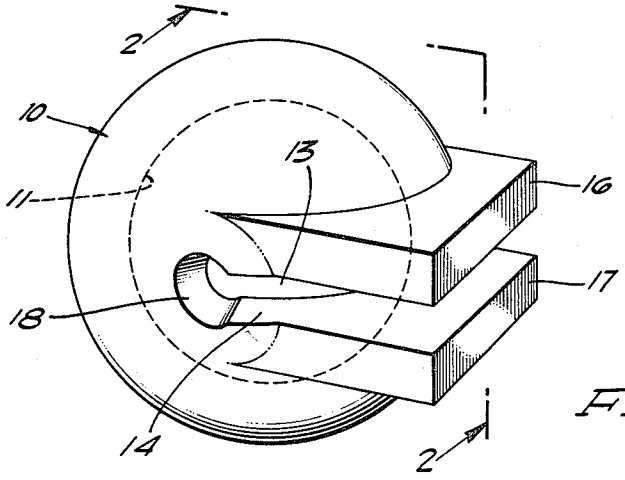


FIG. 1.

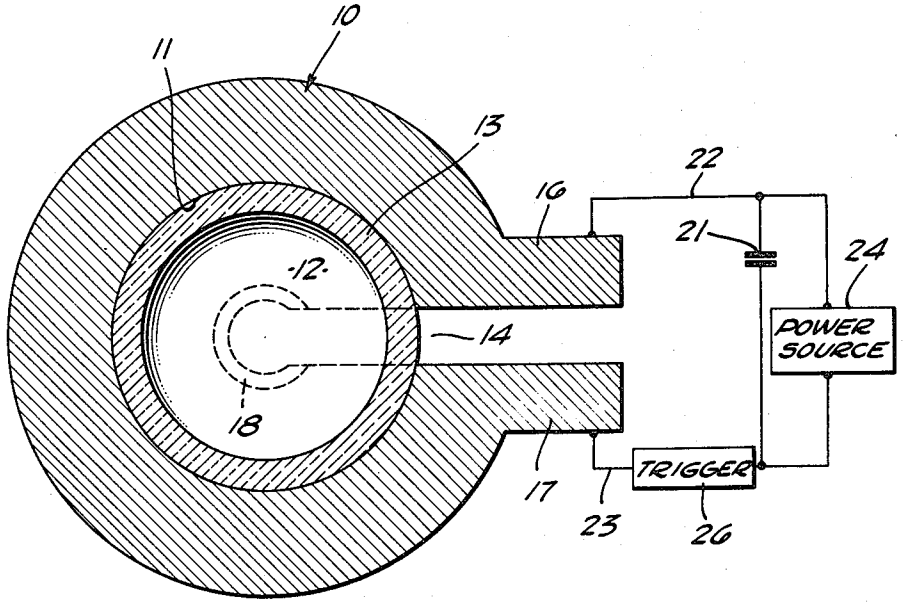


FIG. 2.

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APPARATUS FOR CREATING EXTREMELY HIGH TEMPERATURES

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8 Claims. (Cl. 315—236)

This invention relates to apparatus for generating high temperatures, and high-intensity light. The invention pertains to the general field of discharge-type devices for generating momentarily temperatures measured in the millions of degrees.

Discharge-type devices of the class indicated may be divided into those employing electrodes, and those effecting a discharge in space. Devices employing electrodes present substantial problems of contamination due to the vaporization of electrode material. This produces, particularly in the case of repetitive operation, detrimental effects because of the fact that the radiation capabilities of vapors of impurities are very high. It follows that a large amount of the energy stored in the discharge is dissipated in the form of radiation, thereby reducing the effective temperature of the gas.

With relation to devices which effect discharges in space, that is to say without electrodes, these conventionally consist of a toroidal chamber which produces, in conjunction with magnet means and by virtue of a pinch effect, a toroidal plasma concentration of filament-like dimensions. The energy stored in this pinch of plasma is readily radiated because of the geometry of the apparatus. For this and other important reasons, such apparatus has been characterized by limitations as to the maximum temperature which may be achieved, it being difficult to supply energy at a rate sufficiently fast to permit the attaining of ultra high temperatures. Other limitations and defects of such toroidal-type plasma devices have included various forms of plasma instabilities.

In view of the above factors characteristic of discharge-type devices for obtaining extremely high temperatures, it is an object of the present invention to provide an apparatus for creating a very high temperature in a small volume approximating a point, and in a highly efficient manner.

A further object of the invention is to provide electrical-conductor means for creating a substantially continuous electrically-conductive surface defining a generally spheroidal cavity, in combination with means to effect flow of a single very high current pulse through said electrical conductor, thereby creating a concentric blast or shock in said cavity to produce a high concentration of ionized particles at the center thereof.

These and other objects and advantages of the invention will be more fully set forth in the following specification and claims, considered in connection with the attached drawing to which they relate.

In the drawing:

Figure 1 is a perspective view of one form of apparatus constructed in accordance with the present invention; and

Figure 2 is a section taken on line 2—2 of Figure 1, and showing in schematic form an electric circuit means associated with the electrical conductor which defines the cavity.

Stated generally, the apparatus comprises electrical conductor means to define a substantially continuous,

electrically-conductive surface which forms the wall of a generally spheroidal cavity, the electrical conductor means being split to form a gap along one great semicircle of the cavity. Means are provided for momentarily supplying large amounts of electrical current to the electrical conductor means on opposite sides of the gap or split. This effects a momentary, single-turn flow of current around the cavity to cause a high concentration of ionized particles at the center portion thereof.

Stated more definitely, the high concentration of ionized particles at the center portion of the cavity, in a volume approaching a point, results from the extremely rapid rate of change of magnetic field strength due to the low inductance of the electrical conductor and the large amount of current passed instantaneously therethrough. Because of the rapid rate of change of magnetic field strength, ionized particles in the cavity are accelerated rapidly toward the center and form an inwardly-directed shock, or a spherical implosion. The rapid acceleration of the ionized particles, and the collision thereof in the region of the center, provides a very high temperature on the order of millions of degrees.

Referring to the drawing, the apparatus comprises a relatively strong and thick hollow conductor, illustrated as a ball or spheroid **10** formed of copper alloys or other highly conductive material. The outer surface of the ball or spheroid is not necessarily round and may be somewhat irregular, but the inner surface **11** should be a relatively smooth, rounded surface having the general shape of a spheroid. The inner surface defines within it a cavity **12** which should be substantially evacuated to achieve the selected operating pressure. In order to maintain this vacuum, a hollow spherical envelope **13**, formed of a non-conductor such as quartz, is provided in cavity **12**, and preferably has its outer surface closely adjacent the inner surface **11** of conductor element **10**.

The conductor **10** may also comprise a thick mass of copper, preferably a strong allow such as hardened beryllium-copper, which is not externally spherical. Such mass may be shaped as a block of metal having a spheroidal cavity carved therein. The block is split along one great semicircle of the cavity in order to provide a single-turn electrical circuit around the axis of the cavity.

The hollow spherical conductor **10** is formed with a single split or gap **14** along one great semicircle thereof, the remainder of the conductor being continuous. The gap **14** is sufficiently wide (or insulated) to prevent arcing thereacross under the voltage impressed thereon. In order to conduct current to the ball **10** on opposite sides of gap **14**, plates **16** and **17** are associated with the ball **10** and extend outwardly therefrom generally parallel and close to each other. Plates **16** and **17**, which are preferably integral with the spheroid, are also spaced apart (or insulated) to prevent arcing due to the impressed voltage. Plates **16** and **17** are preferably located very close to each other, in order to minimize inductance, and may be maintained electrically separate by a thin sheet of insulation. It is pointed out that the plates **16** and **17**, and the conductive ball **10**, provide the previously-indicated single-turn continuous circuit around the evacuated cavity **12** and through which a large current may flow. Because of the single-turn nature of the circuit, it has a low inductance permitting substantially instantaneous flow of a very large current, with consequent rapid rate of change of magnetic field strength in the cavity **12**.

A feature of the spheroid **10** is that it is continuous except at the gap **14**, so that it has a high strength adapted to resist the large magnetic forces created when a current on the order of several million amperes is passed through the single-turn circuit mentioned above. It is, however, within the scope of the invention to further reinforce

the elements **10**, **16** and **17** such as by embedding the same in a block of strong insulating material. Such block may be enclased or jacketed at a substantial distance from the sphere.

A hole or opening **18** is formed at each end of the semicircular split or gap **14**, in order to permit closing of the lines of magnetic force created by the current flow. These holes may be generally conical, and inwardly convergent.

Referring to Figure 2, the means for passing a large amount of current through the single-turn circuit is shown as comprising a capacitor **21** connected between the plates **16** and **17** by means of conductors **22** and **23**. The capacitor is charged from a suitable power source **24**, such as a direct current generator, and is discharged under the control of a trigger or switch means **26** which is illustrated as interposed in the lead **23** between capacitor **21** and plate **17**. It is to be understood that the showing of the electric circuit means at the right in Figure 2 is highly schematic, and that the capacitor **21**, the associated leads **22** and **23**, etc., are normally very large and of a low-inductance type adapted to generate the above-indicated large current upon discharging. In the operation of the apparatus, capacitor means **21** is first charged from the power source **24** when the trigger or switch means **26** is in open-circuit condition. Thereafter, the trigger **26** is operated to close the circuit from the capacitor **21** to plates **16** and **17**. A single very large current then flows in a single turn around the hollow spheroid **10**, but only for the short period of time required to discharge the capacitor means **21**. Because of the very high rate of change of current, the current flow tends to concentrate at the inner surface **11** due to skin effect.

The result of the above is a very rapidly changing magnetic field within cavity **12**, and having a very great strength sufficient to effect rapid acceleration of ionized particles toward the center portion of the cavity. The rapid acceleration and speed of the ionized particles, and the collision of the particles, produce an extremely high temperature at the center portion of the cavity. Stated otherwise, a pulsed magnetic field is generated which is such as to effect a radially inwardly directed shock creating the very high temperature at a small volume at the center portion of the spheroid, approaching a point.

To amplify upon the previously-stated theory relative to the present invention, it is pointed out that the flow of current is in a given direction through the conductor means and circumferentially about the axis of the spheroidal cavity. This results in the formation of an induced current sheet flowing in the opposite direction and through the gas. The induced current sheet is located within the evacuated cavity and is initially relatively close to the cavity wall formed by the conductor means. Thus, in the situation in which there is an envelope within the cavity, the induced current initially flows through the gas adjacent the inner wall of the envelope, it being remembered that the envelope is formed of non-conductive material.

The sheet of induced current, composed of ions and electrons, acts as a barricade through which the lines of magnetic force may not penetrate appreciably. This is particularly true when the rate of change of magnetic field strength is great. This being the case, at least the majority of lines of magnetic force initially pass (in a spheroidal configuration) between the conductor metal and the current sheet—or largely through the envelope in cases where there is an envelope.

The generally spheroidal magnetic field acts as a piston to drive (implode) the current sheet, that is to say the ions and electrons, radially inwardly toward the center of the cavity. As the current sheet collapses toward the center, in a shock wave, the lines of magnetic force collapse toward the center (in the above-indicated piston action) to compress the gas, and greatly elevate its temperature because of the speed and collision of the particles. The inward movement continues until the external magnetic pressure is counterbalanced by the internal pressure resulting from compression and temperature increase.

Since the lines of magnetic force may not pass through the electrical conductor metal, the conductor is provided with openings (or non-conductors) at the poles of the cavity. The lines of force thus flow through the poles and externally of the spheroid to form continuous loops. As previously indicated, the reinforcing material in which the apparatus is embedded is non-conductive (except possibly in a casing remote from the sphere) and thus does not interfere with the external portions of the lines of force.

To aid in the above-described action, the gas within the cavity should be pre-ionized before the capacitors commence to discharge. This may be done in any suitable manner, such as by passing radio-frequency waves through the cavity. For example, electrodes may be located near (but outside) the opening at each pole, and energized by a radio-frequency oscillator. Pre-ionization increases the electrical conductivity of the gas, and thus the amount of current flow in the current sheet. Such increased flow in the current sheet aids in preventing initial penetration of the magnetic field into the body of the ionized gas. A very efficient and effective piston action is thus achieved, with consequent rapid inward acceleration of the ions and electrons.

An alternative means of achieving pre-ionization is to inject an ionized cloud of gas into cavity **12**, and immediately subject it to magnetic compression in accordance with the principles set forth herein.

It is emphasized that the present invention produces a relatively stable concentration of high-temperature plasma near the center of the cavity. The plasma is stable because the magnetic field is generated by the flow of current through the metal conductor. This is to be contrasted with pinch-type devices, in which the constricting magnetic field results from flow of current through the gas. In such pinch devices, instability resulting from variation in current flow is compounded by simultaneous variation in the magnetic field.

The present apparatus may be pulsed, for example at a relatively high frequency, instead of being employed as a single-pulse apparatus. This may be accomplished by rapidly charging and discharging the capacitors, or by using a number of sequentially, discharge-sub-banks of capacitors. Such repetitive operation, if at a sufficiently high frequency, may improve the heating effect on the gas.

It is to be understood that the terms "point," "approximating a point," etc., do not mean that the high-temperature occurs only at a geometrical point. What is meant is that the highest concentration of plasma is in a small volume, as close to a point as possible. There may, however, be plasma concentrations of lesser density at regions other than the center of the cavity.

The cavity **12**, conductor **10**, etc., need not be perfectly spherical but may, as previously indicated, be generally spheroidal. For example, the ball may be oblate or prolate, as required to effect optimum magnetic field conditions in the cavity **12**. Throughout the specification and claims, the use of the term "spheroid" includes not only elements which approach spheres, but also perfect spheres.

Various embodiments of the present invention, in addition to what has been illustrated and described in detail, may be employed without departing from the scope of the accompanying claims.

I claim:

1. Apparatus for generating an extremely high temperature which comprises electrical conductor means to define a generally spheroidal cavity, said electrical conductor means being continuous around said cavity ex-

cept for a single split or gap separating said electrical conductor means into a single-turn, continuous electric circuit around said cavity.

2. Apparatus for creating a very high temperature, comprising a continuous, unitary electrical conductor shaped generally as a hollow spehroid having a split or gap around only one great semicircle thereof, said split or gap being sufficiently wide to prevent arcing thereacross under normal impressed voltages, means to maintain a substantial vacuum within the cavity in said hollow spheroid, and separate plate means electrically connected to said spheroid on opposite sides of said gap and extending outwardly therefrom for use in supplying electrical current to said spheroid on one side of said gap so that said current may flow around said spheroid and out the plate means on the other side of said gap.

3. The invention as claimed in claim 2, in which said plate means have widths substantially equal to the diameter of said spheroid, whereby current is supplied to and removed from said spheroid throughout substantially the entire edges of said spheroid at said gap.

4. Apparatus for generating an extremely high temperature, which comprises a block or mass of electrically-conductive material having a cavity therein, the wall of said block or mass which defines said cavity being generally spheroidal in shape, said block or mass being formed with a single split or gap along one great semicircle of said generally spheroidal wall, means to maintain a substantial vacuum in said cavity, and electrical conductor means connected to said mass at points adjacent opposite sides of said split or gap to effect current flow through said mass in a single-turn, continuous circuit around said cavity.

5. The invention as claimed in claim 4, in which said conductor means comprise generally parallel plates provided integrally with said mass on opposite sides of said split or gap, the widths of said plates approximating the diameter of said cavity.

6. Apparatus for generating an extremely high temperature, which comprises a continuous block or mass of electrically-conductive material having a cavity therein, the walls of said block or mass which defines said

cavity being generally spheroidal in shape, said mass or block being formed with a single split or gap along one great semicircle of said generally spheroidal wall, means to maintain a substantial vacuum in said cavity, separate electrical conductor means connected to said mass at points adjacent opposite sides of said split or gap to effect current flow through said mass in a continuous, single-turn circuit around said cavity, and means to momentarily supply a very large current to the conductor means on one side of said split or gap to effect flow of current through said conductor means and through said block or mass around said cavity to the conductor means on the other side of said split or gap.

7. The invention as claimed in claim 6 in which said last-named means comprises capacitor means connected between said conductor means on opposite sides of said split or gap, means to charge said capacitor means, and trigger means to effect discharge thereof.

8. Apparatus for generating very high temperatures in a small volume approximating a point, comprising a thick-walled continuous hollow spheroid formed of highly conductive metal, such spheroid having a spheroidal cavity therein, envelope means to define an evacuated chamber in said cavity, split or gap means provided only along substantially one entire great semicircle of said spheroid, plates formed integrally with said spheroid at opposite sides of said split or gap means and extending outwardly therefrom, said plates extending for substantially the full diameter of said spheroid, capacitor means connected across said plates, and means to discharge said capacitor means into said plates and thus in a single-turn circuit through said spheroid around said cavity to thereby effect an inwardly-directed blast of ionized particles in said cavity with consequent generation of a high temperature at the center portion thereof.

References Cited in the file of this patent

UNITED STATES PATENTS

966,204	Hewitt	Aug. 2, 1910
1,698,691	Buttolph	Jan. 8, 1929
2,030,957	Bethenod et al.	Feb. 18, 1936
2,149,414	Bethenod	Mar. 7, 1939

Notice of Adverse Decision in Interference

In Interference No. 95,080 involving Patent No. 2,939,048, R. W. Waniek, APPARATUS FOR CREATING EXTREMELY HIGH TEMPERATURES, final judgment adverse to the patentee was rendered Mar. 7, 1966, as to claim 1.

[*Official Gazette May 17, 1966.*]

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