

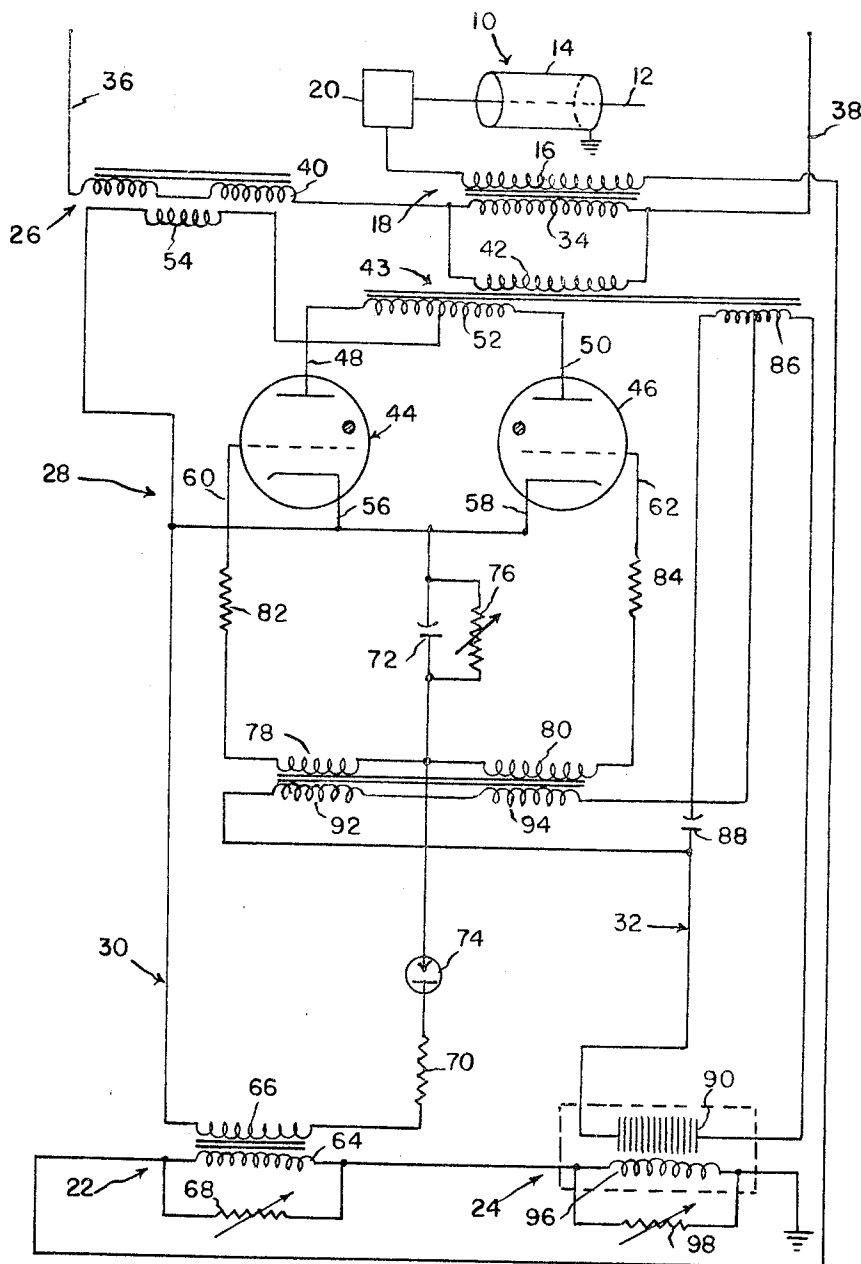
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AUTOMATIC CONTROL FOR FLY ASH PRECIPITATORS

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3,271,931 AUTOMATIC CONTROL FOR FLY ASH PRECIPITATORS

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This application is a continuation-in-part of application Serial No. 828,408, filed July 20, 1959, now abandoned.

The present invention relates to electrical precipitators and the like and refers more particularly to means for automatically controlling the operating characteristics thereof so that higher load currents can be maintained at desired sparking rates without overloading the precipitators.

In the past it has been practice to manually control precipitator sparking rate and current during operation of precipitators for the removal of fine solid particles or impurities from combustion or other impure gases. Using manual control of precipitator units it has been found that overloading of the precipitator units and resultant undesirable trip-outs thereof occur reducing the efficiency of the precipitators.

Therefore it is a purpose of the present invention to provide automatic means for improved control of the sparking rate and the maximum direct current load of precipitator units.

Another object is to provide automatic means for control of precipitator operating characteristics to permit operation of precipitators at maximum efficiency without overloading of the precipitators and resultant trip-outs thereof.

Another object is to provide automatic means for control of precipitator operating characteristics including a precipitator high voltage transformer, thyatron control for a saturable reactor operable to reduce the voltage across the primary winding of the precipitator high voltage transformer on occurrence of precipitator power arcs effective to reduce the arc time of the individual power arcs.

Another object is to provide direct current control bias for a thyatron control of a saturable reactor controlled precipitator which is proportional to sparking rate of the precipitator.

Another object is to provide an alternating current control bias for a thyatron control of a saturable reactor controlled precipitator which is phase adjusted by a carbon pile regulator to limit the amount of direct current to the precipitator.

Still more specifically it is a purpose to provide a precipitator including a precipitator high voltage transformer responsive thyatron controlling a saturable reactor operable to reduce the voltage across the primary winding of the precipitator high voltage transformer on precipitator power arcing to shorten the individual power arcs, said thyatron having a direct current bias proportional to sparking rate of the precipitator and an alternating current bias which is automatically phase adjusted by a carbon pile regulator to limit the direct current to the precipitator whereby the operating characteristics of the precipitator are automatically controlled to permit operation of the precipitator at maximum efficiency thereof without overloading and resultant trip-outs.

Another object is to provide automatic means for control of precipitator operating characteristics as indicated above which is simple in operation, economical to produce, and efficient in operation.

These and other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawing, illustrating a preferred embodiment of the invention, wherein:

The figure is a schematic representation of the automatic precipitator control of the invention.

With particular reference to the drawing, one embodiment of the precipitator control of the invention will now be described.

The precipitator control as shown in the drawing is connected to the well known type of precipitator generally indicated 10 wherein wires or plates 12 having a high charge thereon are placed in proximity with other wires or plates 14 which are connected to ground and both sets of wires or plates are placed in the path of flue gas or other gaseous material from which it is desired to precipitate small solid particles such as fly ash suspended therein. The action of the precipitator causes the suspended particles in the gas to contact the grounded members 14 as they pass between members 12 and 14 and to be collected on the grounded members of the precipitator from whence they are periodically removed. As shown in the figure a high voltage is placed on the charged portion 12 of the precipitator by means of the secondary winding 16 of a high voltage transformer generally indicated 18 in series with a high voltage rectifier 20, direct current transformer 22 and the carbon pile current regulator 24.

As is well known with such precipitators the maximum efficiency is obtained therefrom when an optimum sparking rate between members such as 12 and 14 is maintained or with rated current flow through the precipitator when sparking is low and with power arcs between the members 12 and 14 limited. In accordance with the present invention automatic control means are provided to insure an optimum sparking rate or to maintain a maximum load current and to limit individual power arcs. This control means includes the saturable reactor generally indicated 26 controlled by the thyatron rectifier generally indicated 28 having a plate supply transformer 43 responsive to precipitator power arcs, a direct current bias circuit generally indicated 30 responsive to precipitator spark rate and an alternating current bias circuit generally indicated 32 responsive to precipitator current associated therewith.

The saturable reactor 26 acts to limit the voltage drop across the primary winding 34 of the high voltage transformer 18 on sparking or arcing of the precipitator. The direct current bias circuit indirectly controls the spark rate of the precipitator 10 by applying a direct current bias proportional to the spark rate of the precipitator to the thyatron rectifier 28 which in turn regulates the alternating current impedance of the saturable reactor 26 and determines the voltage drop across the winding 34 of transformer 18 to control the potential difference between members 12 and 14 and the spark rate therebetween. Similarly the alternating current bias circuit 32 acts as a current regulator for the precipitator 10 by controlling the alternating current impedance of the saturable reactor by means of varying the bias on the thyatron rectifier 28 in accordance with current flow through the current regulator 24, thus allowing a maximum average current flow in the precipitator circuit without overloads which would result in operation of precipitator protection devices. On a power arc occurring between the members 12 and 14 the primary winding 42 of the plate supply transformer 43 is effectively short circuited and the plate voltage on the thyatron rectifier 28 is reduced to shorten the length of individual power arcs through the combined action of the rectifier 28 and the saturable reactor 26.

More specifically the high voltage transformer 18 is supplied with power by means of 480 volt alternating current electrical energy connected to the primary winding 34 thereof over conductors 36 and 38 from any convenient power source. The alternating current winding 40 of the saturable reactor 26 as shown is connected in series with the primary winding of the high voltage transformer. It will also be noted that the primary winding 42 of plate supply transformer 43 which functions to supply plate voltage to thyatron rectifier 28 is connected in parallel with the primary winding 34 of the high voltage transformer 18.

The thyatron rectifier 28 includes the thyatron tubes 44 and 46 having their plates 48 and 50 connected together through the secondary winding 52 of the plate supply transformer 43. The secondary winding 52 of the plate supply transformer is center tapped and connected to one end of the direct current winding 54 of the saturable reactor 26 as shown. The other end of the direct current winding 54 of the saturable reactor is connected directly to the cathodes 56 and 58 of both rectifier tubes 44 and 46. Thus it is seen that the rectifier circuit is completed through one of the thyatron tubes 44 and 46, one-half of the secondary winding 52 of the plate supply transformer and the direct current winding 54 of the saturable reactor at any time a voltage is developed across the secondary winding 52 of the plate supply transformer 43.

In operation of the thyatron rectifier and the saturable reactor to limit the arc time of individual power arcs between members 12 and 14 of the precipitator 10 it will be understood that on arcing a high current is drawn through the high voltage transformer secondary winding 16 as is usual with such precipitators which substantially short circuits the high voltage transformer primary winding 34 and the plate supply transformer primary winding 42. The plate voltage of the thyatron tubes 44 and 46 will therefore be caused to drop sharply when arcing occurs due to a low voltage on the secondary winding 52 of the plate supply transformer with the primary winding thereof substantially shorted. The low plate voltage will cause the current through the rectifier circuit set forth above including the direct current winding 54 of the saturable reactor 26 to decrease whereupon the alternating current impedance of the saturable reactor will be caused to increase sharply causing less voltage drop across the primary winding of the high voltage transformer 34 and reducing the voltage applied to the precipitator to cause the arcing to cease whereby normal operation of the precipitator is resumed. Thus the saturable reactor substantially extinguishes the individual power arcs of the precipitator 10.

As previously indicated a direct current bias is applied through the direct current bias circuit 30 between the cathodes 56 and 58 and the grids 60 and 62 of the thyatron rectifier tubes which is proportional to the spark rate of the precipitator 10. Thus as the spark rate of the precipitator 10 increases causing more current surges in the precipitator circuit a direct current bias is applied to the grids 60 and 62 of the thyatron tubes 44 and 46 to cause the conduction thereof to lessen whereby the alternating current impedance of the saturable reactor is increased to lower the voltage drop across the high voltage transformer 18 whereby the spark rate is caused to decrease.

The direct current bias circuit 30 includes the direct current transformer 22 having a primary winding 64 and a secondary winding 66, a variable resistor 68 in parallel with the primary winding of direct current transformer 22, a resistor 70 in series with the secondary winding of the direct current transformer 22, a capacitor 72, and a silicon rectifier 74 as shown in the figure. The circuit 30 further includes a variable resistor 76 in parallel with capacitor 72 and connections as shown to the cathodes 56 and 58 of the thyatron tubes from one

side of the capacitor 72 and a connection through transformer secondary windings 78 and 80 and resistors 82 and 84 to the grids 60 and 62 of the thyatron tubes as shown.

In operation as sparking occurs in the precipitator 10 a pulsating direct current will flow through the primary winding 64 of the transformer 22 to develop a voltage thereacross the magnitude of which may be varied by the setting of the variable resistor 68. The voltage developed in the primary winding 64 is impressed on the secondary winding 66 of transformer 22 and causes a pulsating direct current voltage to be present across the resistor 70, silicon diode 74 and capacitor 72, all in series. Resistor 70 is a current limiter, diode 74 acts as a check valve, condenser 72 stores energy proportional to sparking rate while resistor 76 governs the response time of direct current bias circuit 30.

As indicated the direct current signal developed in the rectifier circuit just described is applied between the cathodes 56 and 58 and the grids 60 and 62 of the thyatrons to cause conduction thereof to increase or decrease depending on whether the spark rate of the precipitator 10 is respectively below or above the desired spark rate thereof. Thus as previously indicated an increase in the spark rate of the precipitator over that which is desirable will cause the direct current bias on the grids 60 and 62 to cause a lesser current flow through the thyatron tubes to decrease the direct current flow in the winding 54 of the saturable reactor which will increase the alternating current impedance of the saturable reactor causing less voltage across the high voltage transformer primary winding 34 decreasing the spark rate of the precipitator.

The direct current flow through the precipitator circuit is regulated by the circuit 32 acting to vary the alternating current bias on the thyatron rectifier 28 to change the reactance of the saturable reactor 26. The bias circuit 32 includes a secondary winding 86 associated with the primary winding 42 of the plate supply transformer 43 as illustrated one end of which is connected through a capacitor 88 to one end of the carbon pile 90 of the carbon pile current regulator 24. The other side of the winding 86 is connected directly to the other side of the carbon pile 90. The secondary winding 86 is center tapped and has connected thereto one end of a pair of bias transformer primary windings 92 and 94 in series. The other end of the series connected windings 92 and 94 is connected between the capacitor 88 and said one end of carbon pile 90 as shown.

In operation as the direct current through the precipitator circuit increases, the current through the winding 96 of the current regulator 24, the magnitude of which may be set by the variable resistor 98, will also increase whereby the resistance of the carbon pile 90 of the current regulator is caused to vary in the well known manner. Varying of the resistance of carbon pile 90 in the bias circuit 32 described causes a change in the phase of the alternating signal impressed across the secondary winding 86 of the plate supply transformer as felt on the primary windings 92 and 94 of the alternating current bias transformers of the thyatron tubes. Varying the phase of the alternating current bias in the correct direction with respect to the phase of the plate voltage of the thyatron tubes so that the bias applied to the tubes will allow the tubes to conduct less will increase the alternating current impedance of the saturable reactor 26 in the manner previously indicated to reduce the voltage felt across the primary winding 34 of the high voltage transformer whereupon the direct current through the precipitator circuit is decreased as desired.

In over-all operation of the automatic precipitator control of the invention it can therefore be seen that as power arcs occur within the precipitator 10 and the high voltage transformer 18 and the plate supply transformer 43 are substantially short circuited, the current through the

thyatron tubes 44 and 46 will be substantially reduced through the lowering of the plate voltage thereof resulting in a diminished direct current flow through the saturable reactor 26 causing the alternating current impedance of the saturable reactor to increase further reducing the voltage drop across the primary winding 34 of the high voltage transformer which reduces the voltage of the precipitator to limit the arc time of the individually occurring power arcs. Thus the arcing time of the precipitator is greatly reduced.

At the same time the direct current bias applied to the thyatron tubes 44 and 46 which is developed from the pulsating direct current signal across the direct current transformer 64 in the circuit including the capacitor 72 and the diode 74 and which is proportional to the sparking rate of the precipitator since the winding 64 of the transformer 22 is in the precipitator direct current circuit and which is applied to the control grids of the thyatron tubes 44 and 46 will cause the thyatron tubes 44 and 46 to conduct in a manner to vary the reactance of the saturable reactor 26 so that the voltage across the primary 34 of the high voltage transformer 18 is such as to produce proper voltage in the secondary winding 16 of the high voltage transformer 18 to maintain a desired spark rate of the precipitator 10 which may variably be determined according to the individual installation.

Furthermore, the alternating current bias circuit is concurrently operative in accordance with the direct current flowing in the precipitator circuit and more particularly through the coil 96 therein which regulates the resistance of the carbon pile 90, and acts to vary the phase of the alternating current bias fed to the grids of the thyatron rectifier 28 through the alternating current bias transformer primaries 92 and 94 to again vary the current output of the thyatron rectifier 28, the reactance of the saturable reactor 26 and the voltage dropped across the high voltage transformer to maintain a regulated and variably determinable direct current flow through the precipitator 10 when the sparking rate is low.

Thus it will be seen that applicant has provided a control circuit for an electrical precipitator including three separate control features each of which backs up the other features to provide smooth and trouble free operation of the precipitator at an optimum sparking rate and maximum current flow with limited individual power arcs. In an actual installation it has been found that the precipitator control described herein using a tube rectifier allows operation of precipitators at three times the current load possible with previously used manual adjustment of the precipitators and at an optimum spark rate. With the use of mechanical rectifiers the automatic control herein disclosed is capable of regulating a precipitator at twice the maximum current possible with manual adjustment thereof and at an optimum spark rate.

The drawing and the foregoing specification constitute a description of improved automatic control for fly ash precipitators in such full, clear, concise and exact terms as to enable any person skilled in the art to practice the invention, the scope of which is indicated by the appended claims.

What I claim as my invention is:

1. An automatic control for an electrical precipitator comprising first means operatively associated with said precipitator responsive to power arcs in said precipitator for automatically decreasing the voltage applied thereto to shorten the arc time of each individually occurring power arc, including a precipitator high voltage transformer having a primary and a secondary winding for supplying voltages to said precipitator, a saturable reactor having a field winding connected in series with the primary winding of said transformer, a thyatron rectifier including plate and output circuits, a thyatron plate voltage transformer having a secondary winding in the plate circuit of the thyatron rectifier and a primary winding in parallel with the primary winding of the precipitator high

voltage transformer and a control winding for said saturable reactor connected in the output circuit of the thyatron rectifier, second means separate from said first means connected in the precipitator circuit in combination with said first means responsive to the rate of sparking of said precipitator for automatically varying the voltage applied to the precipitator conjointly with said first means in a direction to maintain an optimum precipitator sparking rate, and third means separate from said first and second means also connected in the precipitator circuit in combination with said first and second means responsive to precipitator current for automatically varying the voltage applied to the precipitator conjointly with said first and second means in a direction to maintain a maximum current in the precipitator circuit.

2. An automatic control for an electrical precipitator comprising first means operatively associated with said precipitator responsive to power arcs in said precipitator for automatically decreasing the voltage applied thereto to shorten the arc time of each individually occurring power arc, second means separate from said first means connected in the precipitator circuit in combination with said first means responsive to the rate of sparking of said precipitator for automatically varying the voltage applied to the precipitator conjointly with said first means in a direction to maintain an optimum precipitator sparking rate including in series in the precipitator circuit the coil of a carbon pile current regulator, a direct current transformer and the secondary winding of a precipitator high voltage transformer having primary and secondary windings, a saturable reactor and the primary winding of the precipitator high voltage transformer connected in series in a voltage supplying circuit, a thyatron rectifier having plate, cathode and output circuits, a thyatron plate voltage transformer having a secondary winding in the plate circuit of the thyatron rectifier and a primary winding in parallel with the primary winding of the precipitator high voltage transformer, a control winding for said saturable reactor in the thyatron rectifier output circuit and means for developing a bias on the thyatron rectifier in accordance with the pulse rate of current flow through the precipitator circuit including a secondary winding of said direct current transformer, a rectifier and a parallel combination of capacitor and resistor connected in series in the cathode circuit of the thyatron rectifier, and third means separate from said first and second means also connected in the precipitator circuit in combination with said first and second means responsive to precipitator current for automatically varying the voltage applied to the precipitator conjointly with said first and second means in a direction to maintain a maximum current in the precipitator circuit.

3. An automatic control for an electrical precipitator comprising first means operatively associated with said precipitator responsive to power arcs in said precipitator for automatically decreasing the voltage applied thereto to shorten the arc time of each individually occurring power arc, second means separate from said first means connected in the precipitator circuit in combination with said first means responsive to the rate of sparking of said precipitator for automatically varying the voltage applied to the precipitator conjointly with said first means in a direction to maintain an optimum precipitator sparking rate, and third means separate from said first and second means also connected in the precipitator circuit in combination with said first and second means responsive to precipitator current for automatically varying the voltage applied to the precipitator conjointly with said first and second means in a direction to maintain a maximum current in the precipitator circuit, including a precipitator high voltage transformer having primary and secondary windings, a power supplying circuit including the primary winding of the high voltage transformer and a saturable reactor field winding in series, a thyatron rectifier including a plate, grid and an output circuit, a thyatron

plate voltage transformer having a secondary winding in said plate circuit and a primary winding in parallel with the high voltage transformer primary winding, a control winding for said saturable reactor in the output circuit of said thyatron rectifier and a phase shift circuit including another secondary transformer winding coupled to the high voltage transformer primary winding and a capacitor in series transformer coupled to said grid circuit for biasing said thyatron rectifier in response to current surges in said precipitator to vary the current through the control winding of the saturable reactor.

4. An electrical precipitator including a voltage supplying transformer having secondary and primary windings, a direct current transformer having primary and secondary windings, a carbon pile current regulator having a coil and a carbon pile portion, a pair of biasing transformers having primary and secondary windings and a saturable reactor having field and control windings, comprising a series precipitator circuit including a discharge element, a rectifier, the secondary winding of the voltage supplying transformer, the primary winding of the direct current transformer and the coil of the carbon pile current regulator, a voltage supplying circuit including the field winding of the saturable reactor and the primary winding of the voltage supplying transformer connected in series, a rectifier circuit including cathode, plate, grid and output circuits, said plate circuit including a plate circuit transformer secondary winding coupled to the primary winding of said power supplying transformer, said output circuit including the control winding for the saturable reactor connected between the plate and cathode circuits of the rectifier, a direct current biasing circuit connected to the cathode circuit of the rectifier including the secondary winding of said direct current transformer and a rectifier connected in a series loop circuit with the cathode circuit of the rectifier and a phase shift circuit including a phase shift transformer secondary winding having a center tap coupled to the primary winding of the voltage supplying transformer, the carbon pile portion of the carbon pile current regulator and a capacitor connected in a series loop and the primary windings of said biasing transformers connected in series between the center tap of the phase shift transformer secondary winding and the junction of the carbon pile portion of the carbon pile current regulator and the capacitor and the biasing transformer secondary windings connected in series in the grid circuit of the rectifier and a connection therebetween to the direct current biasing circuit.

5. An electrical precipitator including a voltage supplying transformer having a secondary and first and second primary windings, a direct current transformer having primary and secondary windings, a carbon pile current regulator having a coil and a carbon pile portion, a pair of biasing transformers having primary and secondary windings and a saturable reactor having field and control windings, comprising a series precipitator circuit including a discharge element, a rectifier, the secondary wind-

ing of the voltage supplying transformer, the primary winding of the direct current transformer and the coil of the carbon pile current regulator, a voltage supplying circuit including the field winding of a saturable reactor and the first primary winding of the voltage supplying transformer connected in series, a thyatron full wave rectifier circuit including cathode, plate, grid and output circuits, said plate circuit including a plate circuit transformer secondary winding coupled to the second primary winding of said power supplying transformer, said output circuit including the control winding for the saturable reactor connected between the plate and cathode circuits of the thyatron rectifier, a direct current biasing circuit connected to the cathode circuit of the thyatron rectifier including the secondary winding of said direct current transformer, a rectifier and a parallel combination capacitor and resistor connected in a series loop circuit with the cathode circuit of the thyatron rectifier connected between the current transformer secondary winding and the capacitor and resistor combination and a phase shift circuit including a phase shift transformer secondary winding having a center tap coupled to the second primary winding of the voltage supplying transformer, the carbon pile portion of the carbon pile current regulator and a capacitor connected in a series loop and the primary windings of said biasing transformers connected in series between the center tap of the phase shift transformer secondary winding and the junction of the carbon pile portion of the carbon pile current regulator and the capacitor and the biasing transformer secondary windings connected in series in the grid circuit of the thyatron rectifier and a connection therebetween to the direct current biasing circuit between the rectifier and the capacitor and resistor combination.

References Cited by the Examiner

UNITED STATES PATENTS

2,549,782	4/1951	Engelman	55—105 X
2,672,947	3/1954	Klemperer	55—105 X
2,771,150	11/1956	Welts	55—105
2,798,571	7/1957	Schaelchlin et al.	55—105
2,881,855	4/1959	Klemperer	55—105
2,881,856	4/1959	Robinson et al.	55—105
2,897,914	8/1959	Camp et al.	55—105
2,907,403	10/1959	Foley	55—105
2,925,142	2/1960	Wasserman	55—105
2,961,577	11/1960	Thomas et al.	55—105
2,992,699	7/1961	Jarvinen	55—105
3,040,496	6/1962	Brown	55—105
3,147,094	9/1964	Hall et al.	55—139 X
3,166,705	1/1965	Brandt	55—105 X

FOREIGN PATENTS

749,832	6/1956	Great Britain.
769,880	3/1957	Great Britain.

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