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Baker et al.

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[45] **Sept. 10, 1974**

[54] **ELECTROMAGNETIC IMPLOSION X-RAY SOURCE**

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[73] Assignee: **The United States of America as represented by the Secretary of the Air Force,** Washington, D.C.

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[52] **U.S. Cl.** **250/493,** 250/522

[51] **Int. Cl.** **H01j 35/00**

[58] **Field of Search** 250/493, 522

[56] **References Cited**

OTHER PUBLICATIONS

"Fundamentals of Optics" Jenkins et al., McGraw Hill, 1957 pp. 414 to 416.

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Assistant Examiner—B. C. Anderson
Attorney, Agent, or Firm—Harry A. Herbert, Jr.; Richard J. Killoran

[57] **ABSTRACT**

An electromagnetic implosion X-ray source having a thin cylindrical metal foil supported on spaced electrodes within an evacuated chamber. The electrode system is connected through a switch to a capacitor bank power supply with low inductance leads and with the average electrical impedance of the dynamic plasma being matched to the impedance of the power supply. An X-ray radiation path is provided between the X-ray source and a sample holder attached to the X-ray source.

3 Claims, 10 Drawing Figures

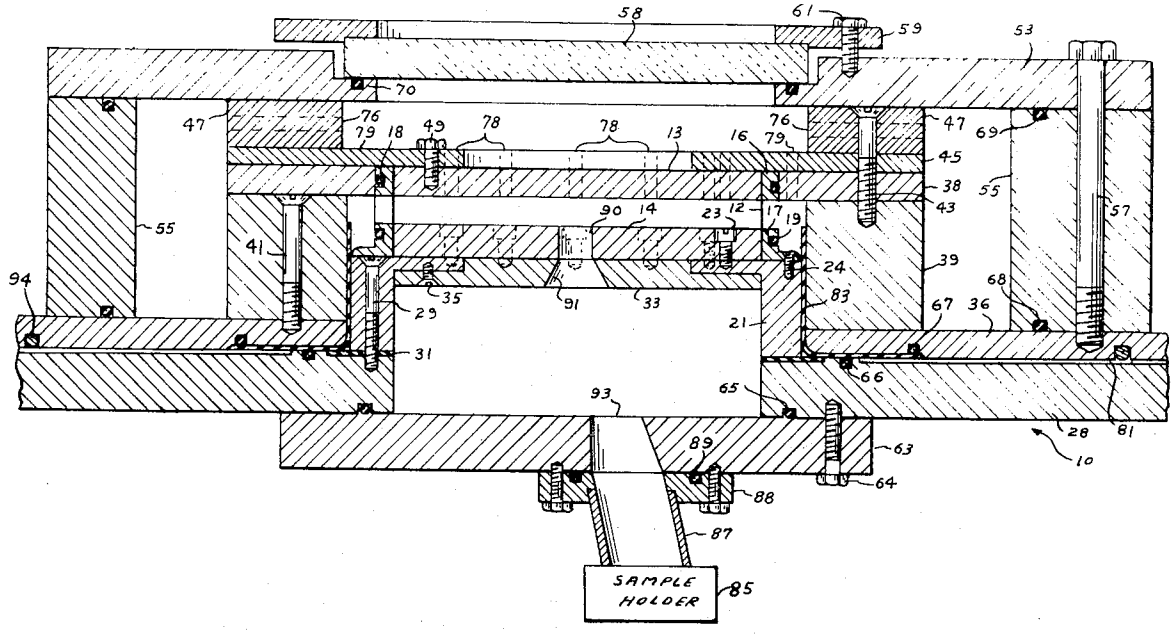


Fig-1

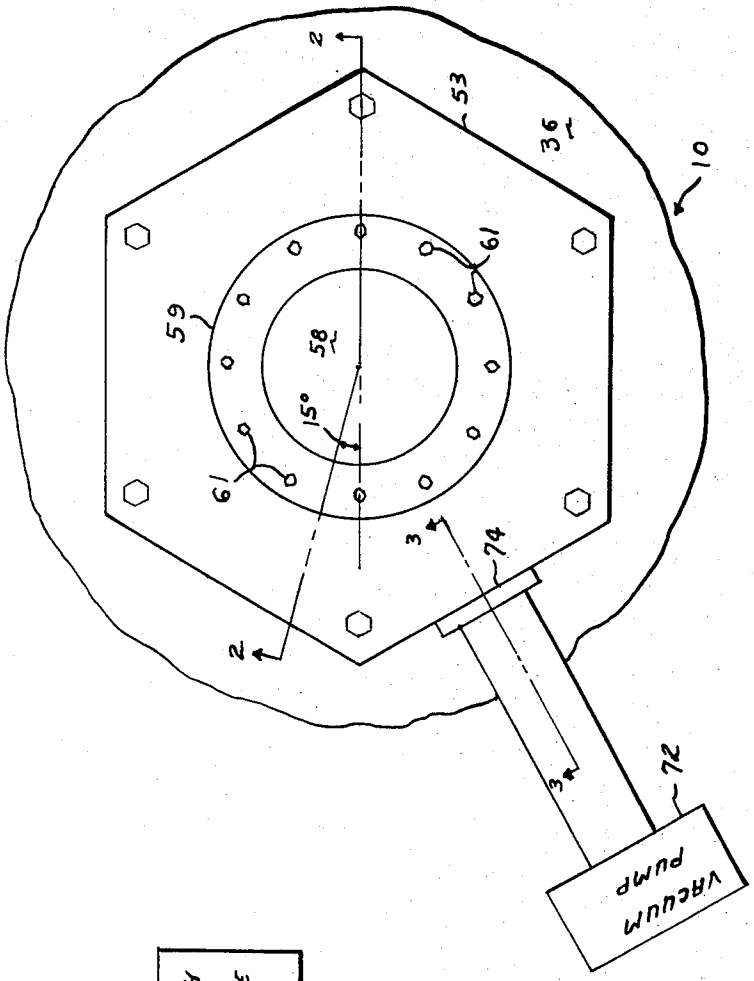


Fig-4

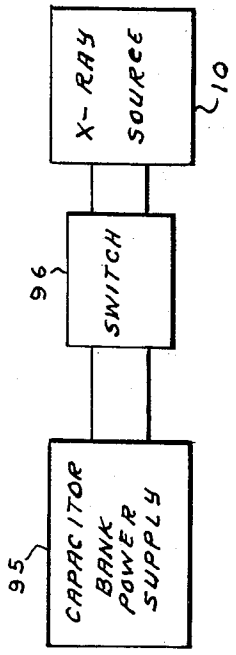
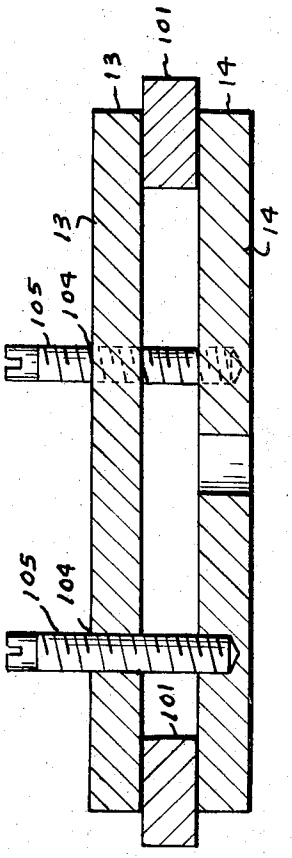


Fig-5



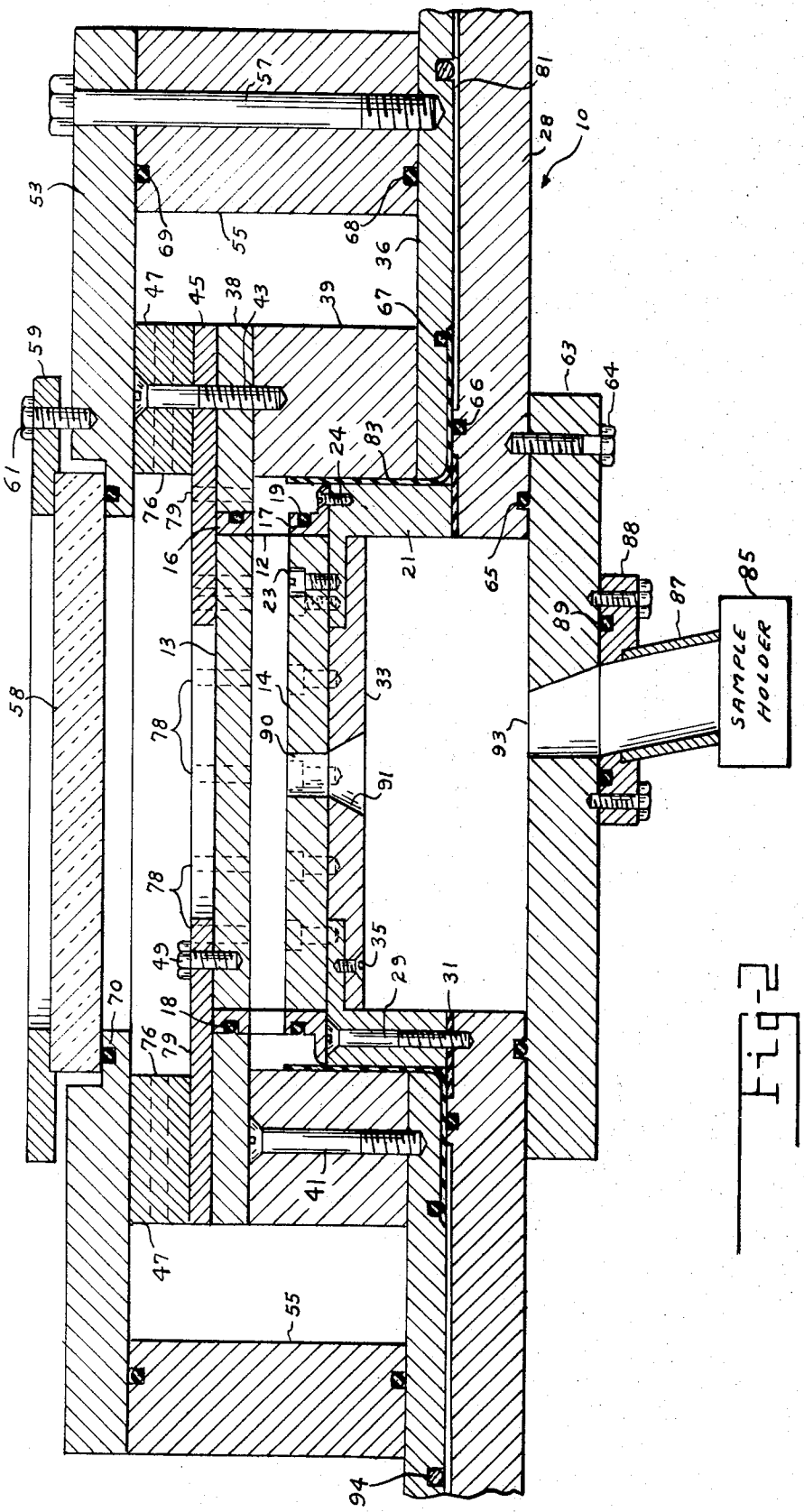


Fig-2

Fig-9

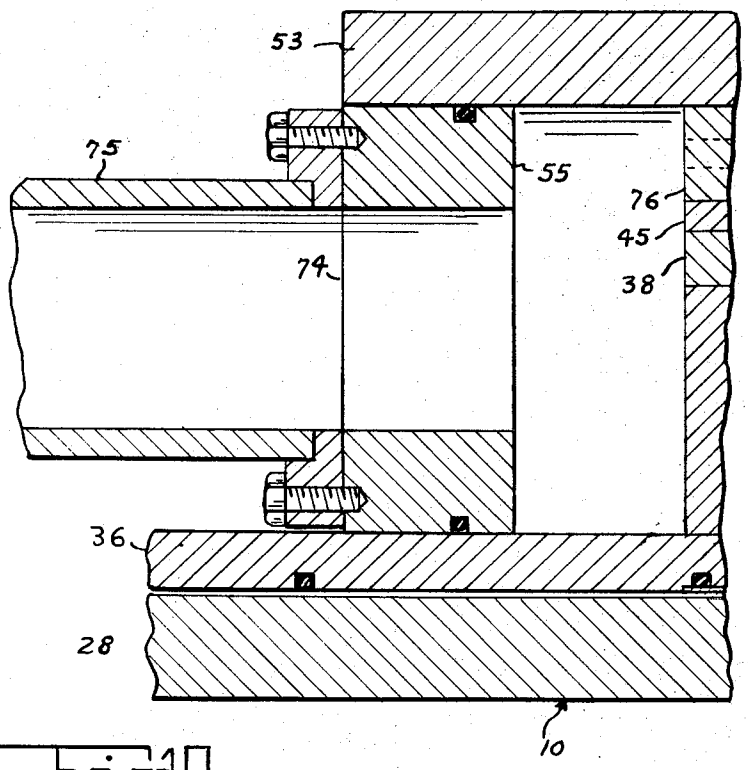

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28
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Fig-10

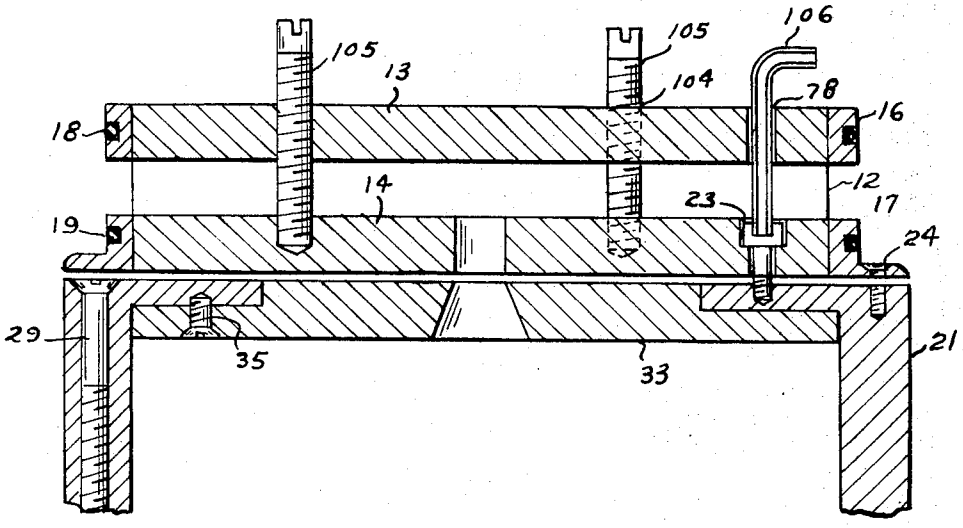

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Fig-5

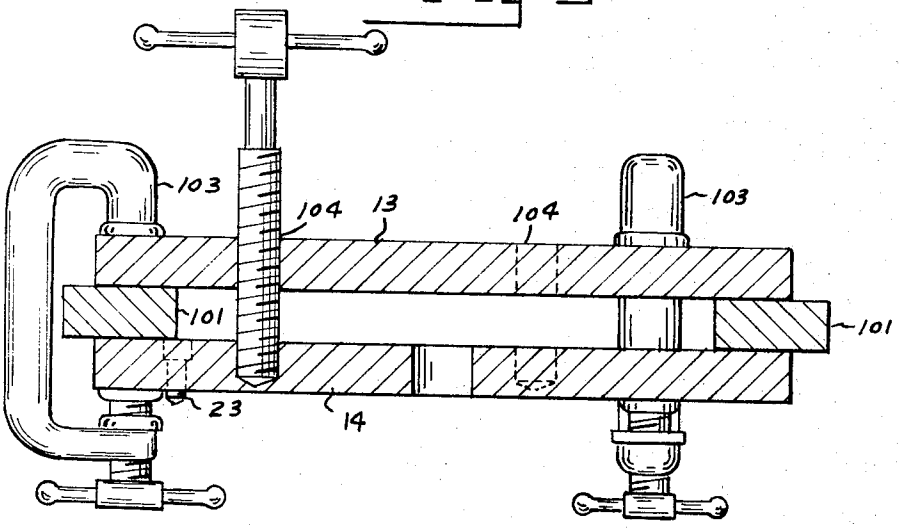


Fig-7

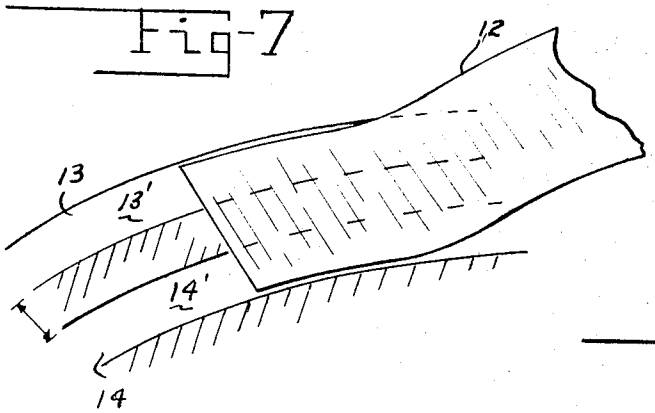


Fig-8

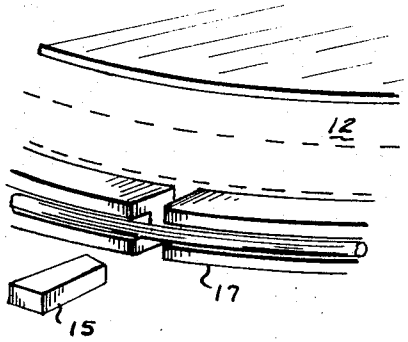
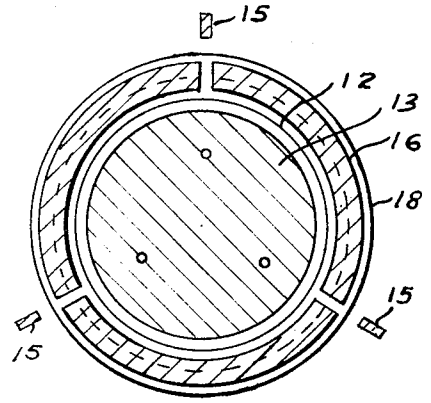


Fig-9



ELECTROMAGNETIC IMPLOSION X-RAY SOURCE

BACKGROUND OF THE INVENTION

There is a continuing effort to transform electrical energy more efficiently into an ultrashort pulse of high temperature radiation from an X-ray source. Two such prior art systems are the Z-pinch system and the adiabatic compression system.

The Z-pinch system requires a gas charge and there is a problem of energy transfer to the gas since the impedance increases too rapidly as the gas begins to accelerate, which limits the maximum current driving the plasma. The adiabatic compression schemes require extreme symmetry of the system which is difficult to maintain and also requires a gas charge.

BRIEF SUMMARY OF THE INVENTION

According to this invention, a high current is driven through a very thin metallic foil cylinder in an evacuated chamber. There are three phases to the operation of the system: (1) initiation of a uniform axial current flow through the thin foil; (2) inward acceleration of the foil (now a plasma) to high kinetic energy, per particle, by the force resulting from interaction of the current with its self-magnetic azimuthal field; (3) conversion of the high kinetic energy plasma to a high temperature, high energy density plasma in the convergent geometry of an implosion. The implosion of material of high atomic number provides both high intensity bremsstrahlung, recombination and line radiation.

IN THE DRAWINGS

FIG. 1 is a top plan view of an implosion X-ray source according to the invention.

FIG. 2 is a sectional view of the device of FIG. 1 along the line 2—2.

FIG. 3 is a sectional view of the device of FIG. 1 along the line 3—3.

FIG. 4 is a block diagram of an energizing system for the device of FIG. 1.

FIG. 5 shows the first step in the assembly of the foil and electrode structure for the device of FIG. 1.

FIG. 6 shows the second step in the assembly of the foil and electrode structure for the device of FIG. 1.

FIG. 7 shows how the foil is applied to the electrode structure of FIG. 1.

FIG. 8 shows how the foil is retained on the electrode structure with clamps and O-rings.

FIG. 9 is an exploded view of structure used in securing the foil to the electrode structure.

FIG. 10 shows how the lower electrode is secured to the current supply leads.

DETAILED DESCRIPTION OF THE INVENTION

Reference is now made to FIGS. 1 and 2 of the drawing which show an EM implosion X-ray source **10** having a cylindrical thin foil **12** supported on electrodes **13** and **14** held thereto by means of a pair of split clamp rings **16** and **17**, which are held by means of O-rings **18** and **19**. The foil should have a thickness between one-half micron and 2 microns. The total foil height will be the active height plus about one inch for electrode attachment.

The electrode **14** is secured to a connector member **21** by means of a plurality of screws **24**, one of which is shown. The connector member **21** is connected to an annular current supply lead **28** by means of a plurality of screws **29**, one of which is shown. An indium ring **31** is located between connector member **21** and lead **28** to provide good contact and to reduce the inductance in the current supply path. A backing plate **33** for electrode **14** is secured to connector member **21** by means of a plurality of screws **35**, one of which is shown.

The other electrode **13** is connected to annular current supply lead **36** by means of annular connectors **38** and **39** and the clamp ring **16**. The connector **39** is connected to the lead **36** by means of screws **41**, one of which is shown. The connector **38** is secured to connector **39** by means of screws **43** which also pass through an annular stainless steel electrode support **45** and an annular stainless steel spacer **47**. Electrode **13** is secured to support **45** by means of a plurality of screws **49**, one of which is shown. A top hexagonal plate member **53** and hexagonal member **55**, with circular central chamber, are secured to lead member **36** by means of screws **57** to provide a closed chamber. A viewing window **58** of a material such as glass or a clear plastic may be secured to the plate member **53** by means of a stainless steel retaining ring **59** and a plurality of screws **61**, one of which is shown. A bottom plate member **63** is secured to lead **28** by means of screws **64**, one of which is shown. O-rings **65, 66, 67, 68, 69** and **70** provide seals for the chamber to permit evacuation by means of a vacuum pump **72** secured to port **74** through a conduit **75**. A plurality of holes **76** are provided in spacer member **47** to permit evacuation of the system. Holes **78** used as a passage for a wrench to tighten socket head screws **23** and additional holes **79** provide for evacuation in the space between the electrodes **13** and **14**.

The leads **28** and **36** are insulated by means of insulator **81** which may be a Mylar sheet sandwiched between two polyethylene sheets. A polyethylene insulator **83** is provided between connector member **21** and connector member **39** and extends between leads **28** and **36** to overlap insulator **81**. The edge of insulator **83** stops at or below the top of electrode **14** to keep the insulator out of the path of radiation from foil **12**.

A sample holder **85** is positioned adjacent bottom plate member **63**. A stainless steel tubular member **87**, welded to a stainless steel flange member **88**, is also sealed to sample holder **85**, by means not shown, so that the sample holder is evacuated with the rest of the system through aperture **90** in electrode **14**, aperture **91** in backing electrode **33** and aperture **93** in plate member **63**. Apertures **90, 91** and **93** also provide a radiation path to the sample in the sample holder **85**. A conventional Rogowski coil **94** may be provided for current monitoring.

The X-ray source **10** is energized from a capacitor bank power supply **95** through a switching device **96**, as shown in FIG. **4**.

While more than one of some of the screws would normally show in the drawing, only one of each is shown in their relative positions to simplify the drawing. For example, since the cut on the left side of FIG. **2** is displaced 15° from the showing on the right side, as can be seen from FIG. **1**, the screws shown on the left side will all be spaced 15° from those shown on the right side. Therefore, only one of each is shown. All material not otherwise specified is aluminum.

In assembling the device, insulators **81** and **83** are positioned between leads **28** and **39** and connector **21**,

with backing plate **33** attached, is secured to electrode **28** with the indium ring **31** filling the voids to provide good contact. Connector **39** is then secured to lead **36** with insulator **83** being positioned between connectors **21** and **39.**

The thin foil **12** is secured to electrodes **13** and **14** in the manner shown in FIGS. **5–10.** Socket head screws **23** are first inserted in the holes in bottom electrode **14.** Then three spacer blocks **101** are positioned between electrodes **13** and **14,** as shown in FIG. **5.** The electrodes are then clamped together with a plurality of clamps **103,** two of which are shown. Three holes **104,** 120° apart are then drilled through electrode **13** extending part way through electrode **14.** The holes are then tapped, as shown in FIG. **5.** Threaded rods **105** are then inserted in the tapped holes, as shown in FIG. **6.**

The spacers **101** are then removed and a thin foil ribbon **12** is applied, as shown in FIG. **7.** The electrode rims **13'** and **14'** are wetted with a liquid, such as water, to aid in holding the foil to the electrode. The amount of wetting should be just enough to permit adjustment and smoothing of the foil. The water is readily removed in the evacuation process. The foil is cut to fit around the electrodes with no overlap.

The clamp rings **16** and **17** are then placed over the foil, as shown in FIGS. **8, 9** and **10.** Each clamp ring is made up of three segments separated by spacers **15.** After the O-rings **18** and **19** are in place, the spacers **15** are removed to permit the clamp rings to evenly clamp the foil to the electrodes.

The electrode assembly is then secured to connector member **21** by aligning the socket head screws **23** with holes in the connector member **21** and by tightening the screws with an Allen wrench, **106,** passed through holes **78** in the electrode **13.** Clamp ring **17** is then secured to connector member **21** with screws **24.** Connector **38,** support **45** and spacer **47** are then secured to connector **39** with screws **43.** Electrode **13** is then secured to support **45** with screws **49.** Rods **105** are then removed and plate member **53** and annular member **55** are secured to lead **36.** Bottom plate member **63** with sample holder **85** attached is then secured to lead **28.**

Evacuation pump **72** is then secured to port **74** and the power supply is connected to leads **28** and **36.** The exact connection made to leads **28** and **36** depends upon the particular power supply used.

In one design of the apparatus, the capacitor bank power supply has the following characteristics.

Charging Voltage	50 kilovolts
Capacitance	400 microfarads
Stored Energy	500 kilojoules
Peak Current to Matched Load	20 megamperas
Rise-Time	600 nanoseconds
Pulse Length	1.2 microseconds

The dimensions of the implosion X-ray system used with this power supply are as follows:

Initial Foil Radius	8 cm

-Continued

Active Foil Height	1 cm
Foil Thickness	1 micron
Foil Material	Aluminum

The implosion characteristics for such a system are as follows:

Implosion Speed	2×10^7 cm/sec
Kinetic Energy Per Particle	5.4 KeV
Total Plasma Kinetic Energy	300 kilojoules
Transfer Efficiency (Total Kinetic Energy/Initial Bank Energy)	60%

In the operation of the device, the discharge chamber is evacuated to 10^{-6} torr.

Upon closing the switch **96,** a uniform axial current flows through the foil cylinder which converts the foil to a plasma which accelerates inwardly to high kinetic energy per particle by the interaction of the current with its self magnetic field.

The X-rays produced by the implosion pass out through apertures **90, 91** and **93** to irradiate the sample in sample holder **85.**

Other arrangements for making use of the X-rays than that shown may be provided.

There is thus provided a system for creating a more powerful X-ray source by more efficiently transforming electrical energy into an ultrashort pulse, approximately 10^{-7} sec or less, of high temperature radiation of 100 ev or higher.

We claim:

1. An implosion X-ray apparatus, comprising: an enclosed container; means for evacuating said container to a predetermined vacuum; a first disc-shaped electrode within said container; a second disc-shaped electrode within said chamber spaced a predetermined distance from said first electrode; a thin cylindrical electrically conducting foil secured to the outer cylindrical surfaces of said electrodes; means for supplying a high energy current pulse to said electrodes and foil to thereby convert said foil to a high temperature, high energy density plasma and means for providng an X-ray path from the space between said electrodes external to said container whereby said X-rays produced by implosion of said plasma may be utilized.

2. The device as recited in claim **1** including a three part split clamp ring surrounding said foil adjacent the outer cylindrical surface of each electrode and an O-ring retaining the split clamp rings in position around the foil and the electrodes.

3. The device as recited in claim **2** including means for viewing the implosion between the electrodes.

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