July 28, 1964 G. C. RICH 3,142,780

COLD CATHODE GAS TUBE COUNTING CIRCUITS

Filed March 16, 1950 2 Sheets-Sheet 1

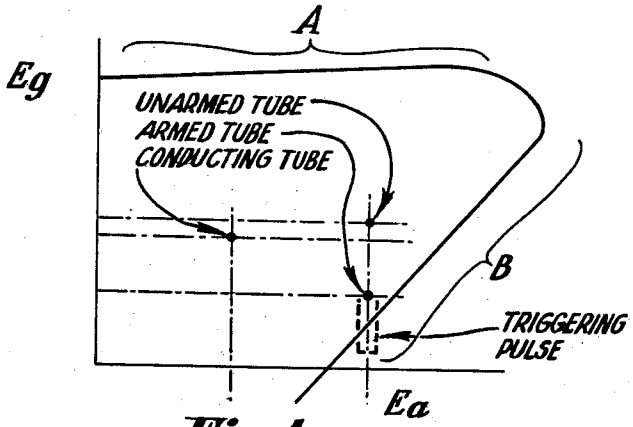


Fig. 1

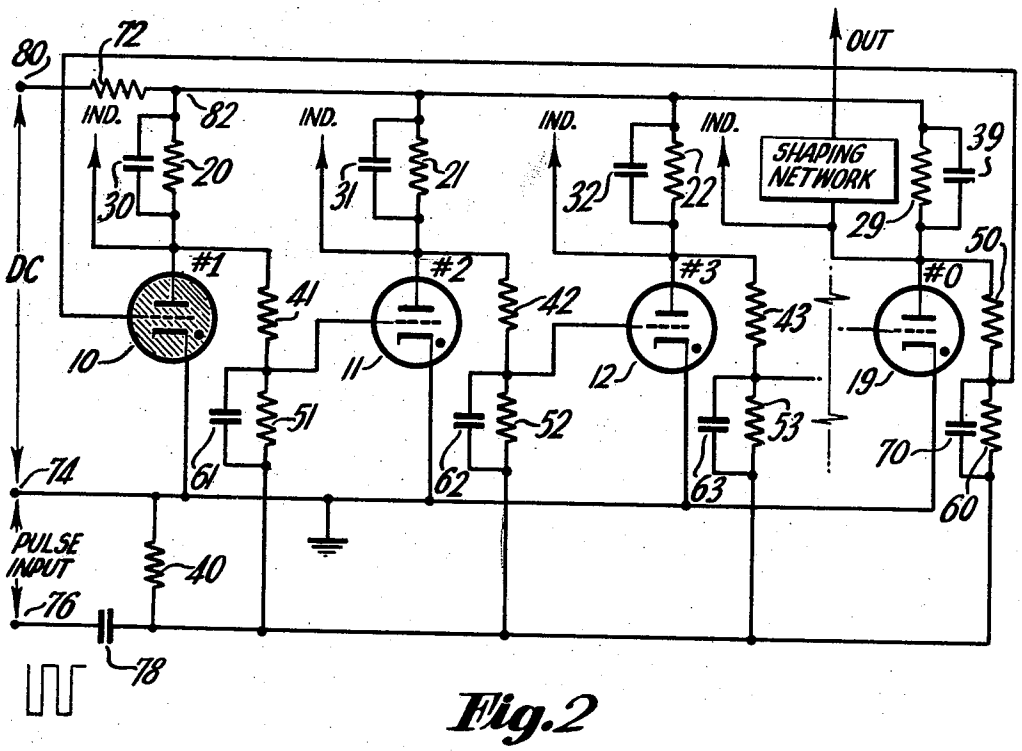


Fig. 2

INVENTOR
GERALD C. RICH
BY Paul S. Martin
ATTORNEY

July 28, 1964 G. C. RICH 3,142,780

COLD CATHODE GAS TUBE COUNTING CIRCUITS

Filed March 16, 1950 2 Sheets-Sheet 2

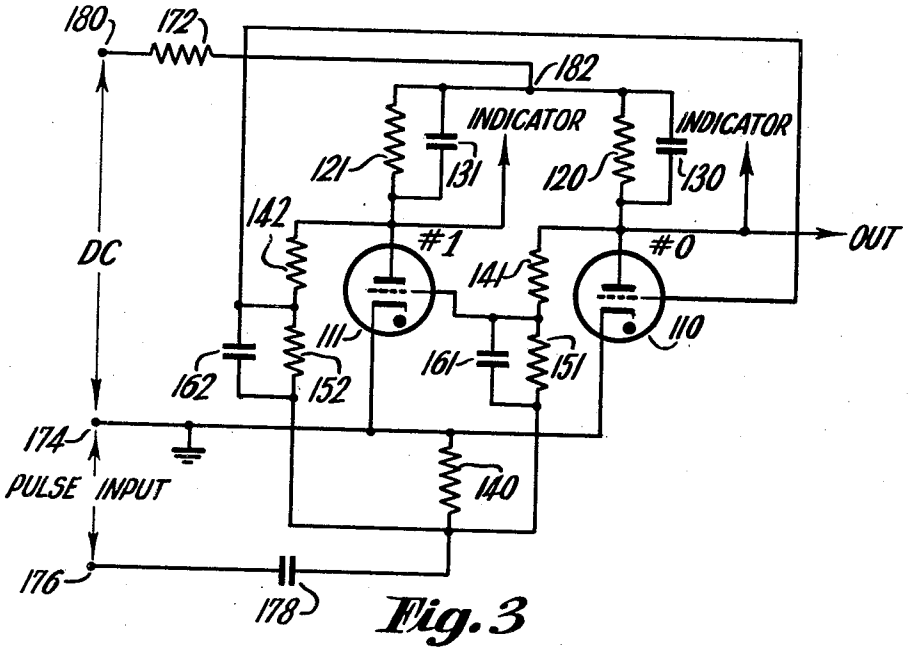


Fig. 3

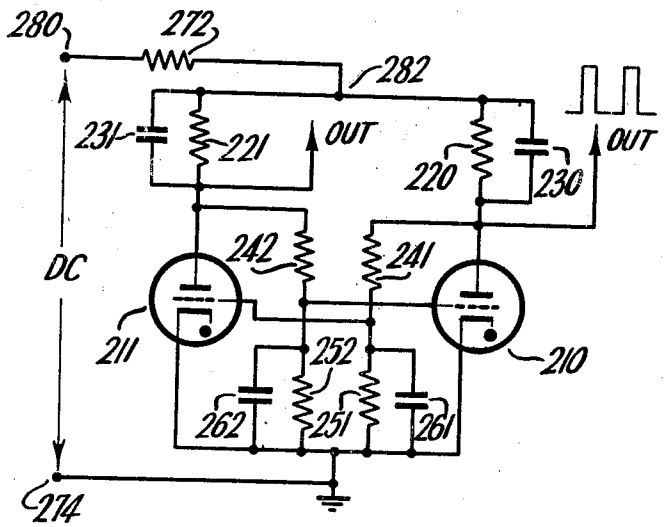


Fig. 4

INVENTOR
GERALD C. RICH
BY Paul S. Martin
ATTORNEY

United States Patent Office 3,142,780 Patented July 28, 1964

3,142,780
COLD CATHODE GAS TUBE COUNTING CIRCUITS

Gerald C. Rich, Manhasset, N.Y., assignor, by mesne assignments, to Sylvania Electric Products Inc., Wilmington, Del., a corporation of Delaware

Filed Mar. 16, 1950, Ser. No. 149,965
13 Claims. (Cl. 315—84.5)

This invention relates to circuits employing the cold cathode type of gaseous discharge tubes, particularly counting circuits, and to methods of operating such tubes in rendering them conductive and non-conductive.

Thermionic cathode gas discharge tubes or thyratrons have been used in computer circuits, both according to the scale-of-two, and according to the scale-of-ten "ring counter" as shown in an article entitled "Electronic Counter and Divider Circutis" by Meinheit and Snyder, page 5 of vol. 1, #3 of "The Sylvania Technologist," published by Sylvania Electric Products Inc., July 1948. This type of tube inherently develops a substantial amount of heat that is unnecessary to the circuit effects produced. The power consumed in rendering the cathode electron-emissive is a waste (significant in portable equipment) insofar as the required performance is concerned, and the serious problem of heat dissipation is raised that is especially troublesome in compact equipment. While it is necessary to heat the cathode in a thyratron to make it electron-emissive, the heat developed does not contribute to the circuit performance of the tube.

In order to eliminate this necessary evil of power consumption and heat dissipation of thermionic cathodes, the use of cold cathode type tubes has for long been considered but has not been practically realized. Cold cathode types of gaseous discharge tubes have for long been known but their characteristics have been so widely different from the characteristics of thermionic gas discharge tubes that they have not heretofore successfully been incorporated in counting circuits and the like. This has evidently been due to the large ionization and deionization time considered to be inherent in cold cathode gas tubes, counting rates with such tubes in conventional circuits being limited heretofore to a speed of the order of two hundred counts per second.

Accordingly, an object of the present invention is to provide high speed counting circuits and the like employing cold cathode tubes. A further object is the simplification of counting circuits employing gas discharge tubes. A more general object is to utilize the slanting portion of the grid voltage-anode voltage characteristic in new, useful circuits.

Tubes best adapted to serve in the circuits here involved are of the type employing a cathode, an anode, and an apertured shielding control electrode interposed between the cathode and the anode, that is itself sensitized to render it electron-emissive. This sensitized control electrode or grid is formed or coated with an alkaline earth metal or compound as for example barium fluoride. Such tubes are more fully disclosed and claimed in my patent application entitled Cold Cathode Gas Tube, Serial No. 149,966, filed March 16, 1950, now abandoned.

This sensitized grid gas tube has a characteristic that resembles known types of cold cathode tubes but in a portion of its firing characteristic has an extended sloping portion in the positive grid voltage-positive anode voltage region. Such a tube is arranged in the circuits here involved to operate inside the characteristic in quiescent state where it can be pulsed into conduction by a slight increase in anode voltage or decrease in grid voltage that crosses the characteristic. Utilization of this sloping part of the characteristic is a signal feature of this invention and will be explained in greater detail in connection with the illustrative circuit embodiments of this invention described in detail below. In the accompanying drawings:

FIG. 1 is the characteristic of a cold cathode discharge tube especially suited to the purposes of the novel circuits;

FIG. 2 is a pulse counting circuit of the "ring" type;

FIG. 3 is the circuit of a flip-flop switching circuit that is also useful as a scale-of-two counter; and

FIG. 4 is a modification of the circuit in FIG. 3 that operates as a free running square wave generator.

The cold cathode gas tube preferred includes a cold cathode advantageously coated with barium fluoride or other material suited to electron emission upon bombardment by ions, photons and metastable atoms, an anode, and a shielding apertured control electrode or grid between the cathode and the anode. This shielding electrode is also treated as with barium fluoride to render it emissive as a cold cathode, so that it can function with the anode as a diode when appropriate potential is applied. Such a tube is well suited to the purposes of this invention by the long sloping portion of its grid-anode characteristic where the characteristic approaches and crosses the anode voltage axis. Cold cathode discharge tubes are known, however, having a sloping firing characteristic in the positive grid voltage-positive anode voltage region, wherein sloping portion is of limited extent that theoretically can be used by critical adjustments in the illustrative circuits. However, with appropriate bias supplies the sloping characteristic of known cold cathode gas tubes in the negative grid-voltage positive anode voltage regions can be utilized in modifications of the illustrative embodiments, as will be readily apparent to those skilled in the art.

In FIG. 1 the characteristic shown includes a long substantially horizontal portion A which is common to cold cathode gas tubes. In this region the firing of the tube requires a certain increase in grid voltage almost without respect to the anode voltage used. Firing is achieved by shifting the potential above the characteristic curve. A long sloping portion B is also shown, the attribute of gas tubes having a shielding control grid sensitized to function as a cold cathode, and it is this portion of the characteristic that is here utilized. Three points are shown within the curve which locate a tube in a counting circuit either in condition for firing and thus "armed," or in no condition to be fired and thus "unarmed," or conducting and thus not in condition to be fired. A tube can readily be fired by impressing a negative pulse on its grid or a positive pulse on its anode. If such a pulse is impressed on either an unarmed tube or a conducting (fired) tube it will have no effect in changing its condition.

In the various circuit applications a conducting tube is arranged to shift the operating point of the next tube to be rendered conducting into the spot identified in FIG. 1 as "armed" tube. The next pulse will fire or trigger the armed tube and appropriate circuit provision is made for quenching the previously conducting tube.

Referring now to FIG. 2, one order to decade counter is shown in which negative pulses applied to all of the grids are effective to fire the tube next adjacent the conducting tube and to quench the previously conducting tube but not to fire the succeeding unarmed tubes of the ring. A series of tubes 10, 11, . . . 19 is shown in which each has an anode load resistor 20, 21 . . . 29 and each load resistor has a shunting condenser 30, 31 . . . 39. A voltage divider is connected between each anode circuit and ground, this voltage divider including a common resistor 40 that is to have an appropriate impedance for the pulse signals impressed. These voltage dividers include resistors 41, 42 . . . 50 and 51, 52 . . . 60. The latter

are shunted by condenser 61, 62 . . . 70. The voltage divider of each tube is connected for applying a signal and biasing potential to the grid of the next following tube in the ring, this direct connection being effective to enable each fired or conducting tube to arm the next. Thus, the control grid of tube 11 is connected to the junction of resistors 41 and 51, and when tube 10 is conducting the grid of tube 11 is shifted from the unarmed to the armed point in FIG. 1. The junction of resistors 50 and 60 of the #0 tube is coupled back to the grid of the #1 tube 19 of the ring. Indicating devices (not shown) can be connected across the anode loads of the several tubes to indicate which one is conducting and thus to exhibit the count, or the glow of the conducting tube may be made prominent. A common resistor 72 is included in the direct current supply for all of the tubes of this ring. Signal is applied between terminals 74 (which may be regarded as the ground of the circuit) and 76, and coupled through condenser 78 that is sufficiently large to impress the pulse on resistor 40 but effective to block direct-current potentials. This signal may be furnished by the electrical source of pulses to be counted or by a preceding order of the counter.

The square wave pulse applied through coupling condenser 78 and the several coupling condensers 61, 62 . . . 70 reaches the grids of all of the tubes in the ring counter illustrated. Tube 10 that is conducting is not affected by this voltage and does not tend to refire after extinguishing, nor are tubes 12 . . . 19 affected because (FIG. 1) they are not shifted outside the sloping characteristic by the pulse. The anode of tube 10 is at a low voltage because of the drop in its anode resistor 20 and, consequently, voltage divider 41, 51, 40 has a lower voltage across it than the other voltage dividers of the circuit. The grid of tube 11 is therefore close to the sloping portion B of the grid-anode characteristic in FIG. 1 and tube 11 is fired by the negative pulse at terminal 76. This abruptly increases the current passed by resistor 72 while condenser 31 is being charged. The voltage available to tube 10 and its anode load 20 is caused to drop below that necessary to maintain conduction, its condenser 30 being charged to the I–R drop in resistor 20 at this time. Consequently, tube 10 is thus extinguished. The time constants of the resistors and condensers in the several anode returns are related to the de-ionization and ionization times of the tubes so that a newly fired tube will remain conducting while a previously fired tube is extinguished. The grid condensers are made large enough to transmit the triggering pulses effectively, but the time constants of the grid circuits should be proportioned so that a newly fired tube will not be enabled to arm the succeeding tube during a single input pulse. In an illustrative circuit where each tube and its associated components are like all the others, anode resistor 20 may be 27,000 ohms, its bypass condenser 30 may be .01 mfd., resistor 41 may be 680,000 ohms, resistor 51 may be 270,000 ohms, condenser 61 may be .001 mfd., resistor 72 may be 10,000 ohms, resistor 40 may be 47,000 ohms, and capacitor 78 may be .005 mfd. In operation of this circuit the following voltages may be considered to be established. At the positive terminal 80 of the direct current supply there may be 220 volts, at the low-voltage end 82 of resistor 72 there may be 178 volts, at the grid of any fired tube there may be 59 volts and 69 volts at its anode, there may be 32 volts at the grid of the armed tube and 63 volts at the grids of the unarmed tubes with perhaps 16 volts across element 40 where it is a resistor. There would be virtually no voltage across this element if it were a choke. Where element 40 is a resistor square waves are preferred, but any appropriate form of pulse may be used.

As each new pulse is applied to all of the grids, the previously conducting tube is extinguished, the armed tube is fired, and the succeeding tube of the ring is armed by a decrease of the voltage applied to its grid by the voltage divider connected to the preceding fired tube. When the

#0 tube of the decade is fired its anode drops abruptly in voltage and this constitutes a negative pulse that can be shaped and utilized in firing a tube of the succeeding decade.

The cold cathode ring counter described is evidently economical in that it eliminates the usual requirement in thyratron ring counters of a heater supply for rendering the cathode electron-emissive. This is of great importance in portable equipment. In fixed equipment where large numbers of circuits are required because of the complexity of the computations to be performed, compactness is extremely important and a limitation on this compactness is the temperature rise to which the entire circuit is exposed by the heating power delivered to the usual thermionic cathodes. This limitation is eliminated in the cold cathode type of circuit. Finally, the circuit described is outstandingly simple, with a limited number of components associated with each tube and without requiring a special transfer tube for triggering the following decade.

Principles of the foregoing ring counter are applicable to a scale-of-two counter as shown in FIG. 3. This counter has a more generalized field of application in various switching purposes where it is referred to as a "flip-flop" or univibrator, and is especially valuable for its compactness and for the elimination of the need and consequences of heater power described above. The circuit in FIG. 3 is seen to include but two tubes and the associated components shown in FIG. 2 with the voltage divider of each tube arranged to trigger and bias the grid of the opposite tube. This circuit (FIG. 3) does not include any unarmed tubes. It has two stable states and is converted from each to the other by each succeeding input pulse. The reference numerals used in this figure correspond to those in FIG. 2, but are different in that the 100 series of numerals is used. The operation is identical to that of the ring counter in FIG. 2 in that each unfired tube is shifted from the conducting state to the armed state and reversely as described in connection with FIG. 1. The appropriate count indicators (not shown) and appropriate output connections may all be included by connections to the anode circuits, for example.

The circuit in FIG. 4 represents a modification of that in FIG. 3 in which the pulse input circuit is eliminated and in which the voltage divider values are adjusted so that each fully conducting tube not only arms the grid of the other tube, but shifts it outside sloping portion B of the characteristic in FIG. 1. This constitutes a free-running multi-vibrator that can be adjusted to any desired operating frequency and any desired duty cycle for each of the tubes, consistent with the de-ionization time of the tubes, by adjustment of the time constants of the circuit components. The parts are given numbers of the 200 series corresponding to the parts in FIG. 2. As in the other embodiments the anode load resistor and condenser of each tube in FIG. 4 are proportioned to insure deionization of the associated tube; and the resistors of the grid biasing voltage dividers together with the respective condensers 261 and 262 largely control the time intervals during which each tube remains conducting.

From the foregoing it is evident that the several circuits represent novel arrangements for accomplishing functions of thermionic-cathode thyratrons in relatively more complex circuits requiring heater supplies and requiring provision for heat dissipation. Various detailed modifications of the illustrative embodiments described will occur to those skilled in the art. For example, resistors 72, 172 and 272 may evidently be shifted from the positive to the negative side of the direct-current power supply and may in special cases be incorporated in that power supply. It also may be found desirable to couple the various grid condensers directly to the signal source, thus eliminating the separate input condenser and impedance shown to be common to all said tubes. Such changes and others will occur to those skilled in the art, as will varied applications

of the circuit fundamentals here involved. Consequently, it is fitting that the appended claims be accorded a broad scope of interpretation, consistent with the spirit of the invention.

What I claim is:

1. A cold cathode gas tube circuit including a gas tube having a cold cathode, an anode and a sensitized control electrode, a resistive voltage divider having its negative terminal connected to said cathode and having a tap connected to said grid, and means to increase the voltage difference between said grid and said anode for shifting said tube from non-conducting into conducting state.

2. A cold cathode gas tube circuit including multiple gas tubes each having a cold cathode, an anode, and a control electrode, positive and negative power supply lines connected to said anodes and cathodes including a common impedance element, a resistance-capacitance load between the anode of each tube and the positive supply line, and a resistance voltage divider connected between one of said loads and the negative supply line having a tap connected to the control electrode of another of said tubes.

3. A cold cathode gas tube circuit including multiple cold cathode gas tubes each having a cathode, an anode and a control electrode, a separate resistance-capacitance load in the anode circuit of each tube and a common impedance between said loads and the positive supply terminal of a direct-current supply, a voltage divider between each anode and the negative terminal of the direct-current supply including a pair of series connected resistors and a condenser shunting the more negative portion of the voltage divider, the junction of said series connected resistors associated with one of said tubes being connected to the control electrode of another of said tubes.

4. The method of firing a cold cathode gas tube having a sensitized control electrode which includes the steps of applying positive potentials to the anode and grid to bias the tube in unfired condition near the 45° sloping portion of its firing characteristic and impressing a negative pulse on the control electrode.

5. A cold cathode gas tube circuit including multiple cold cathode gas tubes each having a cathode, an anode, and a sensitized control grid, direct-current supply lines for said tubes including common resistor for all said tubes, the cathodes of said tubes being connected to the negative supply line, separate load impedances between each anode and the positive supply line and a grid biasing voltage divider for each tube connected to the negative supply line and to the load impedance of another of said tubes.

6. A cold cathode gas tube circuit including multiple cold cathode gas tubes, each having a cathode, an anode, and a control electrode, positive and negative supply lines including resistance means common to all said gas tubes, said anodes being connected through a load to said positive supply line, said cathodes having direct connections to the negative supply line, a respective voltage divider energizing each of said control electrodes and having connections to the anode load of another of said tubes and to the negative supply line, and signal applying means including a common impedance in the connection of said voltage dividers to the negative supply line.

7. A cold cathode gas tube circuit including multiple gas tubes each having a cold cathode, an electron-emissive control electrode, and an anode, arranged in the order named, positive and negative supply lines including a common impedance for said tubes, an anode load impedance-including a parallel resistor and condenser combination, said cathodes being directly connected to the negative supply line, a voltage divider connected between the load impedance of the anode of each tube and the negative supply line and having a tap directly connected to the control electrode of another of said tubes, and signal applying means including an impedance element common to all said voltage dividers and included in the return circuit of said voltage dividers to the negative supply line, and a coupling condenser between each control electrode and said signal applying means.

8. A cold cathode gas tube circuit including at least three cold cathode gas tubes each having a cathode, an anode and an electron emissive control electrode, power supply connections for the anode-to-cathode discharge path of all of said tubes including a common impedance, a resistance-capacitance load in the anode circuit of each of said tubes, a biasing voltage divider for the control electrode of each of said tubes connected to the load impedance of another of said tubes in ring fashion so that each tube controls a succeeding tube in fixed sequence whereby one tube that is conducting biases the succeeding tube into armed condition for firing while the armed tube biases the next tube into unarmed condition, and means to apply negative pulses concurrently to all the control electrodes of said tubes.

9. A cold cathode gas tube circuit including multiple gas tubes each having a cold cathode, an electron emissive control electrode and an anode arranged in the order named, direct-current supply lines including an impedance element common to said tubes and separate resistance-capacitance loads between each of said anodes and the positive supply line, and a resistive voltage divider having connections to said cathodes and to the positive supply line, said cathodes being connected directly to said negative supply line and said voltage dividers each having a tap connected to a respective control electrode for establishing a positive bias on said control electrode.

10. A cold cathode gas tube circuit in accordance with claim 9 including a common signal applying means connected to said tubes and effective to increase the voltage difference between the anode and control electrode of the tube to be fired.

11. A cold cathode gas tube circuit in accordance with claim 9 including separate capacitors connected together and to the respective control electrodes of said tubes for concurrently impressing firing pulses on said control electrodes.

12. A cold cathode gas tube circuit including a gas tube having a cold cathode, an anode, and a control grid sensitized so as to make it electron emissive as a cold cathode, a resistive voltage divider connected between said anode and said cathode, a tap in said voltage divider affording a bias connection for a further tube and an input grid bias voltage divider connected between the cathode thereof and a point of positive potential, said input voltage divider having a signal input coupling capacitor for applying negative pulses for firing the cold cathode tube.

13. A cold cathode gas tube circuit including multiple gas tubes each having a cold cathode, an anode, and a sensitized control grid, positive and negative power supply lines connected to said anodes and said cathodes including a common impedance element, a resistance-capacitance load between the anode of each tube and the positive supply line, a resistance voltage divider connected between each load and the negative terminal of the power supply, each voltage divider having a tap connected to the control grid of another of the tubes, said cathodes also being connected to the negative power supply line.

References Cited in the file of this patent

UNITED STATES PATENTS

2,125,073	Knowles	July 26, 1938
2,349,849	Deal	May 30, 1944
2,401,657	Mumma	June 4, 1946
2,422,583	Mumma	June 17, 1947
2,498,908	Baldinger	Feb. 28, 1950

FOREIGN PATENTS

584,422	Great Britain	Jan. 14, 1947