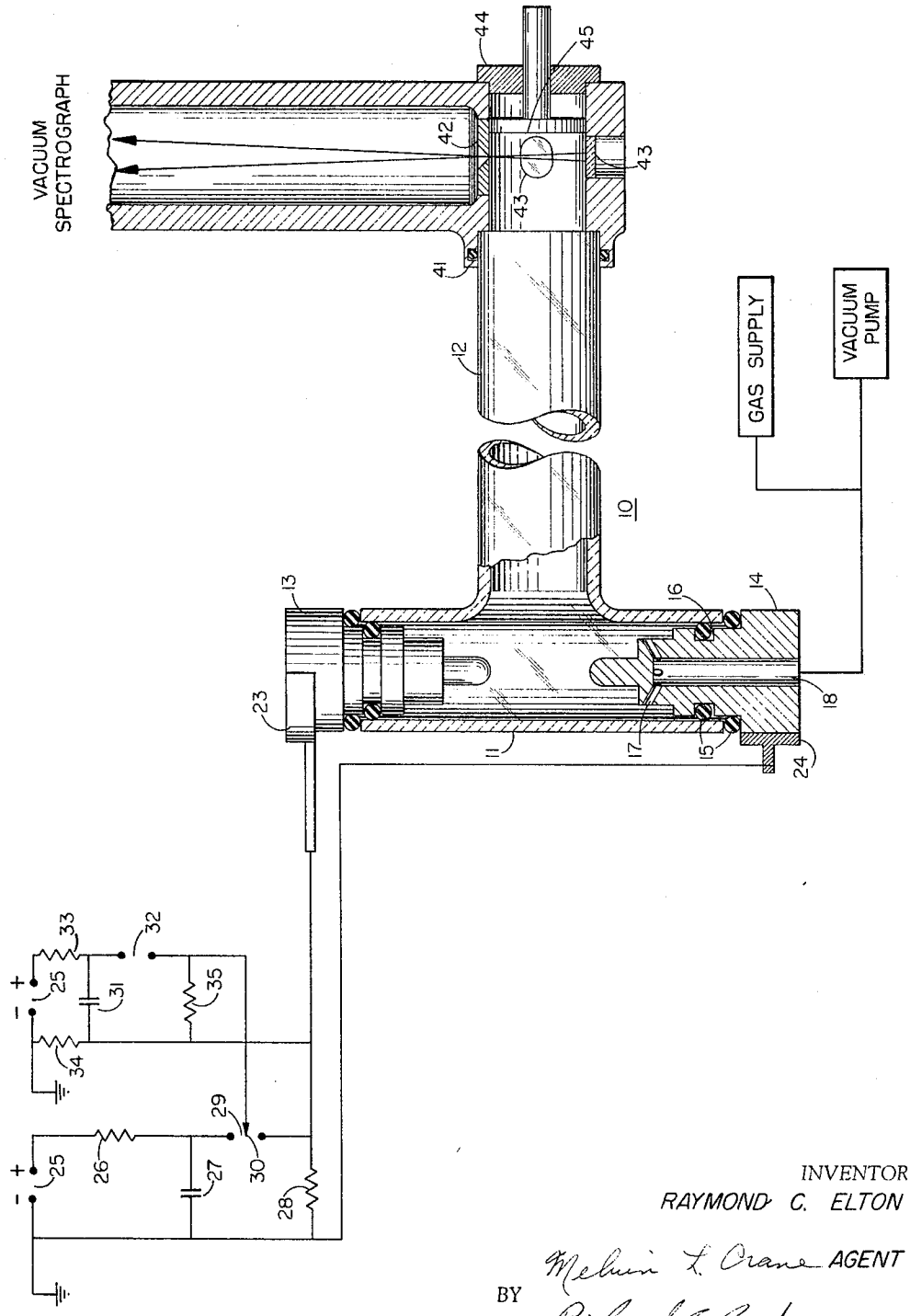
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HIGH INTENSITY REPRODUCIBLE SHOCK RADIATION SOURCE

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INVENTOR
RAYMOND C. ELTON

BY Melvin L. Crane AGENT
Richard Read ATTORNEY

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HIGH INTENSITY REPRODUCIBLE SHOCK RADIATION SOURCE

Raymond C. Elton, Hyattsville, Md., assignor to the United States of America as represented by the Secretary of the Navy

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention is related to high temperature plasma devices and more partciularly to a device for studying the physical state of partially ionized gases through generation of gaseous shock waves.

Heretofore devices have been used in the production of high temperature plasmas both for use as a light source and as a possible medium in which a controlled thermonuclear reaction may be obtained. In order to study high temperature plasmas it is necessary that each generated shock wave be reproducible and operable within a short period of time. Shock waves generated by prior art devices result in less radiation output than required for the desired studies, are not reproducible and shock tubes must be replaced after a few operations. Prior art devices as well as the present invention are described in an article "Stark Profile Measurement of the Lyman-α and Lyman-β Lines of Hydrogen" by R. C. Elton, Report #417,850 available through the Office of Technical Services, U.S. Department of Commerce.

It is therefore an object of the present invention to provide a device which produces an extremely reproducible output.

Another object is to provide a device which produces copious amounts of radiation for simulating solar and astro-physical conditions.

Still another object is to provide a device which has a high operational repetition rate.

Yet another object is to provide a device which is stable, produces substantially pure gaseous shock waves with plane fronts that approach conditions predicted by ideal shock theory.

The nature of this invention as well as other objects and advantages thereof will be readily apparent from consideration of the following specification relating to the annexed drawings, in which:

The drawing illustrates a cross-sectional view of the device of this invention including an electrical circuit necessary for the operation of the device.

A T-type electromagnetic shock tube of specific construction is evacuated and a suitable gas of a specific pressure is admitted into the tube.

The sudden deposit of a large amount of energy from a capacitor storage bank results in the rapid generation of a pressure pulse in the arc region which expands down the long shock tube, driving a Mach 12 shock wave in helium before the pressure wave, the reflection of which produces a light source capable of producing a charged particle density of 10^{17} to 10^{18} cm.$^{-3}$.

Now referring to the drawing there is shown by illustration a T-type shock tube **10** made of quartz in which the cross arm portion **11** is nine centimeters long with an inside diameter of 2.4 centimeters and the length of the quartz tube **12** extending therefrom is of about seventy centimeters in length (75 centimeters to the reflector **45**) with a 2.4 centimeter inside diameter. The wall of the shock tube is three milimeters in thickness. Oppositely opposing cylindrical nickel electrodes **13** and **14** are secured in the cross arm **11** with their linear axis perpendicular to the axis of the elongated tubular portion **12** such that the opposing inner ends of the electrodes are separated by 2.5 cm. The electrodes are machined with sections thereon of different diameter such that the diameter of the sections toward the inner end within the cross arm are of decreasing diameter. The opposing ends of the electrodes are rounded and of much smaller diameter than the outer ends of the electrodes. The outer end of each of the electrodes extends out over the end of the cross arm **11** of the shock tube and are separated from the outer ends of the cross arm by suitable O-rings **15**. One greased O-ring is placed between the nickle electrode at a section of diameter at least as great as the outside diameter of the cross arm of the shock-tube **11** and the smoothly ground end of this cross arm to act as a vacuum seal. Another section of the electrode is made substantially the same diameter as the inner diameter of the cross arm of the shock tube and is provided with a groove **16** therein within which a split O-ring **15** is placed. This O-ring prevents contamination of the hot gas by the volatile vacuum grease on the seal O-ring and also provides a cushion between the cross arm and the electrodes necessary to prevent breakage of the shock-type cross-arm during operation. The split permits evacuation of the region between the O-rings.

The electrode **14** is provided with holes **17** therein from the outer surface of the sides to the center where the holes meet with an axially extending passage **18** which is drilled into the electrode. The holes and passage provide a means through which the T-tube may be evacuated by any suitable vacuum system shown in box form and through which a gas under pressure from a gas supply may be admitted into the chamber area within the T-tube.

Metal plate conductors **23** and **24** are connected to electrodes **13** and **14** by semicircular shaped fittings which conform to the outer surface of the cylindrical electrodes. Each of the conductor plates **23** and **24** are connected with a plurality of coaxial cables which feed an electrical current from a capacitor energy storage bank to the electrodes. Such an electrical system is shown by a simple circuit diagram which includes power supplies for charging different capacitors. One circuit "triggers" the other circuit.

As shown, the electrical circuitry includes suitable direct current power supplies **25**, one for the main discharge circuit and one for the triggering circuit. The main discharge circuit includes the power source **25**, a 4K ohm current limiting resistor **26** and a capacitor bank **27** made of an assembly of fourteen capacitors of 7.7 mf. each connected in parallel to provide a total capacitance of about 108 mf. having a maximum voltage of 20,000 volts with an energy storage capacity of 22,000 joules. The circuit has a time to peak current of 3 microseconds with a peak current of 1.1×10^{6} amperes. The output circuit from the capacitor includes a 1000 ohm. load resistor **28** in parallel with the spaced electrodes **13** and **14** together in series with a group of spark gap switches **29** connected in parallel which are triggered by a triggering circuit shown. The fourteen capacitors are controlled by enclosed air-gap switches such as described in patent application Serial Number 293,566, filed July 8, 1963, with one switch per two capacitors. The current is delivered to the collector plate at the shocktube by twenty-one low inductance coaxial cables with a total circuit inductance of 34 nanohenries.

The seven parallel connected air-gap switches are triggered by a 0.1 mf. capacitor **31** operated at 20 kv. and controlled by a single air-gap switch **32** closed by overvoltage. The capacitor **31** is charged by a suitable power supply **25** through one megohm resistors **33** and **34**. A ten megohm resistor **35** is placed in the circuit

on the load side. The output from the trigger capacitor connects with one electrode of each air gap switch and to a trigger pin which extends through the electrode and is insulated therefrom. A discharge through air-gap switch **32** by overvoltage produces a spark discharge in the main circuit control switch ionizing the air between the electrodes of the main switches to trigger a discharge from the main capacitor bank between the electrodes of the shock tube.

The opposite end of the shock tube is provided with an adapter **41** secured about the end of the tube and sealed against leakage by an O-ring seal **15**. The inside diameter of the adapter is the same diameter as the inner diameter of the tube such that there is a continuous wall surface between the tube and the adapter. The adapter provides a means through which the plasma in the tube may be studied by suitable instruments. The adapter mainly provides an optical aperture **42** precisely adjacent to the hot radiating gas for a vacuum spectrograph, not shown for simplification of the drawing. This adjustable optical slit **42** is positioned along the inner wall of the adapter and sealed against passage of gases from the tube into the vacuum spectrograph except through the optical slit. The adapter is also provided with three quartz windows **43** sealed in the wall thereof such that other instrumentation may be used to study the gases within the tube.

The outer end of the adapter is sealed by an end cover **44** which is provided with an axial aperture therethrough. A shock reflector **45** has a portion thereof that extends through the aperture in the end cover such that the shock reflector may be adjusted to vary the point of reflection of the shock wave with respect to the point of observation in the adaptor.

In operation of the device for studying the physical state of partially ionized gases through an electromagnetic generation of gaseous shock waves, the vacuum spectrograph and shock tube are evacuated to a pressure of about 10^{-5} torr, and the device is then filled with helium gas to a pressure of 40 torr with about 0.03 percent admixture of hydrogen. The main capacitor bank **27** is then charged to 8100 volts. The capacitor bank does not discharge due to the spacing of the electrodes switches **29**. The trigger circuit capacitor bank **31** is then charged; at the time that air gap switch **32** is overvoltaged the capacitor bank **31** discharges across one electrode of each of the main air-gap switches and a trigger electrode **30** assemblied in the electrodes. A discharge between the switch electrode and the trigger electrode ionizes the air between the electrodes of the main-air-gap switches, thus permitting a discharge across the electrodes of the main-air-gap switches **29**. The main capacitor bank **27** then discharges through the system including electrodes **13** and **14** in the shock tube. The discharge across electrodes **13** and **14** produces an arc which in turn, produces a plasma in the area of the arc. The plasma in the vicinity of the arc rapidly builds up pressure in this area of the shock tube wherein this plasma expands down the length of the shock tube away from the arc, driving a shock wave in front of the pressure pulse. The plasma shock wave is driven through the helium gas producing ionization of the gas as the plasma shock wave passes down the tube. Ionization of the helium gas excites the Lyman-α and Lyman-β lines of hydrogen which appear immediately behind the shock front. The vacuum spectrograph views this phenomenon through the optical slit and records the results. The vacuum, e.c., ultraviolet data may be recorded by use of a scintillator material in combination with a photomultiplier tube. Other optical instruments are used to study the ionized gas through the windows in the adapter. Such measurements include a measure of electron density and temperature as functions of time by use of two monochromators. Shock hydrodynamic conditions are determined by use of a streak camera.

In coupling the adapter for the vacuum spectrograph to the end of the shock tube, a third electrode at ground potential is established. This establishes an alternative path for the high arc current along the tube axis, which can lead to destruction of the shock wave and ultimately damage the vacuum spectrograph slit. Thus, means must be taken to prevent such a current. The vacuum pumping system for the vacuum spectrograph is an integral part of such a spectrograph and must normally be coupled to ground through the power lines. Therefore the entire spectrograph is electrically floated above ground by incorporating an air-core isolation transformer such as designed for radio tower beacon lighting. Such an isolation transformer provides 50,000 volts of insulation, with 32 mmf. of coupling capacitance while transmitting 4000 watts of power at an efficiency of 94%.

The device is also provided with cooling water which is connected about the vacuum spectrograph by rubber hoses as a further precaution against axial currents to the spectrograph.

The device as presented herein has long life with reproducible results for many operations. With a suitable vacuum system for pumping the system after each operation, the operation may be carried out within a cycling time of four minutes or less. The electrodes and tube are standard and may be interchangable.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A device for generating highly reproducible gaseous shock waves which comprises;

a quartz shock-tube,

said shock-tube including an open ended elongated tubular portion of about eight times the length of a cross-arm portion.

oppositely disposed nickel electrodes assembled in said cross-arm portion with their longitudinal axis perpendicular to the longitudinal axis of said elongated tubular portion,

said nickel electrodes comprising O-ring cushioning means between themselves and said cross-arm,

and an adapter to be secured to the end of said elongated tubular portion with the inner wall surface thereof in alignment with the inner wall surface of said open ended tubular portion of said shock tube for connecting a vacuum spectrograph thereto at an angle relative to the axis thereof for observing gaseous shock waves produced in said shock-tube.

2. A device for generating reproducible gaseous shock waves which comprises;

a quartz shock-tube,

said shock-tube including an open ended elongated tubular portion of about eight times the length of a cross-arm portion,

oppositely disposed nickel electrodes assembled in said cross-arm portion with their longitudinal axis perpendicular to the longitudinal axis of said elongated tubular portion,

said nickel electrodes comprising O-ring cushioning means between themselves and said cross-arm,

one of said electrodes including a passage therein to permit evacuation of said shock-tube,

and an adapter adapted to be secured to the end of said elongated tubular portion with the inner wall surface thereof in alignment with the inner wall surface of said open ended tubular portion of said shock-tube for connecting a vacuum spectrograph thereto at an angle relative to the axis thereof for observing gaseous shock waves produced in said shock-tube.

3. A device for generating reproducible gaseous shock waves as claimed in claim **2** which includes;

means for evacuating said shock-tube through said passage in said electrode,

means for admitting a gas into said shock-tube through said passage in said electrode, and

means for producing an arc between said oppositely disposed electrodes.

4. A device for generating reproducible gaseous shock waves which comprises;

a quartz shock-tube,

said shock-tube including an open ended elongated tubular portion and a cross-arm portion perpendicular thereto,

said elongated portion having a length of about eight times the length of said cross-arm,

oppositely disposed nickel electrodes assembled in said cross-arm coaxial therewith with their ends facing each other in spaced relationship,

said elongated portion and said cross-arm portion having an inside diameter of about the same measure as said spacing between the ends of said electrodes,

said electrodes being separated from the ends and the inner surface of said cross-arm by O-ring seals which serve as a vacuum seal and a cushioning means,

an adapter adapted to be secured to the end of said elongated tubular portion for connecting a vacuum spectrograph thereto for observing gaseous shock wave produced in said shock-tube,

and said adapter including an optical slit in alignment with the inner surface of said elongated tubular portion to permit optical use of the vacuum spectrograph.

5. A device for generating reproducible gaseous shock waves as claimed in claim 4 which includes;

one of said electrodes includes a passage linearly therethrough,

means for evacuating said shock-tube through said passage in said electrode,

means for admitting a gas into said shock-tube through said passage in said electrode, and

means for producing an arc between said oppositely disposed electrodes.

6. A device for generating reproducible gaseous shock waves as claimed in claim 5 which includes an adjustable shock reflector within said adapter axially outwardly of said optical slit.

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DAVID J. GALVIN, *Primary Examiner.*