June 9, 1959 B. T. WRIGHT 2,890,338

HIGH VOLTAGE REGULATOR

Filed July 11, 1946 2 Sheets-Sheet 1

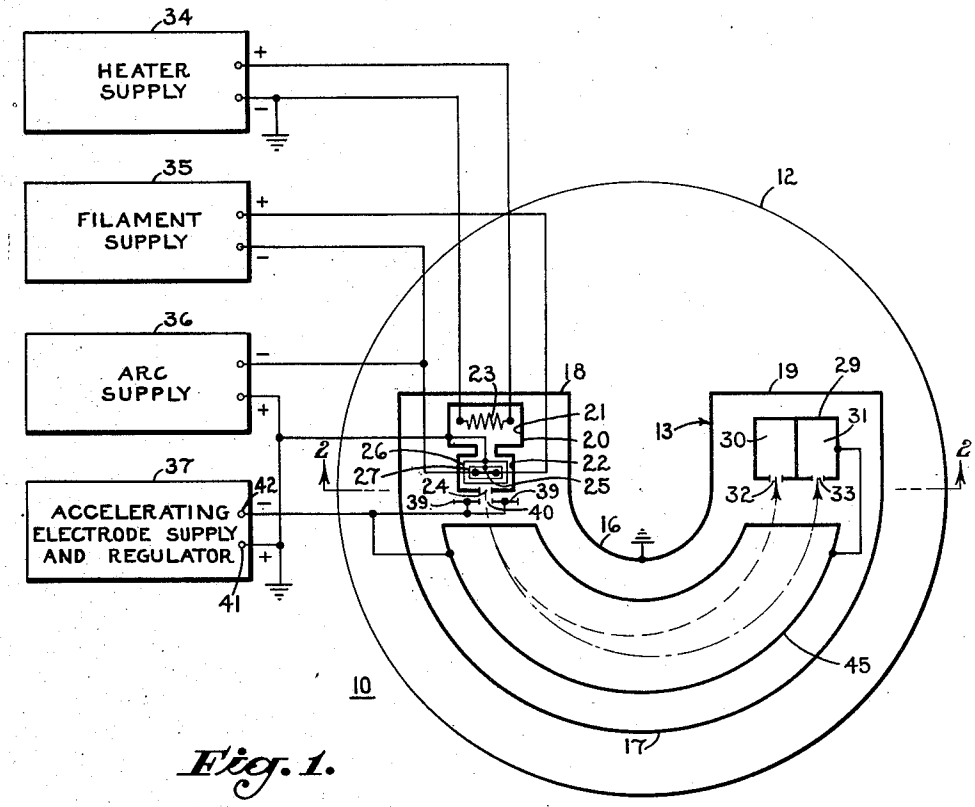


Fig. 1.

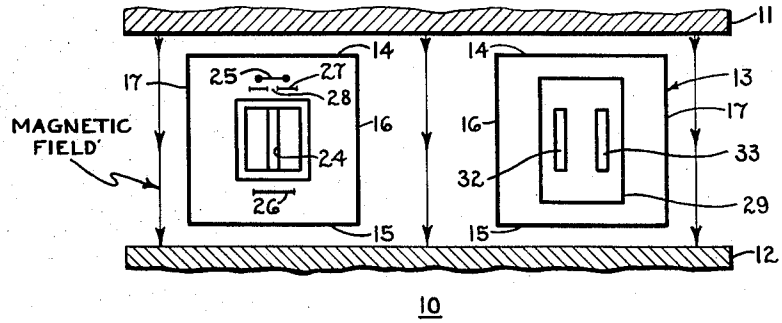


Fig. 2.

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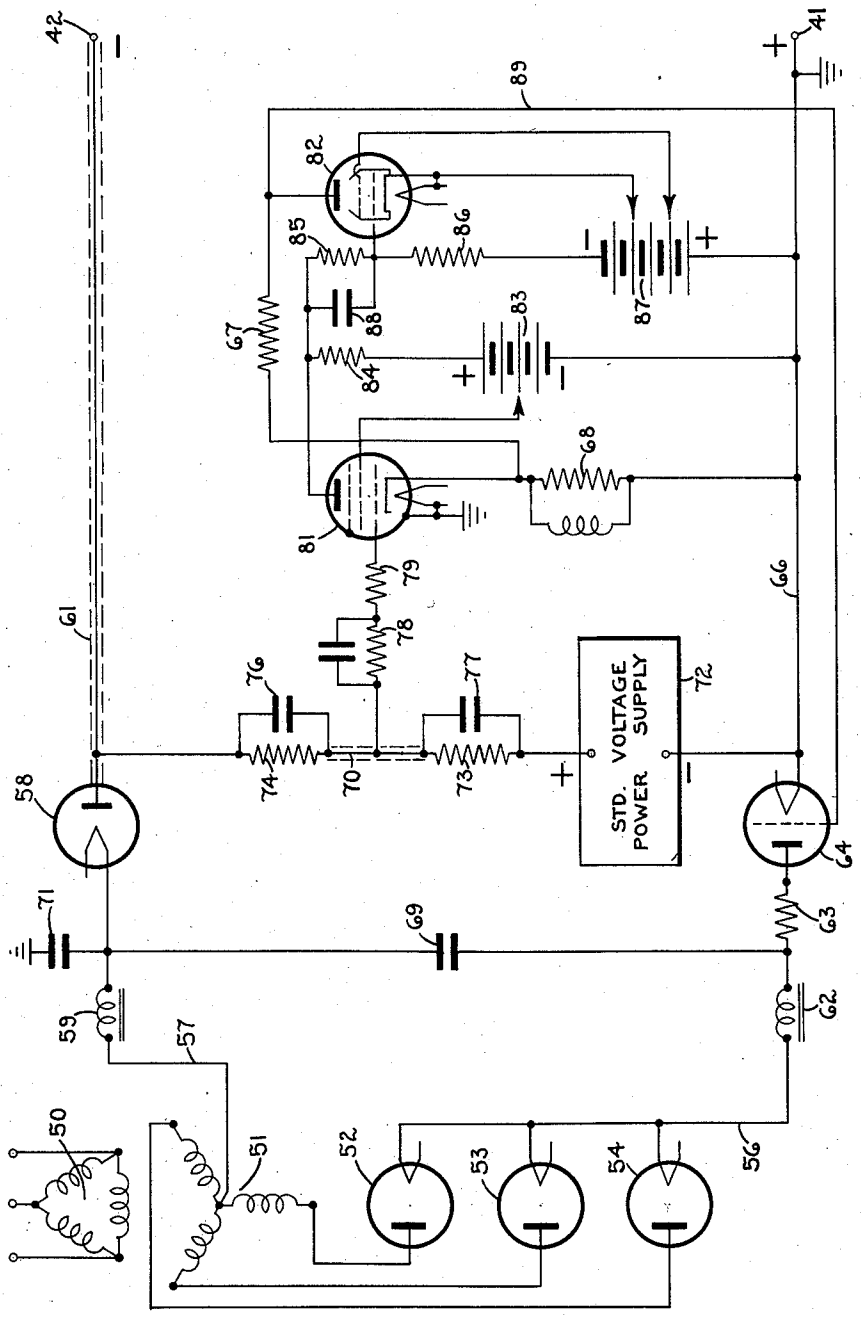


Fig. 3.

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United States Patent Office

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HIGH VOLTAGE REGULATOR

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Application July 11, 1946, Serial No. 682,960

6 Claims. (Cl. 250—41.9)

The present invention relates to high voltage regulators and more particularly to high voltage regulators for the accelerator and other high voltage electrodes of calutrons.

It is an object of this invention to provide an improved high voltage regulator for the accelerator and other high voltage electrodes of a calutron.

Another object of this invention is to provide a high voltage regulator for the accelerator electrode of a calutron, the characteristics of the regulator being such that the accelerating voltage is rapidly restored after a sudden drop therein, such as is caused by sparking.

Another object of this invention is to provide a high voltage regulator for the high voltage accelerating voltage supply of a calutron which upon sudden drop in the accelerating voltage will abruptly restore this voltage in the direction of normal even to the extent of overshooting normal.

Another object of the present invention is to provide a high voltage regulator for the accelerating electrode voltage supply of a calutron isotope enriching or separating apparatus, the high voltage regulator having such characteristics that upon sudden drop in accelerating voltage the regulator will abruptly restore the accelerating electrode voltage in the direction of normal even to the extent of overshooting normal so that the heavy mass portion of the calutron ion beam will be swept across the lighter mass calutron receiving pocket so quickly that the lighter mass pocket is not materially contaminated by the heavier mass portion.

Other and further objects of this invention will be apparent to those skilled in the art to which this invention relates from the following specification, claims and drawing, in which:

Figure 1 is a diagrammatic view of a calutron and the various current supplies and high voltage regulator connected thereto;

Fig. 2 is a diagrammatic sectional view of the calutron taken along the line 2—2 of Fig. 1; and

Fig. 3 is a schematic wiring diagram of the high voltage regulator and high voltage supply embodying features of this invention.

At the outset it is noted that a calutron is a machine of the character disclosed in U.S. Patent No. 2,709,222, issued to Ernest O. Lawrence for Method and Apparatus for Separating Materials, and is employed to separate the constituent isotopes of an element and more particularly to increase the proportion of a selected isotope in an element containing several asotopes in order to produce the element enriched with the selected isotope. For example, the machine is especially useful in producing uranium enriched with U^{235}.

Such a calutron essentially comprises means for vaporizing a quantity of material containing an element that is to be enriched with a selected one of its several isotopes; means for subjecting the vapor to ionization, whereby at least a portion of the vapor is ionized causing ions of the several isotopes of the element to be produced;

electrical means for segregating the ions from the unionized vapor and for accelerating the segregated ions through relatively high velocities; electromagnetic means for deflecting the ions along curved paths, the radii of curvatures of the paths of the ions being proportional to the square roots of the masses of the ions, whereby the ions are concentrated in accordance with their masses; and means for de-ionizing and collecting the ions of the selected mass thus concentrated to produce a deposit of the element enriched with the selected isotope.

Referring now more particularly to Figs. 1 and 2 of the drawings, there is illustrated a representative example of a calutron 10 of the character noted, that comprises magnetic field structure including upper and lower pole pieces 11 and 12, provided with substantially flat parallel spaced-apart pole faces, and a tank 13 disposed between the pole pieces 11 and 12. The pole pieces 11 and 12 carry windings, not shown, which are adapted to be energized in order to produce a substantially uniform and relatively strong magnetic field therebetween, which magnetic field passes through the tank 13 and the various parts housed therein. The tank 13 is of tubular configuration, being substantially crescent-shaped in plan, and comprising substantially flat parallel spaced-apart top and bottom walls 14 and 15, upstanding curved inner and outer side walls 16 and 17, and end walls 18 and 19. The end walls 18 and 19 close the opposite ends of the tubular tank 13 and are adapted to be removably secured in place, whereby the tank 13 is hermetically sealed. Also, vacuum pumping apparatus, not shown, is associated with the tank 13, whereby the interior of the tank 13 may be evacuated to a pressure of the order of 10^{-5} to 10^{-4} mm. Hg. Preferably, the component parts of the tank 13 are formed of steel, the top and bottom walls 14 and 15 thereof being spaced a short distance from the pole faces of the upper and lower pole pieces 11 and 12, respectively, the tank 13 being retained in such position in any suitable manner, whereby the top and bottom walls 14 and 15 constitute in effect pole pieces with respect to the interior of the tank 13, as explained more fully hereinafter.

The removable end wall 18 suitably supports an ion generator unit 20 comprising a charge receptacle 21 and a communicating arc block 22. An electric heater 23 is arranged in heat exchange relation with the charge receptacle 21 and is adapted to be connected to a suitable source of heater supply 34, whereby the charge receptacle 21 may be appropriately heated, the charge receptacle 21 being formed of copper or the like. The arc block 22 is formed, at least partially, of carbon or graphite and is substantially C-shaped in plan, an upstanding slot 24 being formed in the wall thereof remote from the charge receptacle 21. Thus, the arc block 22 is of hollow construction, the cavity therein communicating with the interior of the charge receptacle 21.

Also, the removable end wall 18 carries a filamentary cathode 25 adapted to be connected to a suitable source of filament supply 35, the filamentary cathode 25 being spaced from the upper end of the arc block 22 and arranged in alignment with respect to the upper end of the cavity formed therein. The arc block 22 carries an anode 26 disposed adjacent the lower end thereof and aligned along the magnetic field with respect to the cavity formed therein. Also, the arc block 22 carries a collimating plate electrode 27 disposed adjacent the upper end thereof and having an elongated collimating slot 28 formed therethrough and aligned along the magnetic field with respect to the filamentary cathode 25 as well as the anode 26 and the cavity formed in the arc block 22. Both the anode 26 and the collimating electrode 27 are electrically connected to the source unit 20 which in turn is grounded; likewise, the tank 13 is

grounded. Also, the filamentary cathode **25** and the cooperating anode **26** are adapted to be connected to a suitable source of arc supply **36**. It is noted that the above-described collimating electrode arrangement is disclosed in the copending application of Frank Oppenheimer, and since issued as U.S. Patent No. 2,719,925.

Further, the removable end wall **18** carries ion accelerating structure **39** formed of carbon or graphite and disposed in spaced relation with respect to the wall of the arc block **22** in which the slot **24** is formed. More specifically, a slit **40** is defined by the ion accelerating structure **39** and arranged in substantial alignment with respect to the slot **24** formed in the wall of the arc block **22**. A suitable source of accelerating electrode supply is adapted to be connected between the arc block **22** (or ground potential) and the ion accelerating structure **39**, the positive terminal **41** and negative terminal **42** of the supply **37** being respectively connected to the arc block **22** and to the ion accelerating structure **39**. The voltage of this supply **37** is carefully regulated, and the construction of this regulated voltage supply with the calutron **10** as a whole forms the subject matter of the present invention.

The removable end wall **19** suitably supports a collector block **29** formed of stainless steel or the like and provided with two laterally spaced-apart cavities or pockets **30** and **31** which respectively communicate with aligned slots **32** and **33** formed in the wall of the collector block **29** disposed remote from the removable end wall **19**. It is noted that the pockets **30** and **31** are adapted to receive two constituent isotopes of an element which have been separated in the calutron **10**, as explained more fully hereinafter.

Considering now the general principle of operation of the calutron **10**, a charge comprising a compound of the element to be treated is placed in the charge receptacle **21**, the compound of the element mentioned being one which may be readily vaporized. The end walls **18** and **19** are securely attached to the open ends of the tank **13**, whereby the tank **13** is hermetically sealed. The various electrical connections are completed and operation of the vacuum pumping apparatus, not shown, associated with the tank **13** is initiated. When a pressure of the order of 10^{-5} to 10^{-4} mm. Hg is established within the tank **13**, the electric circuits for the windings, not shown, associated with the pole pieces **11** and **12** are closed and adjusted, whereby a predetermined magnetic field is established therebetween traversing the tank **13**. The electric circuit for the heater **23** is closed, whereby the charge in the charge receptacle **21** is heated and vaporized. The vapor fills the charge receptacle **21** and is conducted into the communicating cavity formed in the arc block **22**. The electric circuit for the filamentary cathode **25** is closed, whereby the filamentary cathode is heated and rendered electron emissive. Then the electric circuit between the filamentary cathode **25** and the anode **26** is closed, whereby an arc discharge is struck therebetween, electrons proceeding from the filamentary cathode **25** through the collimating slot **28** formed in the collimating electrode **27** to the anode **26**. The collimating slot **28** formed in the collimating electrode **27** defines the cross-section of the stream of electrons proceeding into the arc block **22**, whereby the arc discharge has a ribbon-like configuration and breaks up the molecular form of the compound of the vapor to a considerable extent, producing positive ions of the element that is to be enriched with the selected one of its isotopes. A more detailed explanation of the operation of the aforesaid arrangement may be had by referring to the copending application of Frank Oppenheimer, and since issued as U.S. Patent No. 2,719,925.

The electric circuit between the arc block **22** and the ion accelerating structure **39** is completed, the ion accelerating structure **39** being at a high negative potential with respect to the arc block **22**, whereby positive ions in

the arc block **22** are attracted by the ion accelerating structure **39** and accelerated through the voltage impressed therebetween. More particularly, the positive ions proceed from the cavity formed in the arc block **22** through the slot **24** formed in the wall thereof, and across the space between the ion accelerating structure **39** and the adjacent wall of the arc block **22**, and thence through the slit **40** formed in the ion accelerating structure **39** into the interior of the tubular liner **45**. The high-velocity positive ions form a vertical upstanding ribbon or beam proceeding from the cavity formed in the arc block **22** through the slot **24** and the aligned slit **40** into the tubular liner **45**.

As previously noted, the collector block **29**, as well as the tubular liner **45**, is electrically connected to the ion accelerating structure **39**, whereby there is an electric-field-free path for the high velocity positive ions disposed between the ion accelerating structure **39** and the collector block **29** within the tubular liner **45**. The high-velocity positive ions entering the adjacent end of the liner **45** are deflected from their normal straight-line path and from a vertical plane passing through the slot **24** and the aligned slit **40**, due to the effect of the relatively strong magnetic field maintained through the space within the tank **13** and the liner **45** through which the positive ions travel, whereby the positive ions describe arcs, the radii of which are proportional to the square roots of the masses of the ions and consequently of the isotopes of the element mentioned. Thus, ions of the relatively light isotopes of the element describe an interior arc of relatively short radius and are focused through the slot **32** into the pocket **30** formed in the collector block **29**; whereas ions of the relatively heavy isotope of the element describe an exterior arc of relatively long radius and are focused through the slot **33** into the pocket **31** formed in the collector block **29**. Accordingly, the relatively light ions are collected in the pocket **30** and are de-ionized to produce a deposit of the relatively light isotope of the element therein; while the relatively heavy ions are collected in the pocket **31** and are de-ionized to produce a deposit of the relatively heavy isotope of the element therein.

After all of the charge in the charge receptacle **21** has been vaporized, all of the electric circuits are interrupted and the end wall **18** is removed so that another charge may be placed in the charge receptacle **21** and subsequently vaporized in the manner explained above. After a suitable number of charges have been vaporized in order to obtain appropriate deposits of the isotopes of the element in the pockets **30** and **31** of the collector block **29**, the end wall **19** may be removed and the deposits of the collected isotopes of the pockets **30** and **31** in the collector block **29** may be reclaimed.

In the normal operation of the calutron, sparking sometimes occurs between the accelerating electrodes **39** and the arc block **20**. This is deleterious in that the spark current drops the accelerating voltage on the electrodes **39**, and the ion beam then has less energy. As a result, its constituents describe paths of smaller radius, even failing entirely to strike the collector **29**. The electrode supply **37** has a voltage regulator forming an integral part thereof, and upon cessation of the sparking the regulator returns the voltage to its normal value. When ordinary regulators are used, the voltage is restored rapidly at first, but as it approaches the normal value the restoring rate is slowed so as not to overshoot the normal value. The radii of the beam components increase in accordance with the voltage restoration, but when the rate of return is slowest, the U^{238} constituent is just passing the U^{235} pocket. Thus, the U^{238} beam constituent discharges into the U^{235} pocket contaminating the previously separated material. The present invention, therefore, seeks to reduce this contamination to a minimum by sweeping the U^{238} beam constituent rapidly past the U^{235} pocket as will be detailed hereinafter.

Of course, it will be understood that the various dimensions of the parts of the calutron **10**, the various electrical potentials applied between the various electrical parts thereof, as well as the strength of the magnetic field between the pole pieces **11** and **12**, are suitably correlated with respect to each other, depending upon the mass numbers of the several isotopes of the element which is to be treated therein. In this connection, reference is again made to the above-identified patent of Ernest O. Lawrence, for a complete specification of a calutron especially designed for the production of uranium enriched with the isotope U^{235}. By way of illustration, it is noted that when the calutron **10** is employed in order to produce uranium enriched with U^{235}, the compound of uranium which is suggested as a suitable charge in the charge receptable **21** is $UCSl_4$, as this compound may be readily vaporized and the molecular form of the vapor may be readily broken up to form positive ions of uranium with great facility. In this case, uranium enriched with U^{235} is collected in the pocket **30** of the collector block **29**, and uranium comprising principally U^{238} is collected in the pocket **31** of the collector block **29**. Also, it is noted that from a practical standpoint, the deposit of uranium collected in the pocket **30** of the collector block **29** contains considerable amounts of U^{238}, in view of the fact that this isotope comprises the dominant constituent of normal uranium. Furthermore, the deposit of uranium collected in the pocket **30** of the collector block **29** contains a considerably increased amount of U^{234}, in view of the fact that it is not ordinarily feasible to separate U^{234} and U^{235} in the production of relatively large quantities of uranium enriched with U^{235} for commercial purposes. Accordingly, in this example the uranium deposited in the pocket **30** of the collector block **29** is considerably enriched, both with U^{234} and with U^{235}, and considerably impoverished with respect to U^{238} as compared to natural or normal uranium.

In the operation of the calutron **10**, it is highly desirable that a relatively intense stable beam of positive ions be projected by the ion accelerating structure **39** through the liner **45** toward the collector block **29** which operating condition requires that the source unit **20** presents to the accelerating structure **39** a high density plasma surface which is extremely stable in shape, position and ion density. As has been heretofore described, in order to obtain such a plasma surface, the rate of ion production by the arc discharge in the source unit **20** must be substantially constant. This has been accomplished by controlling the heating energy applied to the arc cathode inversely as the arc current.

The wiring diagram of the accelerating electrode voltage supply and regulator **37** of Figure 1 is shown in Fig. 3, the output terminals **41** and **42** appearing at the right. Power is fed into the primary **50** of a transformer adapted to receive commercial polyphase power such as 3-phase 460 volt alternating current. A secondary **51** is Y-connected, the outer ends of the secondary windings being connected to the anodes of three half-wave rectifier tubes **52**, **53** and **54**. When the anodes become positive due to the induced voltages in the secondary windings, the tubes conduct current and a busbar **56** connecting the cathodes of the rectifier tubes forms the positive lead of the rectifier. The neutral of the Y-connected secondary **51** is connected to a busbar **57** forming the negative lead of the rectifier unit.

The current of the rectifier tubes has a maximum value as determined by a limiter tube **58** which protects the rectifier tubes and the transformer in the event of a short or other low resistance condition such as occurs when a spark forms between the electrode **39** and the arc block **22**. The negative rectifier lead **57** is connected through a choke **59** to the cathode of the limiter tube **58**, which is emission limited. The anode of the limiter tube is connected to a concentric cable **61** leading to the negative terminal **42** of the power supply.

The positive lead **56** of the rectifier tubes is connected through a choke **62** and resistor **63** to the anode of a control tube **64** which is a triode type. The voltage on the grid of the control tube **64** is automatically controlled to regulate the current through the tube and thus regulate the voltage of the entire power supply across the terminals **41** and **42**. Tube **64** is connected as a "losser" tube since it imparts a variable loss or resistance in the line by means of which the voltage output is regulated. The cathode of the control tube **64** is connected to a busbar **66** which ends in the positive terminal **41** which is grounded. The grid of the tube **64** is connected through resistors **67** and **68** to the grounded busbar **66**. Thus the grid voltage is at ground potential when the regulator is not operating. In practice, however, the regulator is operating continuously, and the grid of the control tube **64** is held at a voltage that is near the middle of its operating range so as to correct for excesses and deficiencies of voltages at the output terminals **41** and **42**.

The ripple in the output of the rectifier tubes **52**, **53** and **54** is filtered by the chokes **59** and **62** and the resistor **63**, all previously mentioned, and by a capacitor **69**. A capacitor **71** is connected between the choke **59** and the limiter tube **58** to hold the rectifier voltage with respect to ground and accommodate the variations of voltage in the neutral of the transformer.

The driving or signal voltage for the regulator is obtained by tapping the voltage between two resistors connected in series across the power supply output. Inasmuch as the variations in the voltages that the regulator counteracts have various frequencies, the two resistors are each shunted by a capacitor of proper value to make the time constant of one RC network equal to the other. This construction is fully disclosed in the copending application of William Baker, since issued as U.S. Patent No. 2,783,433, to which reference should be made for a more detail description of the advantages and functions. The effect of the equal time constants in the two RC networks is to provide a control voltage that is a true proportion of the instantaneous voltage across the power supply output regardless of the frequencies of the variations of the instantaneous voltage. Thus the left end of the grounded busbar **66** is connected through a standard voltage power supply **72** to a resistor **73** connected by a concentric cable **70** to a resistor **74** connected to the negative output near the anode of the limiter tube **58**. The resistor **74** is shunted by a capacitor **76** and the resistor **73** is shunted by a capacitor **77**. The driving or signal voltage is tapped near resistor **73** and passes through resistors **78** and **79** to the control grid of a pentode **81**.

The pentode **81** is an amplifier tube, the output being passed through a resistor to cause a voltage amplification that is impressed on the control grid of a second amplifier tube **82** of the beam power type. The output of the second tube likewise passes through resistors to create an additional voltage amplification that is applied to the grid of the control tube **64**.

When current passes through the resistors **73** and **74** the voltage drop will cause the voltage in cable **70** to be negative, and thus impress a negative voltage on the control grid of tube **81**. Since the cathode of tube **81** is connected to ground, the tube would be at cut-off at all stages of operation if it were not for the standard voltage supply **72**. The output of the standard voltage supply is therefore equal to, but opposite in sign to the drop across the resistor **73**. When the voltage across the output terminals **41** and **42** is excessive, the voltage of the power supply **72** is overcome and a negative voltage is applied to the grid of tube **81**, which in turn drives negative the grid of the control tube **64**, increasing its resistance and lowering the output voltage to the desired level. When the output voltage drops, the voltage of the power supply **72** predominates over the drop in the resistor **73** making the grid of tube **81** more positive and the amplifier system causes the grid of the control tube **64** to be-

come more positive. This reduces the resistance of tube **64** and restores the output voltage to its proper value.

Considering now the details of the circuit of the amplifier, it will be noted that plate current for the tube **81** is supplied by a battery **83** and passes through a resistor **84**. The voltage for the screen of this tube is also obtained from the battery by a variable takeoff. The plate of tube **81** is also connected through resistors **85** and **86** to a battery **87** that has an output which is negative with respect to ground. Thus, the drop through resistors **84** and **86** is the algebraic sum of the two batteries **83** and **87**.

Since the plate supply of tube **82** is at ground potential, its cathode must be at least several hundred volts below ground and the control grid must be even more negative. Therefore, the cathode is connected near the negative end of the battery **87**, and the screen is connected at a less negative point. The control grid is connected to the most negative point of battery **87** since the drop through resistor **86** is positive, and the grid must be at approximately the voltage of the cathode. A capacitor **88** shunts the resistor **85** and tends to damp out the oscillations induced in the grid-cathode circuit due to the grid-cathode capacity and the inductance of the connections.. As previously mentioned, the plate output of tube **82** passes through the resistors **67** and **68** to create a voltage that is impressed on the grid of the control tube **64** through the conductor **89**.

Considering now the general operation of the entire power supply shown in Figure 3, it will be remembered that the invention includes the use of voltage dividing resistors which are shunted by capacitors that give each RC network the same time constant. More important, however, is the fact that this time constant is greater than the response time of the amplifier system (including tubes **81** and **82**) so that the signal received by the amplifier lags behind the true condition of the voltage at the output terminals **41** and **42**. As a result, the amplifier in correcting for the voltage condition, by regulating the grid voltage of the tube **64**, when the output voltage has already reached its proper value, results in the voltage overshooting its normal value.

This voltage output is impressed on the accelerating electrodes **39** shown in Figures 1 and 2, which gives a greater energy to the ion beam causing it to assume a larger radius, and thus overshoot the receiver slots. The overshoot in itself is not desired, but rather, the most instantaneous return to the normal or greater radius, so that the part of the ion beam containing U^{238} ions will not discharge into the U^{235} pocket and thus contaminate the material being separated. Since the most rapid regulation of a power supply to normal involves an overshoot, this overshoot is tolerated.

Considering now the detailed operation of the voltage supply of Figure 3, a transformer primary transfers commercial three phase power to the secondary **51** which steps it up to a desirable voltage such as 70 kv. and which in turn is rectified by the tubes **52**, **53** and **54**, and filtered by the chokes **59** and **62**, capacitor **69** and the resistor **63**. An emisison limited tube **58** limits the current that can be drawn from the rectifier tubes. The positive output of the rectifier tube is passed through the control triode tube **64** which is automatically controlled to act as a variable resistor to regulate the voltage output, and the cathode of tube **64** is connected to the ground through the grounded busbar **66**.

Two resistors **73** and **74** are connected across the output leads **61** and **66** through a standard power supply **72** that opposes the voltage drop in the resistors. The signal voltage for regulating the output at the terminals **41** and **42** is taken off between the two resistors, which divide it into a proper proportion for passing through the amplifier system including the tubes **81** and **82**. The signal thus obtained passes through the resistors **78** and **79** to the grid of an amplifier pentode **81** the output of which passes through resistor **85** to impress a signal on the grid of tube **82**. The output of tube **82** passes through resistors **67** and **68** to ground to create a control voltage that is impressed through conductor **89** to the grid of the control tube **64**. The varying grid voltages of tube **64** varies the resistance of the tube and this resistance in turn regulates the voltage of the output terminals **41** and **42**.

It will be appreciated that a definite time is required for the amplifier to respond to a signal voltage and for the amplifier output to vary the resistance of the control tube **64**. This time lapse may be considered in terms of frequency and is denoted as the frequency response of the regulator. In ordinary voltage regulators, the variations of voltage that have a frequency less than or smaller than this regulator frequency may be rapidly overcome or regulated out of the system by the regulator. In the instant circuit, however, the amplifier response is not determinative of the frequency response. Rather, the time constants of the RC networks **74**, **76**, **73** and **77** are the determinative factors. The time factors of these two RC networks are made approximately equal to each other, but of greater duration than the time response of the amplifier and control tube. While this results in a delayed signal being applied to the tube **81**, its great merit lies in its effect on the regulation of severe voltage drops across the terminals **41** and **42** such as occur when there is sparking between the accelerating electrode **39** and the arc block. When such sparking ceases, the voltage immediately builds up across the terminals **41** and **42** aided strongly by the regulator tube **64**. When the voltage reaches its normal value, the amplifier is not cognizant of this fact because the RC networks have a time lag and give a signal to the amplifier tube that shows a below normal voltage. Consequently, the voltage is over corrected resulting in a momentary voltage that is higher than normal across the terminals **41** and **42**.

The ion beam radius responds directly to the existing voltages across the terminals **41** and **42** and upon the occurrence of sparking, this voltage may drop greatly so that neither ion beam will even strike the collectors. Upon cessation of the sparking, the regulator restores the voltage, but as the voltage approaches normal, there is no slowing down of the rate of return, contrary to the practice in prior calutron regulating devices. Rather, the voltage sweeps right past the normal mark, and therefore momentarily exceeds normal for the interval of the RC time constant. Thereafter it returns to normal. The beam follows the voltage, the U^{238} beam sweeping rapidly past the U^{235} pocket, adding but very little contamination to this pocket. The U^{235} beam may also sweep past the U^{235} pocket but this is incidental to getting the U^{238} beam to sweep rapidly past the U^{235} pocket. After the momentary overshoot, the beams return to their proper radius, each shooting into its respective pocket, and the regulator acts as any other regulator in eliminating minute voltage variations.

Following are typical values and descriptions of the principal components of Figure 3, which are given for example only since the invention is not limited to specific structure or otherwise except by the terms of the following claims.

Reference Numeral	Component	Description
58	tube	214.
64	do	891, 207, 889R.
81	do	6AG7.
82	do	807.
74	resistor	10 meg.
73	do	10 meg.
78	do	.5 meg.
79	do	30 ohm.
68	do	2K ohm.
84	do	15K ohm.
85	do	.2 meg.
86	do	.2 meg.
76	capacitor	200 mmf.
77	do	200 mmf.
88	do	15 mmf.

While I have described this invention in detail with respect to a certain illustrated embodiment, I do not desire to limit the invention to the details set forth, except insofar as those details appear in the following claims.

What is claimed:

1. A high voltage regulator for the accelerator electrode of a calutron comprising a source of high voltage having the positive terminal thereof connected to the calutron ion source, and the negative terminal thereof connected to the calutron accelerator electrode, a losser regulator tube connected in series with said high voltage supply and said calutron, a resistor-capacitor network connected across said high voltage supply and separated therefrom by said losser regulator tube, an amplifier having the input thereof connected to said resistor-capacitor network and the output thereof connected to the grid electrode of said losser regulator tube, the time constant of the aforesaid resistor-capacitor network being greater than the response time of said amplifier so that the signal received by the amplifier lags behind the true condition of the voltage variation at the output terminals across said resistor-capacitor network whereby the output voltage is caused to overshoot its normal value during substantial regulating actions.

2. A high voltage regulator for the accelerator electrode of a calutron comprising a source of high voltage having the positive terminal thereof connected to the calutron ion source, and the negative terminal thereof connected to the calutron accelerator electrode, a losser regulator tube connected in series with said high voltage supply and said calutron, a resistor-capacitor network connected between said calutron ion source and accelerating electrodes, a degenerative amplifier having the input thereof connected to said resistor-capacitor network and the output thereof connected to the grid electrode of said losser regulator tube, the time constant of the aforesaid resistor-capacitor network being greater than the response time of said amplifier so that the signal received by the amplifier lags behind the true condition of the voltage variation at the output terminals across said resistor-capacitor network whereby the output voltage is caused to overshoot its normal value during substantial regulating actions.

3. A high voltage regulator for the accelerator electrode of a calutron comprising a source of high voltage having the positive terminal thereof connected to the calutron ion source, and the negative terminal thereof connected to the calutron accelerator electrode, a losser regulator tube connected in series with said high voltage supply and said calutron, a resistor-capacitor network connected across said high voltage supply and separated therefrom by said losser regulator tube, an amplifier having the input thereof connected to said resistor-capacitor network and the output thereof connected to the grid electrode of said losser regulator tube, a source of standard voltage connected in series with said network, said source of standard voltage biasing the input stage of said amplifier normally to conduct in the middle of the linear grid response region thereof, the time constant of the aforesaid resistor-capacitor network being greater than the response time of said amplifier so that the signal received by the amplifier lags behind the true condition of the voltage variation at the output terminals across said resistor-capacitor network whereby the output voltage is caused to overshoot its normal value during substantial regulating actions.

4. A high voltage regulator for the accelerator electrode of a calutron comprising a source of high voltage having the positive terminal thereof connected to the calutron ion source, and the negative terminal thereof connected to the calutron accelerator electrode, a losser regulator tube connected in series with said high voltage supply and said calutron, a resistor-capacitor network connected across said high voltage supply on the load side of said losser regulating tube, a degenerative amplifier having the input thereof connected to said resistor-capacitor network and the output thereof connected to the grid electrode of said losser regulator tube, a source of standard voltage connected in series with said network, said source of standard voltage being connected to produce a voltage in opposition to the voltage drop across said resistor-capacitor network and of a value to bias said amplifier to a normally conducting state, the time constant of the aforesaid resistor-capacitor network being greater than the response time of said amplifier so that the signal received by the amplifier lags behind the true condition of the voltage variation at the output terminals across said resistor-capacitor network whereby the output voltage is caused to overshoot its normal value during substantial regulating actions.

5. A high voltage regulator for the accelerator electrode of a calutron comprising a source of high voltage having the positive terminal thereof connected to the calutron ion source, said source comprising a polyphase transformer-rectifier arrangement, and the negative terminal thereof connected to the calutron accelerator electrode, a losser regulator tube connected in series with said high voltage supply and said calutron, a resistor-capacitor network connected across said high voltage supply, an amplifier having the input thereof connected to said resistor-capacitor network, and the output thereof connected to the grid electrode of said losser regulator tube, the time constant of the aforesaid resistor-capacitor network being greater than the response time of said amplifier so that the signal received by the amplifier lags behind the true condition of the voltage variation at the output terminals across said resistor-capacitor network whereby the output voltage is caused to overshoot its normal value during substantial regulating actions.

6. A high voltage regulator for a calutron comprising a calutron having a source of ions consisting of isotopic masses to be separated, said calutron having an accelerator electrode for accelerating the aforesaid ions, said calutron also having at least a pair of receivers for receiving the isotopic masses, one of said receivers being adapted to receive the enriched isotopic mass and the other being adapted to receive the impoverished isotopic mass, a source of high voltage for said accelerator electrode, and a regulator, said regulator including a losser tube connected between said source of high voltage and said accelerator electrode, an amplifier for supplying a signal to the grid of said losser tube and an RC network for supplying a signal to said amplifier, the time constant of said RC circuit being large and thereby supplying a time delayed signal to said amplifier whereby the ion beam of said calutron is rapidly swept across said receiver and then restored to its normal position in cases where the high voltage is suddenly decreased in value under conditions such as sparking between the calutron ion source and calutron accelerator electrode.

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