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RADIO PULSE SYSTEMS UTILIZING RADIOACTIVE MATERIALS

Filed Jan. 31, 1950 2 Sheets-Sheet 1

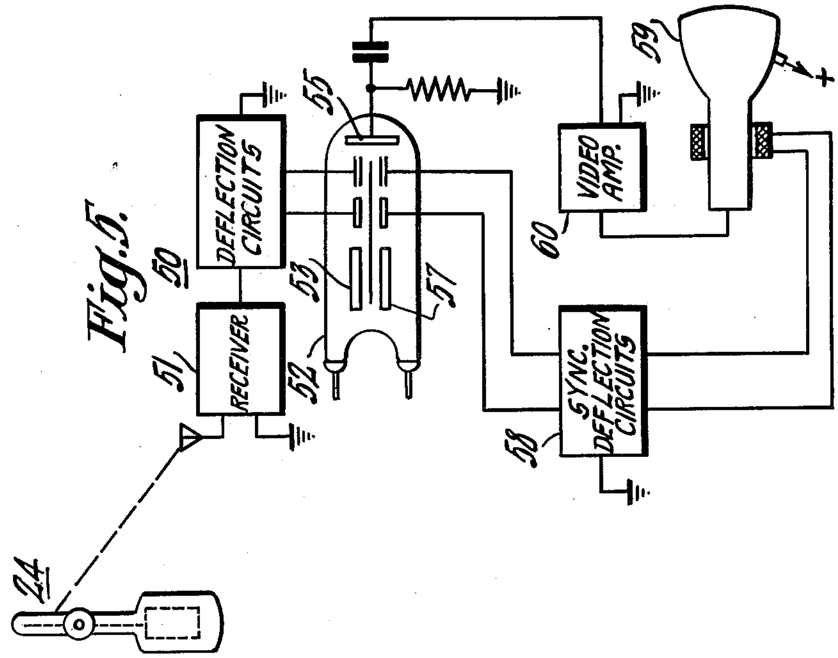

Fig. 5.

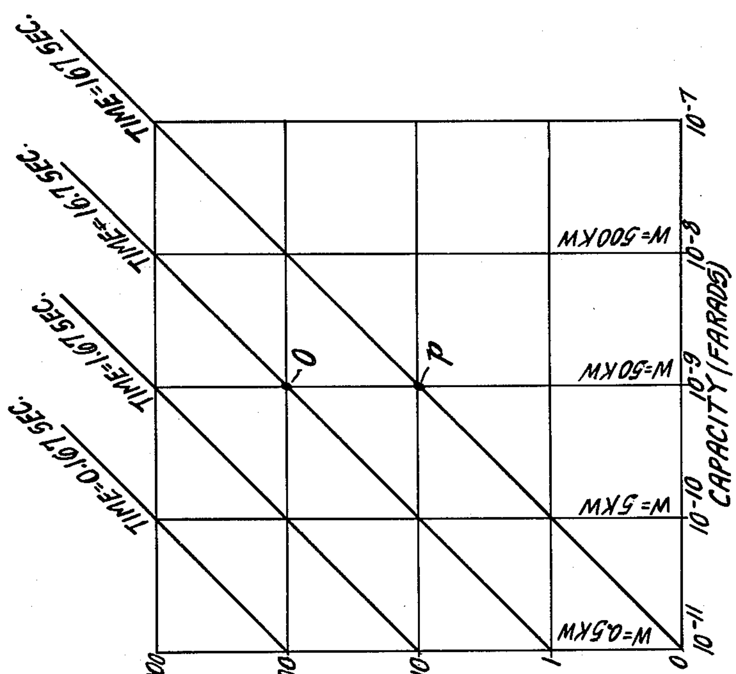

Fig. 1.

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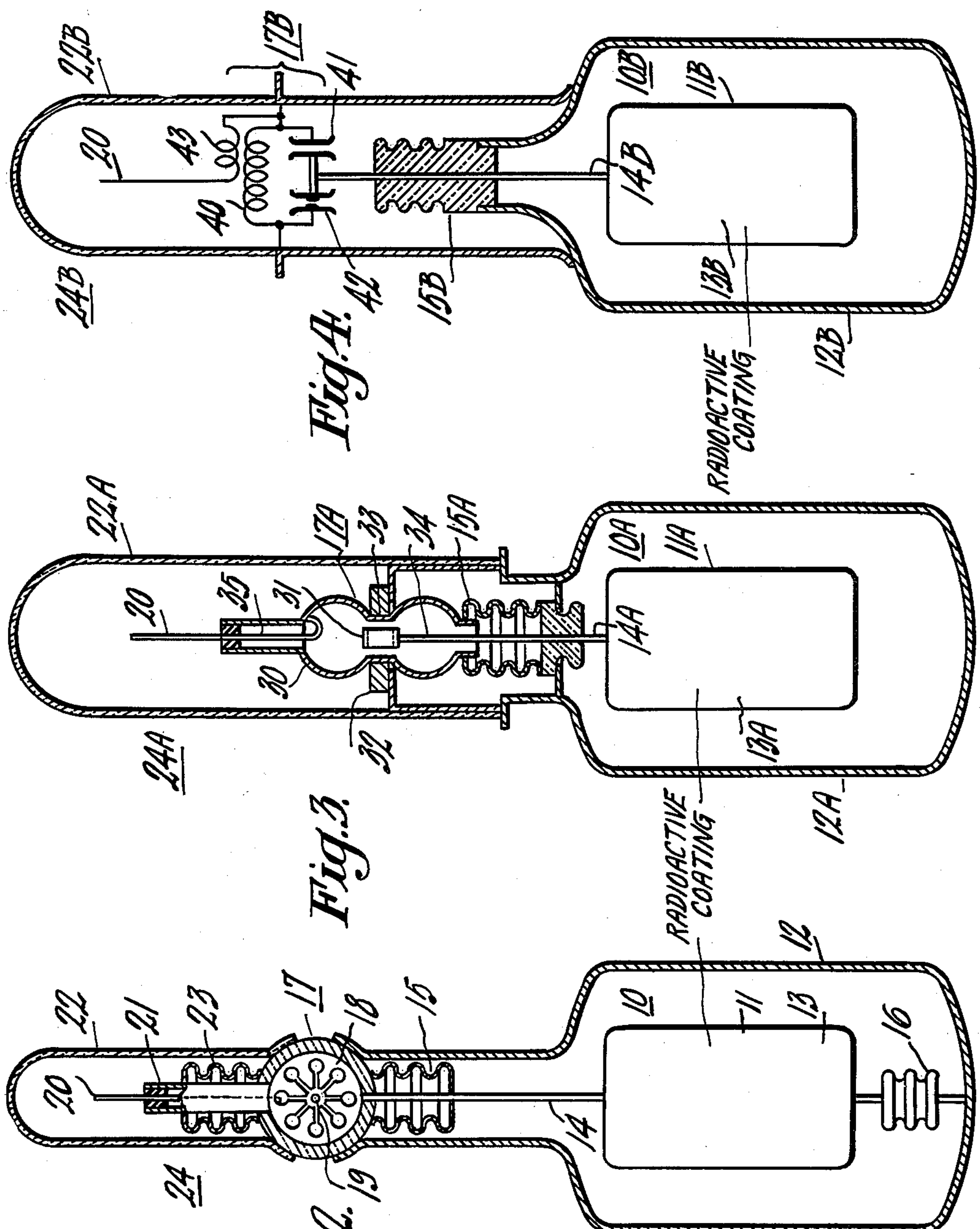

Fig. 2. Fig. 3. Fig. 4.

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RADIO PULSE SYSTEMS UTILIZING RADIOACTIVE MATERIALS

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12 Claims. (Cl. 250—17)

This invention relates to radio pulse systems, and particularly to radio pulse generators and transmitters suited for unattended operation throughout a long period of time.

In accordance with the invention, the charges continuously emitted by radioactive material are stored until there is accumulated a substantial electrical charge which is thereupon rapidly converted to a short burst of oscillatory energy, the cycle of storage of the relatively small emission charges and their conversion to brief oscillatory pulses of high peak power re-occurring at low repetition rate without need for the apparatus maintenance and replenishment of fuel required for other primary power sources.

More particularly the radioactive material is disposed within a high voltage capacitor of capacity suited to provide the required peak power at a voltage not exceeding the emission voltage of the radioactive material and at intervals determined by the activity and exposed area of that material: preferably, the capacitor for storing the emitted radioactive energy comprises two concentric electrodes, the inner of which is coated with the radioactive material, and the outer of which serves as a radiation shield and which in addition may serve as part of an evacuated envelope to minimize leakage of the high voltage produced between the capacitor electrodes.

Further in accordance with the invention, the intermittent conversion of the accumulated radioactive charges to oscillatory energy may be effected without need for auxiliary switching or timing devices by providing, in circuit with the self-charging capacitor and a resonant circuit or device, a high self-restoring resistance whose breakdown voltage is less than the maximum emission voltage of the radioactive material. Such resistance may be afforded by gas at suitably low pressure within a magnetron or other resonant cavity oscillator tube, or may be afforded by air or other gas, at suitable pressure, between electrodes of a spark gap in an oscillatory circuit having lumped constants.

Further in accordance with the invention, the self-charging capacitor, the resonant tube or circuit and an antenna for radiating the pulses of converted radioactive energy are combined in a hermetically sealed unit uniquely suited for long use as an unattended radio beacon in frigid, arid or mountainous regions where installation and servicing of a conventional radio beacon is difficult or impossible.

The invention further resides in methods, systems and apparatus having features of novelty and apparatus hereinafter described and claimed.

For a more detailed understanding of the invention and description and illustration of various embodiments thereof, reference is made to the accompanying drawings in which:

Fig. 1 is a chart referred to in explanation of the invention;

Figs. 2, 3 and 4 are simple schematic illustrations of pulse-transmitter units embodying the invention; and

Fig. 5 is a radio pulse transmitting and receiving system.

As by-products of the manufacture of fissionable substances, radioactive materials are becoming available in increasing amounts and at decreasing prices. The continuously generated power available from radioactive elements is very small, of the order of several milliwatts per curie. By utilizing a pulse-type generator so that the radioactive energy is slowly stored and rapidly dissipated, very high peak powers, of the order of kilowatts, can be obtained from reasonably small amounts of radioactive material. A pulse generator of this type has many uses and is particularly suited for use as an unattended source of energy because with a suitable radioactive material such a generator has a useful life of many years in which it requires no servicing or replenishment: by way of example, cobalt 60 has a half-life of 5.3 years and strontium 90 a half-life of 25 years. Other radioactive materials having alpha and/or beta emission and suitable for radio-frequency generator of shorter life are listed in my copending application Serial No. 679,085, filed June 25, 1946, now Patent No. 2,552,050. The former emits 30 kilovolt beta rays and is now available in substantial quantity at reasonable price.

The charged particle high-voltage cold emission of the radioactive material is stored as electrical energy in a suitable high-voltage capacitor, specific preferred forms of which are hereinafter described. As illustrative of the peak powers available under various operating conditions and for capacitors of different magnitudes, reference is made to Fig. 1 in which the capacitor capacity is plotted along the horizontal axis and the number of curies of radioactive material along the vertical axis. The diagonal lines represent the loci of the constant charging times required for the capacitor voltage to attain 10,000 volts. The vertical lines represent the peak powers for a 1-microsecond pulse.

The points O and P on the graph, Fig. 1, indicate that a 50 kilowatt peak-power pulse may be obtained every 16.7 seconds by using 100 curies of a beta-emitter, or every 167 seconds by using 10 curies. A peak-power voltage of 10,000 is a practical one because affording high peak power pulses of suitable duration and repetition rate at magnitudes consistent with minimizing leakage of the capacitor charge and other practical considerations. This voltage is much lower than the usual beta-particle voltage and with improvement in materials or techniques permitting much higher voltages to be stored, powers of from 3 to 20 times greater become available.

In the preferred form of self-charging capacitor shown in Figs. 2 to 4, the electrodes are two concentric cylinders disposed in a vacuum type envelope and suitably insulated to withstand the high voltage developed between them. Specifically referring to the capacitor **10**, Fig. 2, the inner cylinder **11** has thereon a radioactive coating **13** which serves as a source of charged particle "cold" emission. By "cold" is meant the emission is at ambient temperature. Considering that 1 curie could be coated on 10 square centimeters of electrode surface without serious self-absorption of the beta rays, the 100 curies required, in accordance with one example above, to produce a pulse peak power of 50 kilowatts, will cover 1,000 square centimeters. For a spacing between cylinders of 10 centimeters, which is sufficient safely to withstand the 10,000 volts between electrodes, the capacity from the coated area is only 9 micro-microfarads so that there is ample margin to dimension the total inter-electrode areas to meet the capacity requirements shown in Fig. 1 for the desired peak power.

The outer electrode **12** of the capacitor has closed ends forming an evacuated envelope in which the inner electrode is supported by the conductor **14** and insulators **15** and 16. The insulator 15 seals the top of the capacitor and leaves the conductor 14 accessible.

Intermittently to convert the radioactively-produced charge of capacitor 10 to oscillatory energy, there is provided a resonant circuit device 17 and means for discharging the capacitor when its voltage attains a predetermined high value. In the arrangement shown in Fig. 2, the resonant device 17 is a magnetron whose anode block 18 is connected by conductor 14 to the positively charged inner electrode 11 of capacitor 10. The cathode 19 of the magnetron is connected by conductive means, not shown, to the outer, negatively charged electrode of capacitor 10. The cathode is of the cold type requiring no power supply: it may be of the field emission type or utilize a magnetically controlled gas-discharge.

To effect intermittent switching of the capacitor to the magnetron without recourse to an auxiliary switch or timer, the magnetron contains gas at low pressure insuring breakdown of the resistance of the gas when the capacitor voltage attains, in the above example, 10,000 volts. A magnetron of such type is disclosed in my copending application Serial No. 90,332, filed April 29, 1949. Inert gases such as helium, neon and argon are suitable and the pressures required for breakdown of these gases at the desired peak power voltage are similar to those of magnetic cold-cathode rectifier tubes: in general, these pressures are very low, as of the order of 10^{-3} millimeters of mercury. Condensible vapors, such as mercury, should not be used because of the effect of temperature upon their pressure. The gas cleanup problem in such tube is not serious because assuming 1 microsecond pulses at intervals of about 15 seconds, the total discharge time for a period of over twenty-five years is only about 50 seconds.

Alternatively, the switching may be effected by an auxiliary switch such as shown in my copending application Serial No. 36,241, filed June 30, 1948, now Patent No. 2,555,143, which is of a type utilizing radioactive material to effect periodic movement of the switch member.

For propagation of the bursts of the high-frequency energy output of the magnetron 17, or equivalent, an antenna 20 may be connected or coupled thereto in conventional manner: specifically, it may be coupled by means including the transmission line 21 and a loop or probe (not shown) to one of the cavities of the anode block 18.

The antenna 20 is preferably enclosed in a pressurized housing sealed at its lower end by the insulator 23 and through which the transmission line 21 extends for connection by suitable terminals, not shown, to the output terminals of the magnetron. The housing 22 should be of ceramic, glass, or other material transparent to the high-frequency energy radiated by antenna 20 and capable of withstanding weather conditions for a long period of time.

Preferably, and as shown in Fig. 2, the capacitor 10, the energy converter 17 and the energy radiator 20 form a hermetically sealed unit which may be dropped in isolated or uninhabited regions for long continued use as a radio beacon requiring no attention.

Because of the radioactive nature of the capacitor 10, the usual precautions must be taken in its manufacture and handling. So far as shielding against the beta rays is concerned, the outer envelope or electrode 12 need be only a few millimeters thick to afford ample protection. Some of the suitable radioactive materials, including cobalt 60 are potent gamma-ray emitters and additional protection is therefore necessary. In handling or shipping, the capacitor 12 may be temporarily disposed within a thick lead case.

The radioactively charged capacitor 10A, shown in Fig. 3, is essentially similar to that shown in Fig. 2, and the corresponding elements are identified by the same reference characters with addition of the suffix A. In this modification, the resonant device 17A for intermittently converting the accumulated radioactive charges into high-frequency oscillatory energy comprises a toroidal cavity 30 resonant at the desired frequency. A ring electrode 31 disposed centrally of the cavity is connected by conductor 34 and a suitable terminal to the upper end of the capacitor lead 14A. Permanent magnets 32 constrain oscillation of electrons between the secondarily-emissive surfaces 33 of the cavity to parallel paths through the ring or grid electrode 31. The toroidal cavity of the "multipactor" 17A is filled, as in the corresponding resonant cavity tube 17 of Fig. 2, with an inert gas at such pressure it breaks down for discharge of the capacitor 10A when the capacitor voltage obtains a predetermined high magnitude less than the emission voltage of the radioactive coating 13 on the inner electrode 11A of the capacitor.

The antenna 20 for radiation of the oscillatory energy intermittently developed by the multipactor 17A is coupled to the cavity thereof as by the coupling loop 35 and preferably is disposed within a pressurized housing 22A transparent to the radiated energy. The housing 22A may be provided at its lower end with a conductive coating or inner metal ring serving as part of the capacitor discharge path from the outer electrode 12A to the cavity 30.

The radioactively charged capacitor 10B shown in Fig. 4 is essentially similar to that shown in Fig. 2 and the corresponding elements are identified by the same reference characters with addition of the suffix B. In this modification, the resonant device 17B for intermittently converting the accumulated radioactive charges of the capacitor into high-frequency oscillatory energy comprises an inductance 40 and a capacitor 41 forming a circuit resonant at the desired frequency. This circuit includes a spark gap 42 to prevent discharge of the capacitor 10B until the voltage of the charge attains a high value predetermined by the spacing and shape of the spark-gap electrodes, their shape and by the pressure of air or other gas within the enclosure 22B. Upon breakdown of the high resistance of the spark gap, the stored energy of the capacitor is converted to oscillatory energy of frequency determined by the constants of the circuit 40, 41. The path of discharge of the capacitor includes the conductor 14B, the spark gap 42 and a connection therefrom to the outer electrode 12B afforded by a conductive coating or sleeve enclosed by or surrounding the lower part of the enclosure 22B or forming the lower separate part of the enclosure and joined to the antenna housing by a flanged coupling.

For radiating the bursts of high-frequency energy produced by the resonant circuit, there is provided the antenna 20 and a coil 43 or equivalent coupling means. As in the preceding modifications, the self-charging capacitor, the resonant circuit device and the antenna system form an enclosed unit suited for use as an unattended radio beacon for long periods of time.

Because of the brief duration of the pulses and their low repetition rate, the associated receiver or receivers should include a cathode ray tube using a high-sensitivity phosphor and a deflection circuit having a high sweep rate. The incoming signal may trip or trigger one sweep circuit and the signal may be applied through a delay line to the other sweep circuit. The incoming signal may also operate a camera shutter to produce a permanent record of the trace. Alternatively and preferably however, the receiving system 50, Fig. 5, includes a picture storage tube 52 fully described in RCA Review, volume X, No. 1, pages 59 to 73. Briefly, the picture storage tube or "Graphecon" 52 includes a writing gun 53 producing a cathode ray beam which is subjected to deflection by plates to which are applied the pulse signals received by the receiver 51 from the remote pulse generator or transmitter 24. There is thus produced and retained upon the target screen 55 or tube 52 an electron image of each brief individual pulse.

The picture storage tube 52 is provided with a reading gun **57** producing a cathode ray beam which in the long interval between successive pulses repeatedly scans the target screen to produce a repeating video signal and gradually to erase the electron image of the earlier pulse. The deflection circuits **58** for the electrodes associated with the second or reading gun **57** are synchronized with those which produce deflection of the cathode ray beam of a second cathode ray tube or "Kinescope" **59**. The video signal output of the picture storage tube **52** is applied through the video amplifier **60** upon the beam-intensity electrode of the Kinescope **59** thus to produce on its screen a persistent or prolonged image of each brief pulse received from the transmitter **24**.

What is claimed is:

1. A radio pulse generator comprising a capacitor having disposed therein radioactive material which at ambient temperature continuously emits high-voltage charges at low rate, and a high-frequency device coupled to said capacitor for conversion of charges accumulated in said capacitor to oscillatory energy comprising a resonant cavity tube having a cold cathode and containing gas at pressure providing for breakdown of its high resistance at voltage lower than the maximum of the emission from said radioactive material.

2. A radio pulse generator comprising a capacitor having disposed therein radioactive material which continuously emits high-voltage charges at low rate, and a high-frequency device coupled to said capacitor for conversion of charges accumulated in said capacitor to oscillatory energy comprising a resonant circuit including a spark gap whose breakdown voltage is less than the maximum voltage of the emission of said radioactive material.

3. Apparatus for producing pulses of high-frequency energy at low repetition rate throughout a long period of time which comprises electrode means for storing the energy of high-voltage charged particle emission from radioactive material as an electrical charge, and means providing for intermittently dissipating the accumulated charge in a resonant electric device.

4. A radio pulse generator comprising means for primarily generating electrical energy including a source of radioactive material providing charged particle cold high energy emission, and electrode means disposed in a region adjacent to said source for collecting said emitted particles to establish a potential with respect to said source; and a resonant high frequency device including an ionizable gaseous discharge element coupled to said source and said electrode and responsive to said potential, said discharge element having a breakdown voltage less than the maximum attainable value of said potential whereby pulses of oscillatory energy are generated in said resonant device in response to voltage breakdown across said discharge element.

5. A radio pulse generator comprising means for primarily generating electrical energy including a source of radioactive material providing charged particle cold high energy emission, and electrode means disposed in a region adjacent to said source for collecting said emitted particles to establish a potential with respect to said source; and a high frequency cavity resonator device including an ionizable gaseous discharge element coupled to said source and said electrode and responsive to said potential, said discharge element having a breakdown voltage less than the maximum attainable value of said potential whereby pulses of oscillatory energy are generated in said cavity resonator device in response to voltage breakdown across said discharge element.

6. A radio pulse generator comprising means for primarily generating electrical energy including a source of radio-active material providing charged particle cold high energy emission, and electrode means disposed circumferentially about said source for collecting said emitted particles to establish a potential with respect to said source; and a resonant high frequency device including an ionizable gaseous discharge element coupled to said source and said electrode and responsive to said potential, said discharge element having a breakdown voltage less than the maximum attainable value of said potential whereby pulses of oscillatory energy are generated in said resonant device in response to voltage breakdown across said discharge element.

7. A radio pulse generator comprising means for primarily generating electrical energy including a source of radioactive material disposed upon conductive support means for providing charged particle cold high energy emission, and cylindrical electrode means disposed circumferentially about and concentric with said support means for collecting said emitted particles to establish a potential with respect to said source; and a resonant high frequency device including an ionizable gaseous discharge element coupled to said source and said electrode and responsive to said potential, said discharge element having a breakdown voltage less than the maximum attainable value of said potential whereby pulses of oscillatory energy are generated in said resonant device in response to voltage breakdown across said discharge element.

8. A radio pulse generator as claimed in claim 7 wherein said support means and said electrode means comprise a pair of concentric cylinders, the inner of said cylinders being coated with radioactive material and the outer of said cylinders having closed ends forming a vacuum-tight enclosure.

9. A radio pulse generator as claimed in claim 8 including an antenna system coupled to said resonant high frequency device for the purpose of radiating said generated oscillatory energy.

10. A radio pulse generator as claimed in claim 9 wherein said concentric cylinders, said high frequency device, and said antenna system are physically connected to form an enclosed unit, the enclosure for said cylinders being air tight and substantially opaque to the emission of said radio-active material and the enclosure for said antenna being pressurized and essentially transparent to oscillations of frequency produced by said high frequency device.

11. Apparatus as claimed in claim 3 wherein said resonant electric device comprises a magnetron.

12. Apparatus as claimed in claim 3 wherein said resonant electric device comprises a toroidal cavity resonator.

References Cited in the file of this patent

UNITED STATES PATENTS

2,395,623	Goldstein et al.	Feb. 26, 1946
2,448,713	Hansell	Sept. 7, 1948
2,555,143	Linder	May 29, 1951
2,558,434	Hofberg	June 26, 1951
2,598,925	Linder	June 3, 1952
2,633,542	Coleman	Mar. 31, 1953

FOREIGN PATENTS

160,990	Germany	May 30, 1905