

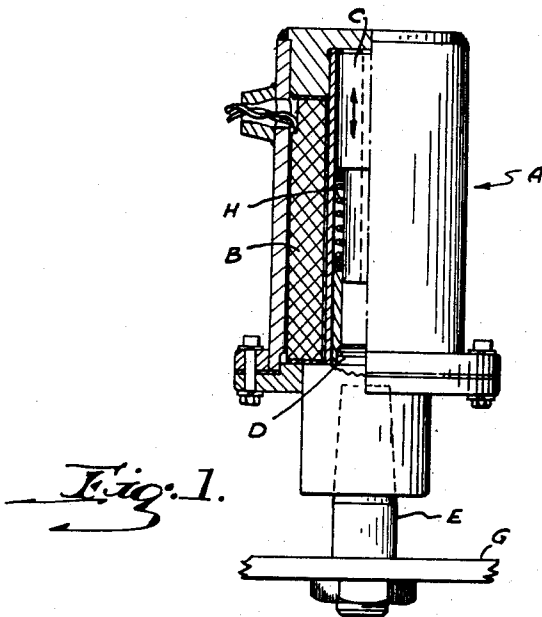
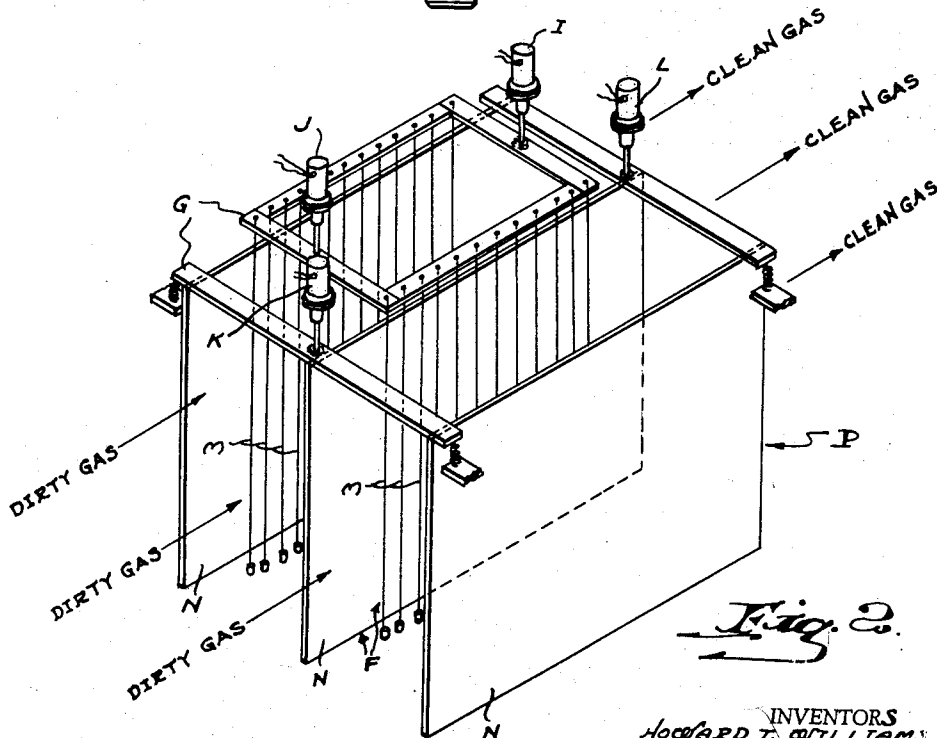
Jan. 19, 1960

J. W. DRENNING ET AL
ELECTRICAL PRECIPITATOR

2,922,085

Filed Sept. 5, 1958

3 Sheets-Sheet 1



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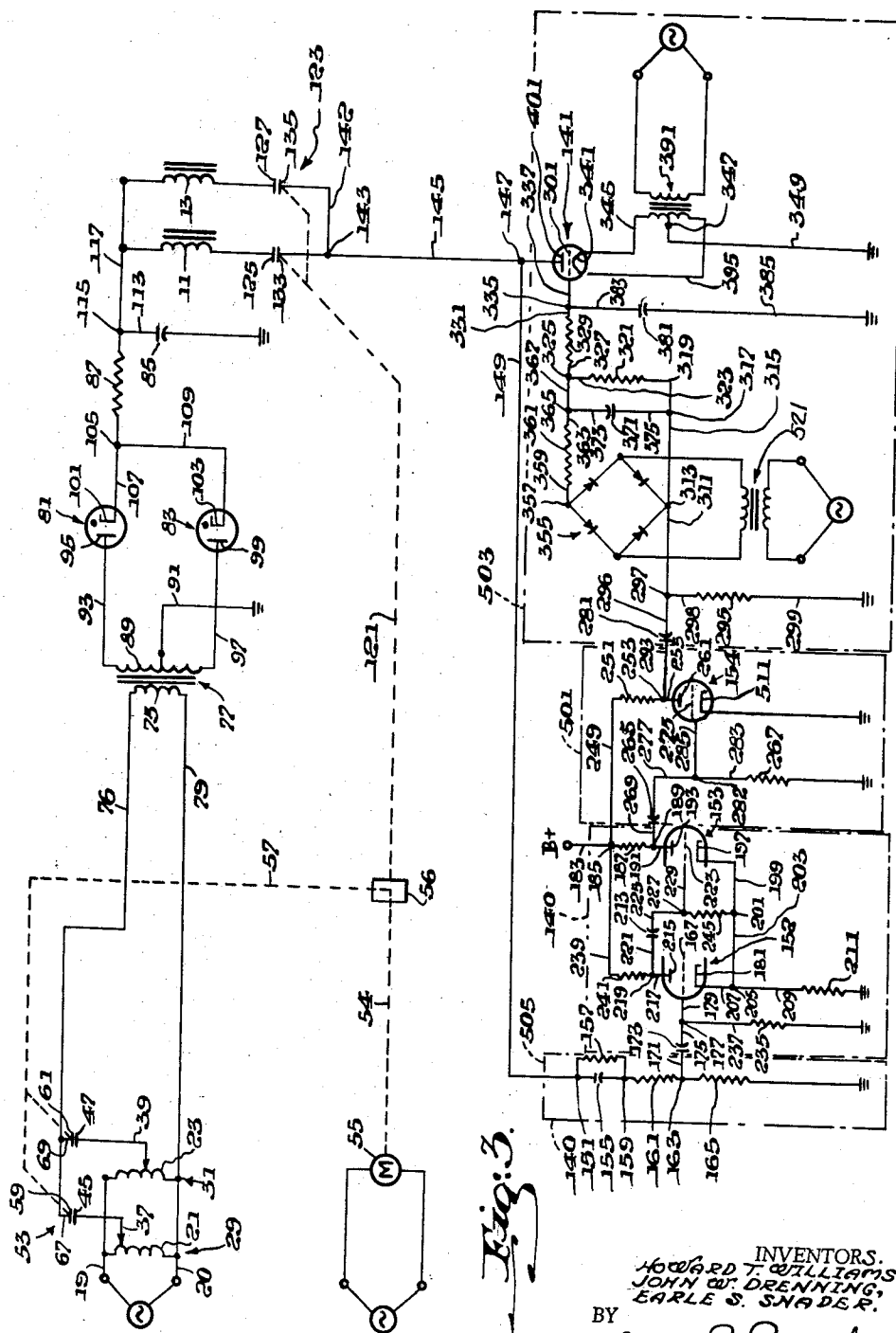
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ELECTRICAL PRECIPITATOR

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3 Sheets--Sheet 2



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ELECTRICAL PRECIPITATOR

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3 Sheets-Sheet 3

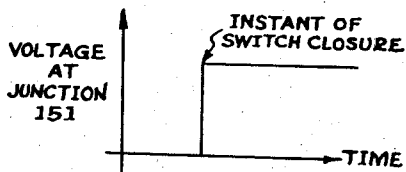


Fig. 4.

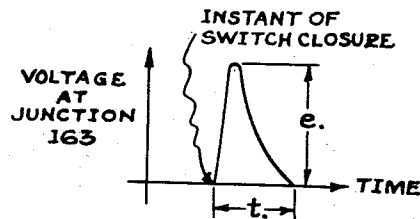


Fig. 5.

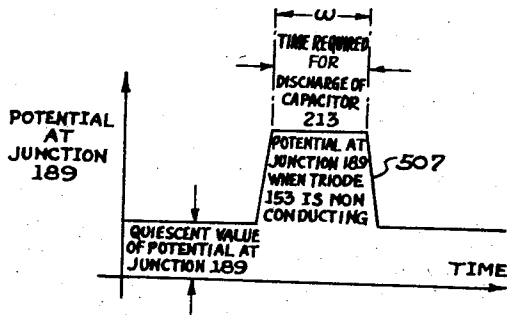


Fig. 6.

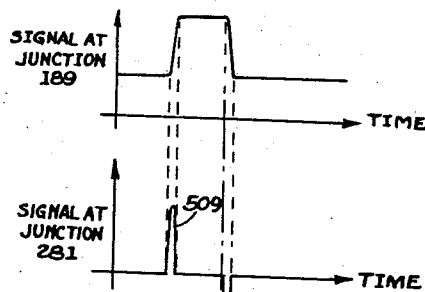


Fig. 7.

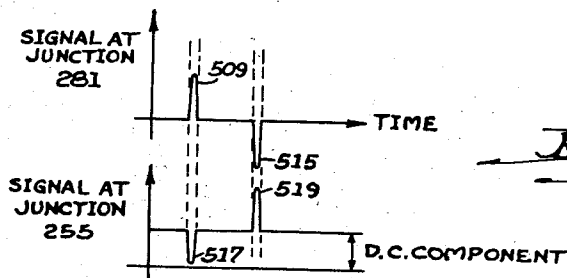


Fig. 8.

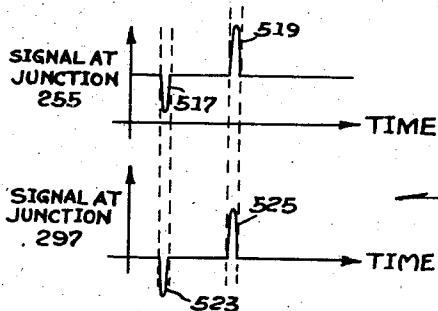


Fig. 9.

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ELECTRICAL PRECIPITATOR

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Application September 5, 1958, Serial No. 759,254

7 Claims. (Cl. 317-139)

This invention relates to electrical precipitators and more particularly to the actuating of electromagnetic rappers used to remove particles from electrodes in electrostatic precipitators.

Particles are conveniently removed from the collecting and discharge electrodes of electrostatic precipitators by sequentially imparting transient vibrations to the respective electrodes at predetermined intervals. Electromagnetic rappers, such as described in co-pending U.S. application No. 724,674 of John W. Drenning, filed March 28, 1958, are advantageously actuated for this purpose. These rappers are connected to the electrode assemblies by convenient mechanical means also described in Drenning supra.

To actuate these rappers, an electric current is caused to flow in the coil of the rapper. This current sets up a strong magnetic field within the rapper to accelerate downwardly a hammer which is spring supported at the rear of the rapper housing until the hammer strikes an anvil end of the rapper. This imparts the kinetic energy of the hammer which is determined by mass and final velocity of the hammer to the precipitator electrode structure via mechanical connecting means between the rapper and the electrode structure. This energy dissipates as a damped mechanical vibration of the electrodes which in turn dislodges the collected dust. When the coil is de-energized, the spring support returns the rapper hammer to its initial position whereby the coil can be re-energized to cause further actuation of the rapper to cause further vibrations in the electrodes.

Conventionally, a plurality of rappers is used; some of which operate at different energy levels. For example, the rappers connected to the discharge electrodes may operate at one energy level and those connected to the collecting electrodes may operate at different energy levels. The former energy level will usually require low energizing voltages while the latter will usually require voltages as high as 2500 volts D.C. or more. This presents the problem of supplying variable voltages.

For maximum efficiency, the rappers are energized in a sequence at predetermined intervals. This requires a switch that will provide the proper variable voltages sequentially at predetermined intervals. Conventional multiple timer switches have not been satisfactory heretofore for sequentially energizing the rappers attached to the collecting electrodes because such switches are rated at 115 and 220 volts and when the high voltage necessary for actuation of the rappers connected thereto is applied through such switches, the occurrence of arcing and burning of the contacts results in short contact life.

According to this invention, the coils of a plurality of electromagnetic rappers are energized by a control system which, through conventional switches supplies a variable voltage sequentially at predetermined intervals to the coils in a trouble-free manner that prevents arcing and burning of the switch contacts.

The above and further novel features of the invention will appear more fully from the following detailed de-

scription when the same is read in connection with the accompanying drawing. It is to be expressly understood, however, that the drawing is not intended as a definition of the invention but is for the purpose of illustration only.

Fig. 1 is a partial cross section and elevation of a rapper which is actuated by the control system of this invention.

Fig. 2 is a schematic drawing showing rappers of Fig. 1 mounted on collecting plates and discharge electrodes of an electrostatic precipitator.

Fig. 3 is a schematic view of the control of this invention for the rapper of Fig. 1.

Fig. 4 is a schematic diagram of voltage impressed on the pulse forming circuit of this invention.

Fig. 5 is a schematic diagram of a pulse formed by the pulse forming circuit of this invention.

Fig. 6 is a schematic diagram of a pulse produced by the multivibrator of this invention.

Fig. 7 is a schematic diagram of pulses produced by the capacitor of the inverter-amplifier-differentiator of this invention compared to the pulse of Fig. 6.

Fig. 8 is a schematic diagram of the pulse produced by the triode of the inverter-differentiator-amplifier of this invention compared to the pulse produced by the capacitor of the inverter-differentiator-amplifier of Fig. 7.

Fig. 9 is a schematic of the pulse produced by the resistance-capacitance series circuit of the thyatron firing circuit of this invention compared to the pulse produced by the triode of the inverter-differentiator-amplifier of Fig. 8.

Referring to Fig. 1, a rapper A corresponding to the rappers I, J, K, and L, shown in Fig. 2, is energized by the novel control system of this invention. This rapper has an electromagnetic coil B corresponding to the coils 11 and 13 of Fig. 3. Energization of the rapper coil accelerates downwardly a hammer C against an anvil D so as to transmit damped vibrations through a shaft E to the electrodes F (Fig. 2) suspended from supporting cross bar G. Spring H returns hammer C to its initial position at the rear of the rapper after coil B is de-energized so that the coil can be re-energized to cause further vibrations in the electrodes.

Referring to Fig. 2, rappers I, J, K, and L are shown. These are the same kind of rappers as rapper A of Fig. 1. Rappers I and J are mounted on cross bar G connected to the discharge electrodes M of the electrostatic precipitator P which, as shown, has its shell removed. Rappers I and L are mounted on a cross bar like cross bar G connected to the collecting electrodes N. The material entrained in the dirty gas coming into the precipitator is deposited primarily on the collecting electrodes N, and the rapping energy required to remove the material deposited on the collecting electrodes is quite large. Sometimes material from the dirty gas is deposited on the discharge electrodes M but the deposits thereon are usually quite small. Usually the rapping energies required to remove the material deposited on the discharge electrodes is different from that required to remove particles from the collecting electrodes. Since the rapping energies are determined by the electrical energy supplied to the rapper coils B, variable voltages must be supplied to rapper coils depending on the location of the rappers on the discharge electrodes or on the collecting electrodes.

Referring now to Fig. 3, there is shown schematically a multiple intensity control which supplies variable voltages to a plurality of electromagnetic rapper coils 11 and 13. Leads 19 and 20 supply alternating current from a suitable source (not shown) to the windings 21 and 23 of variable autotransformers 29 and 31. Each autotransformer has a slider 37 and 39 connected to a first contact 45 and 47 of a multicontact-type switch 53 having second companion contacts 59 and 61. The engagement

of two of these first and second contacts of switch 53 supplies current through an appropriate lead 67 or 69 which are all connected by lead 76 to the primary winding 75 of a step-up transformer 77, and through lead 79 and lead 20 back to the energy source mentioned so as to complete a circuit which energizes primary winding 75 of transformer 77. Thus, closing of one pair of these first and second contacts supplies a predetermined voltage to transformer 77. For example, when slider 37 is set to deliver 115 volts from autotransformer 29, the engaging of contacts 45 and 59 supplies this output to winding 75 of step-up transformer 77 to develop a very high voltage which may be 5000 volts or more, at secondary winding 89 of the transformer 77.

The alternating current output from transformer 77 is fed to conventional mercury vapor diode tubes 81 and 83 which provide full wave rectification. To this end, the secondary winding 89 of transformer 77 has its center top grounded through lead 91 and its end terminal connected to mercury vapor rectifier diodes 81 and 83. Thus, when the anode 95 of diode 81 becomes positive in respect to the anode 99 of diode 83, diode 81 conducts from anode 95 to cathode 101; and when anode 99 becomes positive relative to anode 95, diode 83 conducts from anode 99 to cathode 103. This gives a pulsating direct current at junction 105 of the leads 107 and 109 which connect the cathodes of diodes 81 and 83.

Advantageously this high voltage pulsating direct current energy is stored for quick discharge to a rapper coil by means of a resistor-capacitor (R-C) series circuit comprising capacitor 85 and a resistor 87. The values of resistor 87 and capacitor 85 may be varied by one skilled in the art of electrical precipitators and R-C series circuits to the proper values to meet the conditions required in a particular precipitator. Thus, capacitor 85 is charged at a rate determined by resistor 87 every time two contacts of the electrical switch 53 are closed.

Discharging capacitor 85 through appropriate rapper coils, in a manner to be described hereinafter, has the advantage of supplying sufficient electrical energy to the rapper coils to meet the high energy levels needed while eliminating costly and bulky components which would be necessary to supply the necessary high energy levels directly from conventional electrical power supply sources. Furthermore, the above described system provides a multiple intensity control for supplying high as well as relatively low energy levels to rapper coils.

One end of resistor 87 is connected to junction 105 and the other end is connected with capacitor 85 through junction 115 and lead 113. One side of capacitor 85 is grounded and the other side connected to rapper coils 11 and 13 by means of lead 113, junction 115, and lead 117 and thence through a conventional multicontact-type switch 123, and an electronic switching circuit to ground.

Switch 123 has a shaft 121 to which are connected a plurality of contacts 125 and 127 so that, as the shaft rotates, the latter contacts engage respectively with companion contacts 133 and 135. Advantageously the rotation of shaft 121 is regulated so that two or more companion contacts of switch 123 engage and then disengage while two contacts of switch 53 are engaged. Thus, by means of motor 55, shaft 54, and gear box 56 which rotates shaft 57 of switch 53 as well as shaft 121 of switch 123, contacts 133 and 135 engage their companion contacts in switch 123 in timed relation with the engagement of the companion contacts of switch 53. This provides that several rapper coils can be energized from a single autotransformer. For example, rapper coils K and L may be energized from autotransformer 29 and rapper coils I and J may be energized from autotransformer 31.

Switch 123 is advantageously a commercially available switch rated at 115 or 220 volts. When discharging high voltage from capacitor 85 through one of the rapper coils mentioned directly through two contacts of switch 123,

there could occur arcing and burning of the contacts due to bouncing of the contacts when closing, which would cause short contact life. Such arcing and burning is prevented, in accordance with this invention, by a novel circuit including a pulse forming circuit 505, a multivibrator 140, an amplifier inverter differentiator 501 and a thyatron firing circuit 503, to be described hereinafter which discharges capacitor 85 through the contacts of the electrical switch 123 at a predetermined time, about 0.25 second after the engagement of the contacts of switch 123.

The pulse forming circuit 505 consists of resistors 157, 161, and 165 and capacitor 155. This pulse forming circuit obtains a signal from the energy stored in capacitor 85 through lead 117, a rapper coil 11 (for example), switch contacts 125 and 133, lead 145 and lead 149. This signal is in the form of a steep front voltage as illustrated in Fig. 4. Capacitor 155 will, therefore, become charged when switch contacts 125 and 133 are engaged. During charging of capacitor 155 current will flow through resistors 161 and 165 so that a signal having the characteristics illustrated in Fig. 5 appears at junction 163. The values of capacitor 155, resistors 161 and 165 are selected so as to obtain a value of t sub 1 in the order of 0.05 second and e sub 1 in the order of 80 volts and thereby to generate a signal which is sufficient to trigger the multivibrator 140. Resistor 157 is employed as a "bleeder resistor," the use of which will be apparent from the description to follow. The signal shown in Fig. 5 appears only once for each and every closing of two contacts in switch 123.

The multivibrator 140 is a "one-shot" type multivibrator including resistors 235, 211, 241, 245 and 187, capacitors 173 and 213 and triode tubes 152 and 153. This multivibrator 140 receives the signal from junction 163 of the pulse forming circuit 505, as previously described. A suitable source of direct current B+ (not shown) is supplied to the multivibrator tubes 152 and 163. Immediately before receiving the signal from the pulse forming circuit 505 the multivibrator 140 is in what is called a quiescent condition; that is, triode 153 is conducting current from B+ through resistor 187 through lead 199, junction 201, lead 203, junction 205, lead 209, resistor 211 to ground. Triode 152 is not conducting since the previously mentioned current flowing through resistor 211 creates a cathode bias voltage in that tube. The signal at junction 163 is applied to junction 177 through capacitor 173 and across resistor 235.

This signal is also applied to the grid 167 of triode 152 through lead 179 in such a manner as to overcome the cathode bias previously described thereby causing triode 152 to conduct current from B+ to resistor 241, junction 219, lead 217, lead 207, junction 205, lead 209, resistor 211 to ground. The potential drop across triode 152 is thereupon substantially decreased. Therefore, the charge on capacitor 213 must also be decreased. To this end, capacitor 213 must discharge through lead 221, junction 219, lead 217, triode 152, lead 207, junction 205, lead 203, junction 201, resistor 245, junction 227 and lead 225. Thus a current flows momentarily through resistor 245 from junction 201 to junction 227 causing the potential of the latter to become negative with respect to the former. Since the grid 223 of triode 153 is connected to junction 227 and the cathode 197 of triode 153 is connected to junction 201 the grid 223 will therefore become momentarily negative, thus causing tube 153 to cease conducting. The previously described cathode bias in triode 152 which was created by current from triode 153 and resistor 211 therefore no longer exists and triode 152 will continue to conduct even after the signal at junction 163 has terminated as shown in Fig. 5. Triode 153 remains non-conducting as long as the grid 223 is sufficiently negative with respect to cathode 197. This condition exists until the previously described potential across resistor 245 decreases sufficiently. This

will occur when capacitor 213 has nearly discharged. The time required for this to occur is determined primarily by the values of capacitor 213 and resistor 235. The larger the value of the product of resistance and capacitance the longer the time required to discharge capacitor 213. When capacitor 213 has been nearly discharged triode 153 will again conduct and triode 152 will cease to conduct.

While triode 153 is non-conducting the potential at junction 189 is relatively high. When triode 153 is conducting the potential at junction 189 is relatively low. The signal transformation at junction 189 during the action above described is best shown by the diagram of Fig. 6.

For each and every signal entering the multivibrator 140 from junction 163 a positive substantially rectangular pulse 507 (Fig. 6) is produced in the output junction 189. The width w of this pulse 507 is approximately determined by the product of the value of resistor 245 and capacitor 213 so that the width w is advantageously about 0.25 second.

The amplifier inverter differentiator circuit 501 includes capacitor 265, resistors 267 and 251 and triode 154. This amplifier inverter differentiator circuit receives the output from junction 189 of the multivibrator 140 in the form of the rectangular pulse 507. To this end rectangular pulse 507 is applied from junction 189 through lead 269, capacitor 265, lead 277, junction 282, lead 283 and resistor 267 to ground. The values of capacitor 265 and resistor 267 may be calculated so that the signal produced across resistor 267 is an approximation of the mathematical derivative of the rectangular pulse 507. This is described graphically by the diagram in Fig. 7. To this end the grid 275 of triode 154 is connected to junction 282 by lead 285 and therefore receives pulses 509 and 515 (Fig. 7). Pulse 509 causes grid 275 of triode 154 to go positive with respect to cathode 511 thereby causing current flow from B+ to increase through lead 249, resistor 251, lead 253, junction 255, triode 154 and lead 512 to ground. The potential of junction 255 will therefore decrease momentarily while pulse 509 is applied to grid 275. When pulse 515 is applied the reverse is true and the potential at junction 255 will increase. This action is best described by the diagram in Fig. 8. Thus, the pulses 509 and 515 are inverted by triode 154 and appear at junction 255 of the amplifier inverter differentiator circuit. Some amplification also takes place in triode 154 and, therefore, the magnitudes of pulses 517 and 519 are somewhat larger than pulses 509 and 515.

The thyatron firing circuit 503 includes resistors 295, 361, 321, and 329, capacitors 281, 371 and 381, transformers 521 and 391, full wave bridge rectifier 355 and thyatron tube 141. This thyatron firing circuit 503 receives the pulses 517 and 519 from junction 255 of the amplifier inverter differentiator 501 previously described. In the absence of pulses 517 and 519 (Fig. 8) the grid 301 of the thyatron 141 is maintained at a quiescent negative potential with respect to the cathode 341 thereof. To this end a bias is supplied to grid 301 by means including transformer 521, rectifier 355, resistors 361 and 321 and capacitor 371 thus, even though a large positive potential may be applied to the plate 401 of the thyatron 141, the thyatron 141 will not conduct.

Pulses 517 and 519 are received from junction 255 of the amplifier inverter differentiator 501 through capacitor 281 and appear across resistor 295 in modified form at junction 297 of the thyatron firing circuit 503 as shown diagrammatically in Fig. 9 in which pulse 523 corresponds to pulse 517 and pulse 525 corresponds to pulse 519.

Before pulse 523 occurs the potential at junction 297 is zero and no current flows through resistor 295, therefore, the bias voltage previously described is the only signal appearing at grid 301 of thyatron 141. When pulse 523 occurs junction 297 becomes momentarily nega-

tive and current flows from ground to lead 299, resistor 295, lead 298, junction 297, lead 296, capacitor 281, junction 255, resistor 251, lead 249 to B+. Therefore, the bias on the grid 301 becomes even more negative. This, however, does not affect the tube 141. It is understood that the occurrence of pulse 523 is coincidental with the closures of contacts in switch 123 thereby allowing potential to be applied to plate 401, thyatron 141 from capacitor 85 through junction 147 as previously described and that the thyatron will not conduct until the negative bias is removed from its grid.

Pulse 525 appears at junction 297 through capacitor 281 and being positive cancels out the quiescent negative bias on grid 301 thus causing the thyatron 141 to conduct current from capacitor 85 through junction 147, plate 401, cathode 341, leads 345 and 395, junction 347, lead 349 to ground thereby energizing a rapper coil.

The operation of this novel control system can best be described with relation to the energization of one rapper coil connected to the collecting electrodes. First motor 55 engages contacts 45 and 59. Autotransformer 29 is connected to a suitable alternating current supply (not shown) and may, depending upon the setting of wiper 37, supply any alternating voltage from 0 volts to 115 volts. Advantageously, therefore, this is a 115 volt, 60 cycles per second alternating current supply so that it may be set to deliver 115 volts to the primary winding 75 of transformer 77 which boosts this voltage to an output of approximately 5000 volts. Through rectifier tubes 81 and 83, this output is changed to a pulsating direct current of approximately 2500 volts and impressed on capacitor 85 through resistor 87 so that capacitor 85 becomes charged. The engagement of contact 125 with contact 133, however, supplies a signal to the junction 151 of the pulse forming circuit 505. The output pulse is applied through line 171 to the multivibrator 140. This causes a pulse to be supplied to grid 301 of thyatron 141 about 0.25 second after contacts 125 and 133 engage, and this pulse causes thyatron 141 to conduct to ground so that capacitor 85 is discharged through rapper coil 11. The energization of coil 11 actuates a hammer (see Fig. 1) to cause transient vibrations in a collecting electrode on the inlet field and the magnitude of these vibrations is governed by the voltage supplied to the rapper coil. The values of resistor 87 are selected so that the discharge of capacitor 85 through rapper coil 11, which has inductance, will be oscillatory, that is, current will attempt to reverse. The elapsed time between the commencement of this discharge and the attempted current reversal is large compared to the duration of the firing pulse 525. Therefore, at the time when current tries to reverse. The elapsed time between the commencement of this quiescent negative condition. Therefore, since tube 141 cannot conduct current in the reverse direction, current ceases to flow and capacitor 85 will begin to recharge even though contacts 115 and 133 are still closed. Thus, these contacts are not required to interrupt current thereby further protecting them from burning and splitting. Thus the spring (see spring H, Fig. 1) in the rapper causes the return to the top of the rapper of the rapper hammer (see hammer C, Fig. 1) associated with rapper coil 11 to a position whereby re-energization of the coil will cause further actuation of the rapper to cause further vibrations to the precipitator electrodes associated with the rapper, for example, rapper K. Motor 55 then rotates shaft 121 so that contact 125 disengages contact 133 and contacts 45 and 59 remain closed until other contacts (not shown) in switch 123 close to actuate other coils in rappers connected to the collecting electrodes, for example, rapper L (Fig. 2).

After all the rappers on the collecting electrodes are actuated, then contacts 45 and 59 open and contacts 47 and 61 close. Then contacts 127 and 135 engage and disengage. Thus, coil 13, corresponding to rapper I (Fig. 2), is energized and then de-energized in the same manner.

as coil 11, described above, so that capacitor 85 is discharged through coil 13 about 0.25 second after contacts 127 and 135 engage. Other contacts (not shown) may be engaged in switch 123 to energize other coils in other rappers on the discharge electrodes for example, rapper J. After all the rappers on the collecting electrodes are actuated, then contacts 47 and 61 disengage.

It is understood that the voltage for energization of coil 13 may be different than for coil 11. Therefore, slider 39 is set accordingly.

In summary of the above operation, motor 55 is energized from a suitable source (not shown) to rotate shaft 54 which simultaneously rotates the contacts of switches 53 and 123. Thus, after two first contacts of switch 53 close to supply energy to capacitor 85 determined by the setting on a first cooperating autotransformer, two or more cooperating contacts of switch 123 engage and then disengage to supply electrical energy from capacitor 85 to one or more rapper coils. Before this energy is discharged from capacitor 85 to these rapper coils, however, a signal is supplied from the capacitor 85 to the one-shot multivibrator circuit described, so that the energy in capacitor 85 is discharged to ground through a rapper coil connected to the respective contacts of switch 123 which are closed approximately 0.25 second before capacitor 85 is discharged. First contacts of switch 53 remained engaged and while these first contacts are engaged another set of contacts of switch 123 engage and then disengage. This energizes other rapper coils attached to the collecting electrodes at voltages determined by the setting on the autotransformer 29. The latter is true because the energy contained in capacitor 85 is determined by the voltage applied to capacitor 85 and this in turn determines the voltage applied to energize a rapper coil. Then contacts 45 and 59 disengage and other contacts of switch 123 engage and disengage in like manner to energize one or more rappers attached to the discharge electrodes.

It is understood that the number of rapper coils that can be energized by this novel invention is only limited by the number of contacts in switches 123 and the number of different rapping intensities that can be utilized is limited only by the number of contacts in switch 53.

Also, since the time interval between the closing of any two contacts of switch 123 determines the time interval between energization of any rapper coil connected thereto, it is understood, therefore, that by changing the speed of the connecting shaft 121 from motor 55 to switch 123, the time interval between energization of any one rapper coil can be changed. Moreover, the time interval of closing of the contacts in switch 53 can be changed.

By using this control, momentary pulses of variable constant high energy may be supplied from conventional power sources. Furthermore, tests have shown that this novel control can be used with conventional electrical switches such as a multicontact piano-type switch for long periods of time without any arcing or burning of the contacts thereof.

What is claimed is:

1. Apparatus for preventing the arcing and burning of first and second contacts of an electrical switch which are engageable to conduct high voltage electricity comprising a source of high voltage electricity connected to said first contact, a thyatron having a grid for selectively causing said thyatron to be conductive and non-conducting, said thyatron being connected to said second contact so that said thyatron is capable of selectively discharging and blocking the discharge of high voltage from said high voltage source across said contacts when said first and second contacts are engaged, means for supplying a negative grid bias to the grid of said thyatron so that said thyatron is normally prevented from conducting high voltage from across said first and second contacts, and control means connected in par-

allel with said thyatron to said second contact and cooperating with said thyatron to cause said negative bias to be removed from said grid of said thyatron so that said thyatron conducts high voltage from across said first and second contacts about 0.25 of a second after said first and second contacts engage comprising a pulse forming circuit including a first resistance-capacitance series circuit responsive to said high voltage source by the engagement of said first and second contacts to form a single first pulse of a small predetermined voltage, means responsive to said first pulse including a one-shot multivibrator for producing a second rectangular shaped pulse of small voltage about 0.25 second after said first pulse is formed, means including a triode for changing said second pulse into a sequential short third negative pulse and a fourth positive pulse of predetermined values in that order and supplying them to the grid of said thyatron so that said fourth pulse removes the negative bias on the grid of said thyatron whereby said thyatron is made conductive to high voltage from across said first and second contacts after about 0.25 of a second from the time said first and second contacts engage and whereby said first and second contacts may be firmly engaged before high voltage is discharged across said first and second contacts thereby preventing burning and arcing of said first and second contacts.

2. In an electrical precipitator apparatus for energizing the magnetic rapper coils of electromagnetic rappers mounted on the electrodes of said precipitator comprising means for producing a predetermined high voltage including an alternating electrical energy source and means having a plurality of autotransformers for supplying predetermined variable constant voltages from said electrical energy source, means for supplying said predetermined variable constant voltages from said autotransformers in a predetermined sequence including a first multicontact switch having first engageable contacts connected to said plurality of autotransformers, means for stepping up said predetermined variable constant voltage including a step-up transformer for boosting said predetermined variable constant voltage supplied from said first multicontact switch, means connected to said step-up transformer for supplying predetermined boosted direct variable constant voltage from said step-up transformer, first resistance-capacitance series circuit for storing said predetermined boosted direct variable constant voltages supplied thereto from said rectifying means, means for distributing said predetermined boosted direct constant voltages from said first resistance-capacitance series circuit to predetermined electromagnetic rapper coils including a second multicontact switch having contacts which engage to selectively cause said predetermined boosted direct variable constant voltage stored in said first resistance-capacitance series circuit to be discharged to ground through various of said electromagnetic coils, coordinating means for closing said first contacts of said first multicontact switch and said second contacts of said multicontact switch in timed relation at predetermined times so that various predetermined boosted direct constant variable voltages are supplied from said first resistance-capacitance series circuit through predetermined electromagnetic coils at predetermined times in a predetermined sequence, and means for delaying the discharge of said predetermined boosted direct variable constant voltage across said contacts including a thyatron interposed between said second multicontact switch and ground having a grid for selectively causing said thyatron to be conductive and non-conductive so that said thyatron is capable of selectively discharging and blocking the discharge of the predetermined boosted direct variable constant voltages stored in said first resistance-capacitance series circuit, means for supplying a negative grid bias to the grid of said thyatron so that said thyatron is normally prevented from conducting, and control

means connected in parallel with said thyatron to the contacts of said second multicontact switch and cooperating with said thyatron to cause said negative bias to be removed from said grid of said thyatron so that said thyatron conducts 0.25 of a second after the second contacts of said second multicontact switch are made conductive including a pulse forming circuit having a second resistance-capacitance series circuit which produces a single first pulse of small predetermined voltage, means actuated by said first pulse including a one-shot multivibrator for producing a rectangular shaped pulse of small voltage about 0.25 second after said first pulse is formed, means including a triode for changing said second pulse into a sequential short third negative pulse and a fourth positive pulse of predetermined values in that order and supplying them to the grid of said thyatron so that said fourth pulse removes the negative bias on the grid of said thyatron whereby said thyatron is made conductive to said predetermined boosted direct constant variable voltages stored in said resistance-capacitance series circuit whereby said second contacts are firmly engaged and then said predetermined boosted direct constant variable voltage is discharged from said first resistance-capacitance series across said second contacts to ground through predetermined magnetic rapper coils at predetermined times in a predetermined sequence.

3. In an electrostatic precipitator having electromagnetic rappers with coils, the combination comprising an electrical energy source, means interposed between said electrical energy source and said coil for storing large quantities of electrical energy, switch means for periodically conducting said large quantities of electrical energy through said coils, means for discharging said electrical energy through said coil, said switch means being operative when said contact means are conductive for supplying a portion of the electrical energy in said storage means to develop a signal, and means responsive to said signal for delaying for a predetermined time the discharge of large quantities of electrical energy from said storage means when said contact means are conductive thereby to prevent damage to said contact means due to the sudden discharge of said large quantities of electrical energy flowing thereto.

4. The invention as defined in claim 3 in which said electrical energy storage means comprises a condenser.

5. The invention as defined in claim 3 in which said electrical energy storage means comprises a condenser and said discharge means comprises a thyatron.

6. In an electrostatic precipitator having electromagnetic rappers with coils, the combination comprising a direct current electrical energy source, a condenser in-

terposed between said electrical energy source and said coil for storing large quantities of electrical energy, switch means for periodically conducting said large quantities of energy through said coils, means for discharging said electrical energy through said coil including a thyatron, said switch means being operative when said contact means are conductive for supplying a portion of the electrical energy in said condenser to develop a signal, and means including a multivibrator responsive to said signal for delaying for a predetermined time the discharge of said large quantities of electrical energy from said condenser when said contact means are conductive thereby to prevent damage to said switch means due to the sudden discharge of said large quantities of electrical energy flowing thereto.

7. In an electrostatic precipitator having a plurality of electromagnetic rappers with coils, the combination comprising a plurality of alternating current electrical energy sources of which each source is at a different level of electrical energy, a rectifier for converting said alternating current into direct current, an electrical energy storage device disposed between said electrical energy source and said coils, switch means including first contact means to connect selectively one of said sources of electrical energy with said rectifier, means for discharging said electrical energy through said coils, said switch means also including second contact means operative in timed relation with said first contact means to selectively connect at least one of said coils with said rectifier, means operative when said second contact means are conductive for supplying a portion of the electrical energy in said storage means across said second contact means to develop a signal, and means responsive to said signal and operatively associated with said discharge means for delaying for a predetermined time the discharge of large quantities of electrical energy from said storage means when said second contact means are conductive thereby to prevent damage to said second contact means due to the sudden discharge of said large quantities of electrical energy flowing thereto.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,922,085

January 19, 1960

John W. Drenning et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 37, for "163" read -- 153 --; column 6, line 48, for "slapsed" read -- elapsed --; line 52, for "reverse. The elapsed time between the commence-" read -- reverse in the tube 141, the grid 301 has returned to --.

Signed and sealed this 28th day of June 1960.

(SEAL)

Attest:

KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON
Commissioner of Patents

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