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RADIANT ENERGY HEATING APPARATUS

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FIG. 1.

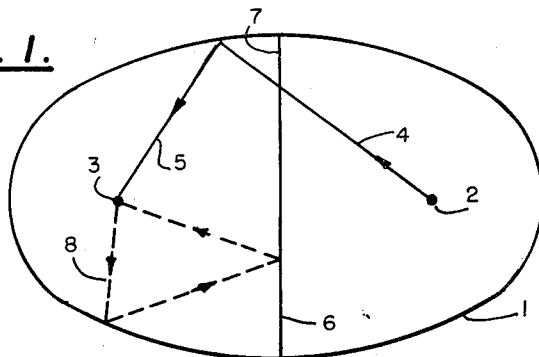


FIG. 2.

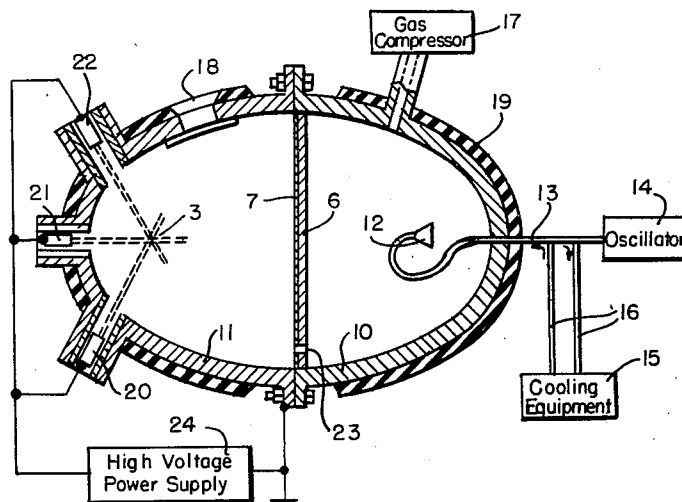
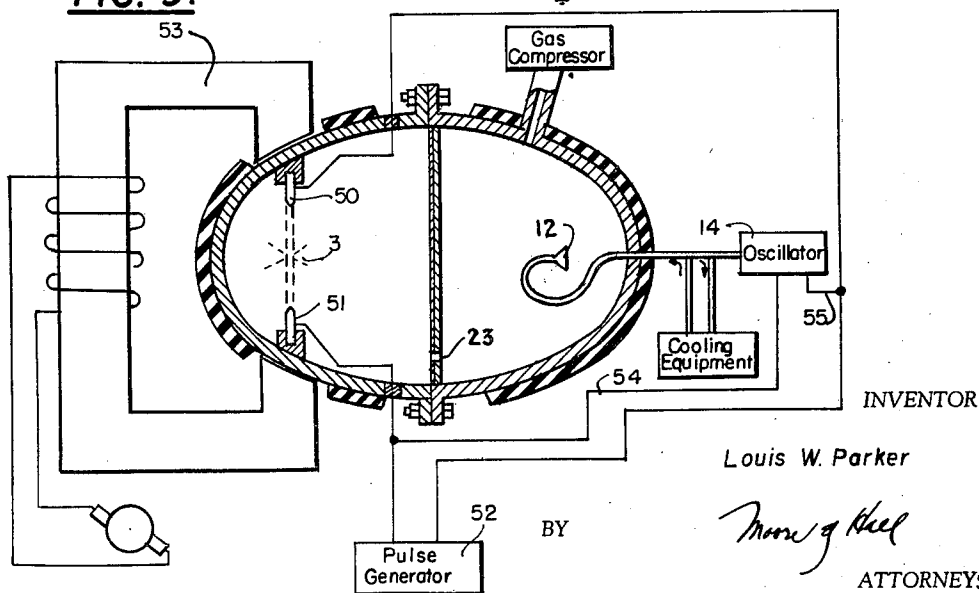


FIG. 3.



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RADIANT ENERGY HEATING APPARATUS

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The present invention relates to devices for obtaining a high temperature in a limited space by the use of electromagnetic radiation, and is more particularly concerned with an apparatus adapted to operate with greater efficiency and to secure higher temperatures in such a limited space, than has been possible heretofore.

It is often desired to produce an extremely high temperature in a limited space, such temperatures being required for various research and manufacturing techniques, and being particularly desired in the production of a controlled thermonuclear reaction. Various structures have been suggested in the past for obtaining high temperatures, and one such structure is in fact set forth in my prior U.S. Patent No. 2,543,053, issued February 27, 1951, for "Radiant Energy High Temperature Heating Apparatus." The present invention comprises an improvement on the structure set forth in said prior patent; and the specification of said prior patent is accordingly incorporated herein by reference, for a more complete discussion of the structure, utility and theory of operation to be discussed hereinafter.

The particular form of heating apparatus disclosed in my aforementioned prior patent comprises an ellipsoidal shell having an inner surface of electromagnetic radiant energy-reflective material. A source of radio waves or high frequency oscillations, taking for example the form of an electromagnetic horn is disposed at one focus of the aforementioned ellipsoidal shell whereby radio waves emanating from said one focus pass directly, or by reflection from the inner walls of the said shell, to the other focus of the shell. A substance to be heated is disposed at said other focus, and this substance is preferably gaseous in nature. Means are provided for introducing the substance to be heated to the interior of said shell at its other focus, and in the event that the substance so introduced is non-gaseous, means such as carbon arc are also provided for vaporizing and ionizing the substance at said other focus. By reason of this structure, therefore, radio waves emanating from the first-mentioned focus are concentrated at the second focus, and absorbed in the gaseous substance at said second focus whereby said gaseous substance is raised to a high temperature.

While the structure discussed above and disclosed in my said prior Patent No. 2,543,053, operates quite satisfactorily to raise the temperature of a substance to be heated, the actual temperature rise is severely limited by the fact that heat, generated at the focus having the substance to be heated, is reflected back to the first focus having the source of radio waves. This heat reflection causes severe heating of the antenna or other source of radio waves at said first focus notwithstanding the fact that all parts of this antenna have highly polished reflecting surfaces. Cooling means must accordingly be provided to dissipate substantial quantities of heat concentrated at the source of radio waves, with a resultant loss in efficiency for the overall apparatus. In addition, the heat reflection discussed above places

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an upper limit upon the temperature which may be generated in the substance being heated, which upper limit is substantially below that required for production of a controlled thermonuclear reaction.

5 The present invention avoids this difficulty of my said prior device by inhibiting the transfer of heat from the substance being heated back to the source of radiations thereby permitting the substance being heated to be raised to a temperature much higher than has been
10 possible heretofore, and simultaneously improving the efficiency of the overall device by reducing the amount of heat which must be dissipated.

It is accordingly an object of the present invention to provide an improved apparatus for obtaining a high tem-
15 perature in a limited space.

Another object of the present invention resides in the provision of an improved apparatus for raising the temperature of gases to a degree substantially exceeding the temperature of an electric arc.

20 Still another object of the present invention resides in the provision of an apparatus capable of generating a temperature sufficient to produce a controlled thermonuclear reaction.

25 A still further object of the present invention resides in the provision of an apparatus for combining the heat generated by simultaneously passing a strong electrical discharge through, and electromagnetic radiation into, ionized gas.

30 In providing for the foregoing objects and advantages, the present invention contemplates the provision of a heating apparatus generally of the type already described. In particular, the device comprises an ellipsoidal shell having a pair of foci therein with a source of radio waves being disposed at one of said foci, and with a substance to be heated disposed adjacent the other focus.
35 The shell has an inner surface of radiation-reflective material, whereby radio waves emanating from one focus of the shell are radiated and reflected to the other focus thereby to raise the temperature at said other focus, as described previously.

40 In accordance with the improved form of the present invention, means are provided for concentrating heat at said other focus and for inhibiting transfer of heat from said other focus back to the source of radio waves. These improved means comprise a wall disposed between the foci of the shell preferably at the minor axis of the ellipsoid, with the said wall comprising a material transparent to radio waves emanating from the first mentioned focus. One surface of said wall, facing the
45 substance to be heated, comprises a reflective material adapted to reflect heat waves, radiated from the substance being heated, back into the substance being heated and away from the source of radio waves. This selectivity of the reflecting wall with respect to passage of radio waves and reflection of heat waves, is made possible by the great difference between the wave lengths of the said radio and heat waves; and such difference may be in the order of 100,000 to 1. As a result of this improved structure, therefore, the heat produced in the
50 substance being heated is concentrated to a greater extent than has been possible heretofore, thereby permitting far greater temperature rises than in the past; and in addition, the transfer of heat to the source of radio waves is inhibited whereby less heat need be dissipated and the overall efficiency of the device is substantially increased.

55 The foregoing objects, advantages, construction and operation of the present invention will become more readily apparent from the following description and accompanying drawings, in which:

70 Figure 1 is a diagrammatic representation of energy

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reflections produced within an ellipsoid container constructed in accordance with the present invention;

Figure 2 is a cross-sectional view of one embodiment of the present invention; and

Figure 3 is a cross-sectional view of another embodiment of the present invention.

Referring now to Figure 1, it will be seen that a container constructed in accordance with the present invention takes the form of a vessel or shell 1 of ellipsoid configuration, whereby said shell defines a pair of foci 2 and 3. Means are provided at focus 2 for radiating radio waves; and energy is concentrated at focus 3 through reflection from the internal surfaces of shell 1 thereby to perform the intended function of heating a gas present in the ellipsoid adjacent focus 3. One typical path for the transfer of radio waves from focus 2 to focus 3 is shown by the lines 4 and 5; and the radio frequency energy at focus 2, radiating in all directions about said focus 2, is reflected from the internal surface of shell 1 at an infinite number of points, with all such reflected waves being thereafter directed to and concentrated at focus 3.

It will be appreciated that heat generated at focus 3 tends to radiate from said focus 3; and in the absence of any other structure, this radiating heat would reflect from the internal walls of shell 1 back to focus 2, in accordance with known principles of reflection in ellipsoids. The heat so appearing at focus 2 thereby limits the temperature rise at focus 3 and further requires that cooling means be associated with focus 2 to dissipate substantial quantities of heat appearing at said focus 2, with a resultant decrease in overall efficiency. These factors are obviated in large part by the provision of a wall 6 disposed, as indicated in Figure 1, at the minor axis of the ellipse or ellipsoid 1, thereby dividing the ellipsoidal shell into two semi-ellipsoids each of which contains one of the foci 2 and 3.

The wall 6 comprises a material, such as ceramic or quartz, which is substantially transparent to radio waves emanating or radiating from focus 2, whereby said radiated waves may be passed through wall 6, either directly or after reflection, toward focus 3 without substantial obstruction. One surface of wall 6 facing focus 3 is mirrored in nature; and in particular, said one surface may have a molecular thick layer 7 of some metal, such as iridium, evaporated, sprayed, or otherwise adhering thereto. This extremely thin metallic layer 7, facing focus 3, is capable of reflecting heat waves radiating from focus 3 back toward the interior of the ellipsoid adjacent said focus 3 and away from focus 2. One such possible path of heat reflection is shown by the dotted lines 8.

It will be appreciated that the dividing wall 6, having the metallic layer 7 thereon, acts as a selective filter, in that it is capable of reflecting heat waves back toward the interior of the ellipsoid adjacent focus 3 while at the same time permitting most of the very much longer radio waves emanating from focus 2 to penetrate said wall and pass to focus 3. The metal layer 7 in fact acts as a highly efficient mirror for heat waves; and, looking from focus 3, the overall ellipsoid appears in this mirror as it did without wall 6, inasmuch as the ellipsoid is symmetrical with respect to its minor axis.

All of the heat reflections described in my prior Patent No. 2,543,053 will take place with the exception that these heat reflections will all occur on the focus 3 side of the ellipsoid; and this is in fact illustrated in Figure 1 wherein the radio waves 4 and 5 are shown as reflected normally just as if the wall 6 did not exist, while heat waves 8 bounce back from mirror surface 7 into focus 3 without going through wall 6. The benefit derived from mirror 7 therefore resides mainly in the fact that the heat concentrates at focus 3 and does not pass to any material extent back to focus 2, whereby it is not necessary to cool the radiator of radio waves as much as was the case with-

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out mirror 7. This, of course, increases the efficiency of the apparatus and also permits higher temperatures to be generated at focus 3.

A typical structure constructed in accordance with the analysis and theory of operation given in respect to Figure 1 is shown in Figure 2. In particular, the ellipsoid shell 1 may comprise a pair of shell sections 10 and 11, each of semi-ellipsoid configuration removably bolted to one another adjacent the minor axis of the ellipsoid. Semi-ellipsoid 10 supports the radio wave transparent wall 6 having metallic layer 7 thereon adjacent its outer open end; and the mirror surface 7 is in fact disposed at a minor axis of the ellipsoid when the two semi-ellipsoids 10 and 11 are fastened to one another.

Shell section 10 may further include a radiator of radio or high frequency waves, such as an electromagnetic horn 12, disposed at the focus 2 (see Figure 1); and said horn 12 may be coupled via waveguide 13 to an oscillator 14, with said waveguide being cooled by cooling equipment 15 through coolant lines 16. Shell section 10 may further be associated with a gas compressor 17 in the event that it is desired to compress gas within shell section 10; and there may be an opening 23 through wall 6—7 in order to equalize the gas pressures on both sides of the wall.

Shell section 11 contains focus 3, as described previously, and means (not shown) may be provided for introducing a substance to be heated at the position of focus 3. Shell section 11 may further include a window 18 of quartz, or other heat resistant material, for permitting observation of substances being heated or to obtain light or other radiation from focus 3. The overall shell may be covered by a suitable layer of heat insulating material 19.

It will be appreciated that, as discussed in my prior Patent No. 2,543,053, the substance being heated at focus 3 is preferably gaseous in nature and have a large number of free electrons at the focus whereby said gaseous medium absorbs radio waves directed and reflected to focus 3, thereby to raise the temperature of said gaseous substance. Means may be provided adjacent focus 3 for initially raising the temperature of the substance being heated thereby to vaporize and ionize said substance; and these auxiliary heating means may take the form of a carbon arc such as has been described in my said prior patent. However, the electrons which take part in the heating process (by assuming rapid motions under the force of the aforementioned radio waves, with transfer of these motions by elastic collisions to other particles), may be introduced into focus 3 by other means.

Figure 2 particularly illustrates one form such other means may take; and this improved form of auxiliary heating apparatus comprises a plurality of electron guns 20, 21 and 22 disposed at spaced locations in the walls of shell section 11. The said electron guns 20, 21, 22, etc. may be energized by a high voltage power supply 24 grounded at one end to the shell 10—11; and the several electron guns are so disposed that they individually shoot beams of electrons into focus 3. The electron guns 20, 21, 22, etc. are in fact well known in the art, and may take the form conventionally employed in cathode ray and X-ray tubes, with the only difference being in the higher potentials and currents utilized in order to supply more electrons at high velocities in the region of focus 3.

While wall 6 is generally transparent to radio waves such as 4—5 (see Figure 1), notwithstanding the provision of reflective surface 7 a small amount of the longer wave radiations emanating from focus 2 tend to be reflected from mirror surface 7 back toward focus 2. This energy may, through proper choice of wavelength, appear at focus 2 in additive phase with radiations emanating from said focus 2. For this reason, therefore, the wavelengths of energy being radiated from focus 2 should be so selected that reflections of that energy from mirror surface 7 appear in additive phase at focus 2. Inasmuch as the total length of paths 4 and 5 is always the same

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regardless at what point on the ellipsoid the reflection takes place, it is possible to set up standing waves by making the sum of paths 4 and 5 an integral number of wave lengths. At each point of reflection the phase reverses, but since it takes two reflections to return to the original focus, the two phase reversals cancel.

There is no theoretical upper limit to the temperatures that may be reached with the apparatus thus described. By making the physical dimensions of the ellipsoid very large, and by utilizing a high peak power radio frequency generator, extremely high temperatures may be obtained in focus 3 without destroying the vessel, inasmuch as nearly all of the heat is reflected back into focus 3 and the heat absorbed by the vessel is divided over a very large area. In this respect, therefore, the invention described is superior to so-called "magnetic bottles" wherein a magnetic field is employed to concentrate hot gases into a single column. Such a column is in fact much larger than the focal point in the ellipsoid described; and in practice, it is much more efficient to reflect heat into a point rather than into a column. The effect of heat on the ellipsoid vessel may be reduced by applying the radio waves emanating from the radiator 12 in short bursts. In this way the average amount of energy radiated may only be one percent or less of the maximum energy applied.

As has been mentioned previously, the improved heating apparatus of the present invention may be employed for various research and manufacturing techniques, and may in addition theoretically be employed to bring about controlled thermonuclear reactions. Inasmuch as the invention is primarily concerned with the actual apparatus to generate ultra high temperatures in gases, the foregoing description has not included any detailed discussion regarding such thermonuclear reactions. However, with great enough energy applied from oscillator 14, and with sufficiently large vessel dimensions, it is expected that a temperature of several million degrees Kelvin may be obtained for several microseconds at focus 3. At such temperatures, thermonuclear reactions can conceivably take place. Such thermonuclear reactions generate a great amount of energy which may be extracted by any of conventional means of changing heat into a more useful form, the description of which means is superfluous here.

The particular heating and ionizing source shown in Figure 2 comprises a plurality of electron guns forming high velocity beams which intersect at the focus 3. As has been mentioned previously, and as is discussed in my said prior U.S. Patent No. 2,543,053, this auxiliary heating source may in fact comprise means producing an arc discharge; and the invention, as also discussed in my said prior patent, is particularly adapted to compound the heat produced at a focus such as 3 by both the arc discharge and the radiowave energy. In particular, the electric arc, as described in my said prior patent, was employed not only to deliver electrons necessary for the generation of heat from the comparatively long wave electromagnetic radiation, but was also employed to supply part of the heat energy necessary to raise the temperature at focus 3 to very high values, whereby the total heat introduced at focus 3 comprises a summation of that produced by the electric arc and that produced by the absorption of the aforementioned electromagnetic radiation.

Figure 3 illustrates this concept of compounding heat, as applied to the improved structure of the present invention. The ellipsoid utilized is generally similar to that already described in Figure 2. As before, a mirror structure is disposed in the ellipsoid, and means are provided for radiating electromagnetic waves from one focus of the ellipsoid toward the other focus, whereafter heat waves are reflected and concentrated at said other focus, in the manner already discussed.

The auxiliary heating source, in the embodiment of

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Figure 3, comprises means producing an arc or spark discharge; and in particular comprises a pair of electrodes 50 and 51 disposed, as shown in Figure 3, in substantially colinear relation to one another on opposite sides of the focus 3. The two electrodes 50 and 51 are coupled to a pulse generator 52 which can take the form, for example, of a bank of condensers periodically discharged. The pulse generator 52, therefore, is operative to produce a high-voltage high-current pulse which creates an arc of short duration between electrodes 50 and 51 passing through focus 3. The power involved may in fact be in the order of megawatts for a few microseconds.

In order to assist the arc in remaining in a fairly straight line across the electrodes 50 and 51 and through focus 3, a powerful magnetic field is provided by an electromagnet 53 disposed as shown relative to the electrodes 50 and 51. The electromagnet 53 is so placed that the magnetic lines of force produced between the poles of said magnet surround the arc between electrodes 50 and 51 and are roughly parallel to that arc, whereby the arc is caused to remain in a fairly straight line, passing directly through focus 3. The heating effect produced by this arc at focus 3 is augmented and receives an additional boost due to the concentration of both heat waves and electromagnetic waves at the said focus 3, in the manner already described, whereby the compound heating effect of the electric arc and of the reflected electromagnetic radiations and heat waves raises the temperature at focus 3 to a high level.

The oscillator 14 which generates the radio waves, as already described, should either be synchronized with pulse generator 52 by means of control lines such as 54, 55; or in the alternative, the two sources 14 and 52 should comprise a single source producing both the electric arc and the electromagnetic radiations. When such a single source or synchronized sources are employed, the electric arc and the electromagnetic radiations are introduced in the ellipsoid substantially simultaneously, whereby these two sources of heat energy cooperate in synchronism with one another to raise the temperature at focus 3 to a very high level for the time period during which the synchronized energy is applied.

While I have thus described preferred embodiments of the present invention, many variations will be suggested to those skilled in the art. It must therefore be stressed that the foregoing description is meant to be illustrative only and should not be considered limitative of my invention; and all such variations and modifications as are in accord with the principles described, are meant to fall within the scope of the appended claims.

Having thus described my invention, I claim:

1. A device for obtaining a high temperature in a limited space comprising an ellipsoidal shell having an electromagnetic radiant energy reflecting inside surface, an antenna located at one focus of said shell, means for feeding high frequency energy to said antenna whereby energy is radiated by said antenna and reflected by the inside surface of said shell to the other focus of said shell, and a surface extending across said shell at the minor axis thereof for dividing said shell into two halves, said surface comprising a material transparent to energy radiated by said antenna toward said other focus and including a mirrored face facing said other focus for reflecting heat, radiating from said other focus, back into said other focus.

2. The device of claim 1 including auxiliary heating means at said other focus.

3. The device of claim 2 wherein said auxiliary heating means comprises means directing plural electron beams in intersecting relation to one another at said other focus.

4. The device of claim 1 including an electron gun disposed adjacent the inner walls of said shell for directing a beam of electrons through said other focus.

5. A device for obtaining a high temperature in a limited space comprising an ellipsoidal shell having an

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electromagnetic radiant energy reflecting inside surface, an antenna centered at one focus of said shell, heating means at the other focus of said shell, a substance to be heated disposed at said other focus, a mirrored surface extending across said shell at the minor axis thereof for reflecting heat radiating from said other focus back to said other focus and away from said one focus, and means for feeding high frequency energy to said antenna whereby energy is radiated by said antenna and reflected by the inside surface of said shell to said other focus thereby to effect further heating of said substance.

6. The device of claim 5 wherein said substance is vaporized and ionized at said other focus by said heating means, whereby said radiated and reflected energy from said antenna is absorbed by the ionized vapors of said substance to produce a high temperature.

7. Apparatus for the treatment of substances with extremely high temperatures, comprising a ellipsoidal shell, having an electromagnetic radiant energy reflecting inside surface, a heat reflecting mirrored surface extending across said shell between the foci thereof, means for supporting a substance to be treated in a zone at the center of which is one focus of said shell, means for vaporizing the substance to be treated into an ionized gaseous medium in that zone, and means for radiating electromagnetic energy in all directions from the other focus of said shell, which energy upon reflection from the inner wall of the shell is focussed on said substance and absorbed by the ionized vapor thereof, said mirrored surface being operative to direct heat radiating from said heated substance back into said substance and away from said other focus.

8. The combination of claim 7 wherein said vaporizing means comprises means producing an electric arc discharge passing through said one focus.

9. The combination of claim 8 including means for producing a magnetic field adjacent said arc discharge for confining said discharge to a path passing through said one focus.

10. A heating device comprising an ellipsoidal shell having a radiation reflective inner surface, a substance to be heated located at one focus of said shell, means for radiating electromagnetic energy in all directions from the other focus of said shell whereby said radiated energy is concentrated by radiation and reflection at said one focus, and a substantially planar mirror structure disposed in said shell between the foci thereof, said structure having a mirrored surface facing said one focus for reflecting heat radiating from said one focus away from said other focus.

11. The device of claim 10 wherein said mirror structure extends across said shell at the minor axis thereof, said structure being adapted to pass radiated and reflected energy from said other focus without substantial reflection thereof.

12. The device of claim 10 wherein said means for radiating electromagnetic energy is operative to radiate said energy in spaced bursts of high frequency oscillations.

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13. The device of claim 10 wherein said radiated electromagnetic energy has a wavelength such that electromagnetic energy reflected by said mirror structure to said other focus arrives at said other focus in additive phase with electromagnetic energy emanating from said other focus.

14. A device for obtaining a high temperature in a confined space comprising a chamber of semi-ellipsoidal configuration having one end thereof closed by a substantially planar wall, the inner surfaces of said chamber and wall comprising radiation reflective material, and a source of high frequency energy disposed external of said chamber for directing high frequency energy through said planar wall into said chamber, whereby said energy is concentrated substantially at a point within said chamber.

15. A device for obtaining a high temperature in a confined space comprising an enclosed shell divided by a planar wall into two chambers, at least one of said chambers having curved radiation reflective walls adapted to reflect energy impinging thereon into a common focal point within said chamber, said planar wall having a radiation reflective surface facing said common focal point adapted to reflect heat radiating from said focal point back into said focal point and away from the other of said chambers, said planar wall having a non-reflective surface facing said other chamber, and means in said other chamber for radiating high frequency energy through the non-reflective surface of said planar wall into said one chamber.

16. The device of claim 15 including a plurality of electron guns in said one chamber spaced from said focal point for directing plural beams of electrons into said focal point.

17. The device of claim 15 including means for producing an arc discharge passing through said focal point.

18. A device for obtaining a high temperature in a confined space comprising an ellipsoidal shell having a radiation reflective inner surface, a source of radio waves at one focus of said shell, a gaseous substance to be heated disposed at the other focus of said shell whereby radio waves from said source are radiated and reflected to said other focus for absorption in said gaseous substance thereby to heat said gaseous substance, and means for concentrating heat at said other focus and for inhibiting transfer of heat from said other focus to said one focus comprising a wall fabricated of a material transparent to radio waves from said source, said wall being disposed between said foci at the minor axis of said shell, said wall having a molecular thick metallic layer covering one surface of said wall facing said other focus whereby said one wall surface is heat reflective.

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