

March 23, 1954

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VOLTAGE CONTROL IN PRECIPITATORS

Filed May 3, 1951

3 Sheets-Sheet 1

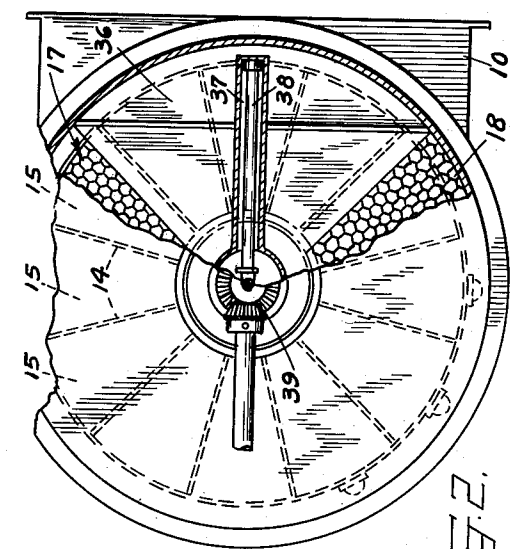


Fig. 2.

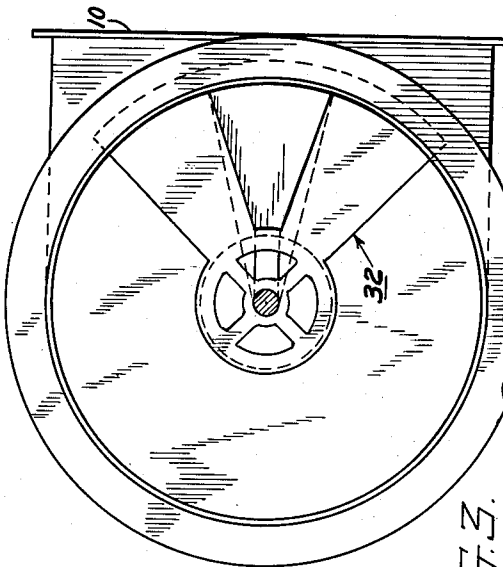


Fig. 3.

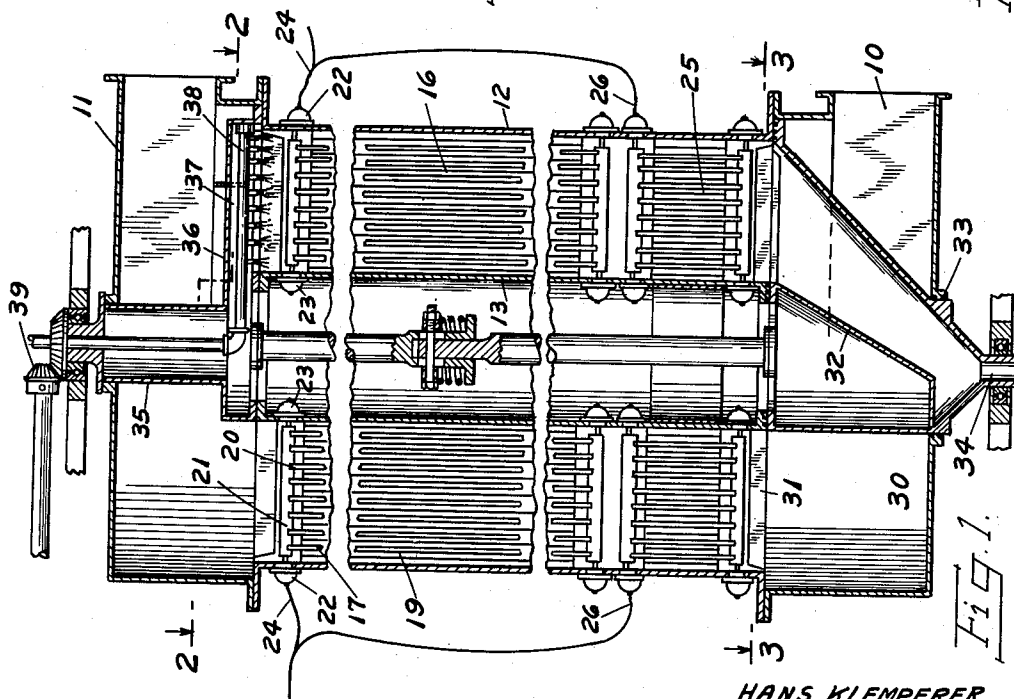


Fig. 1.

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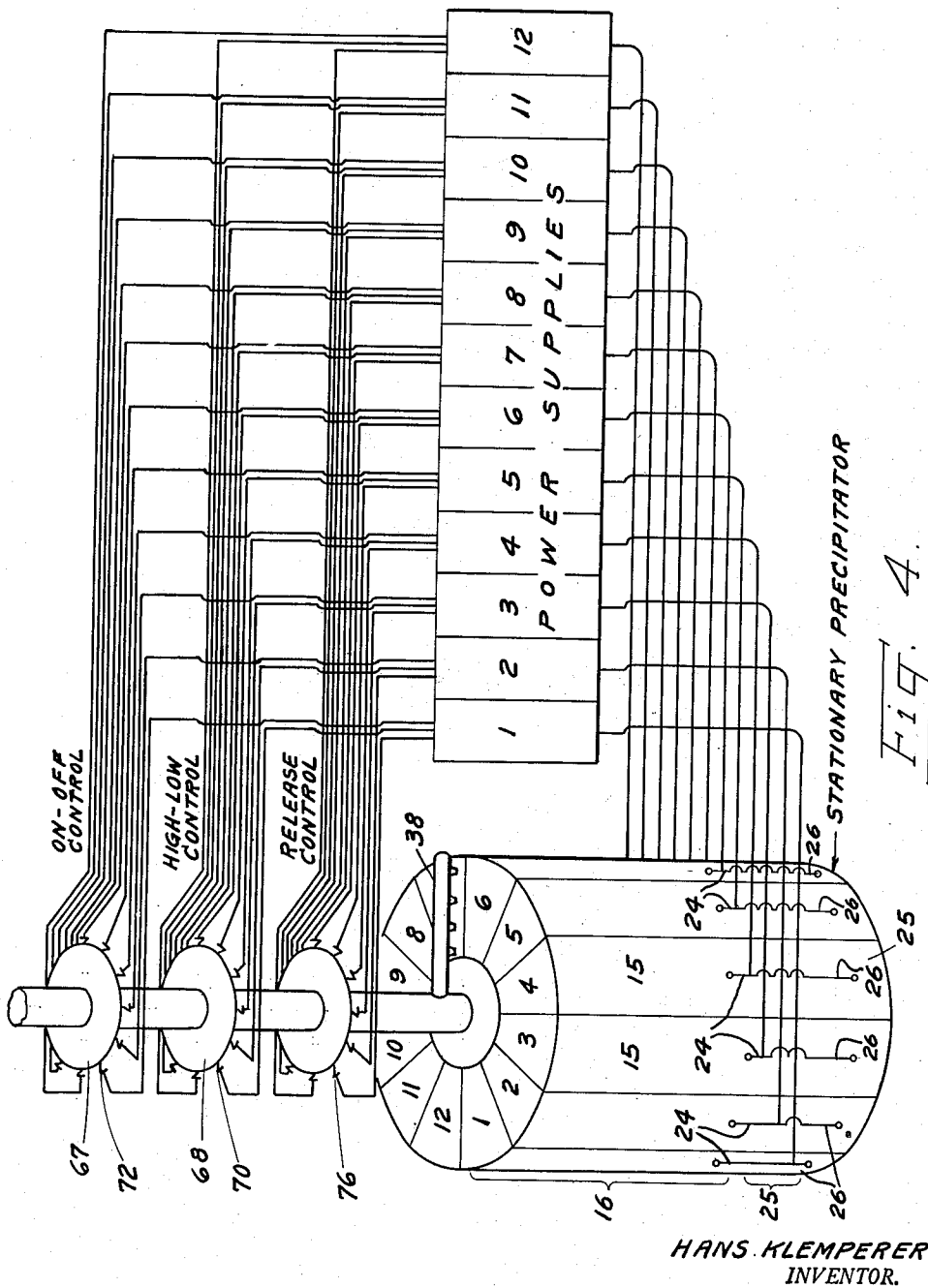
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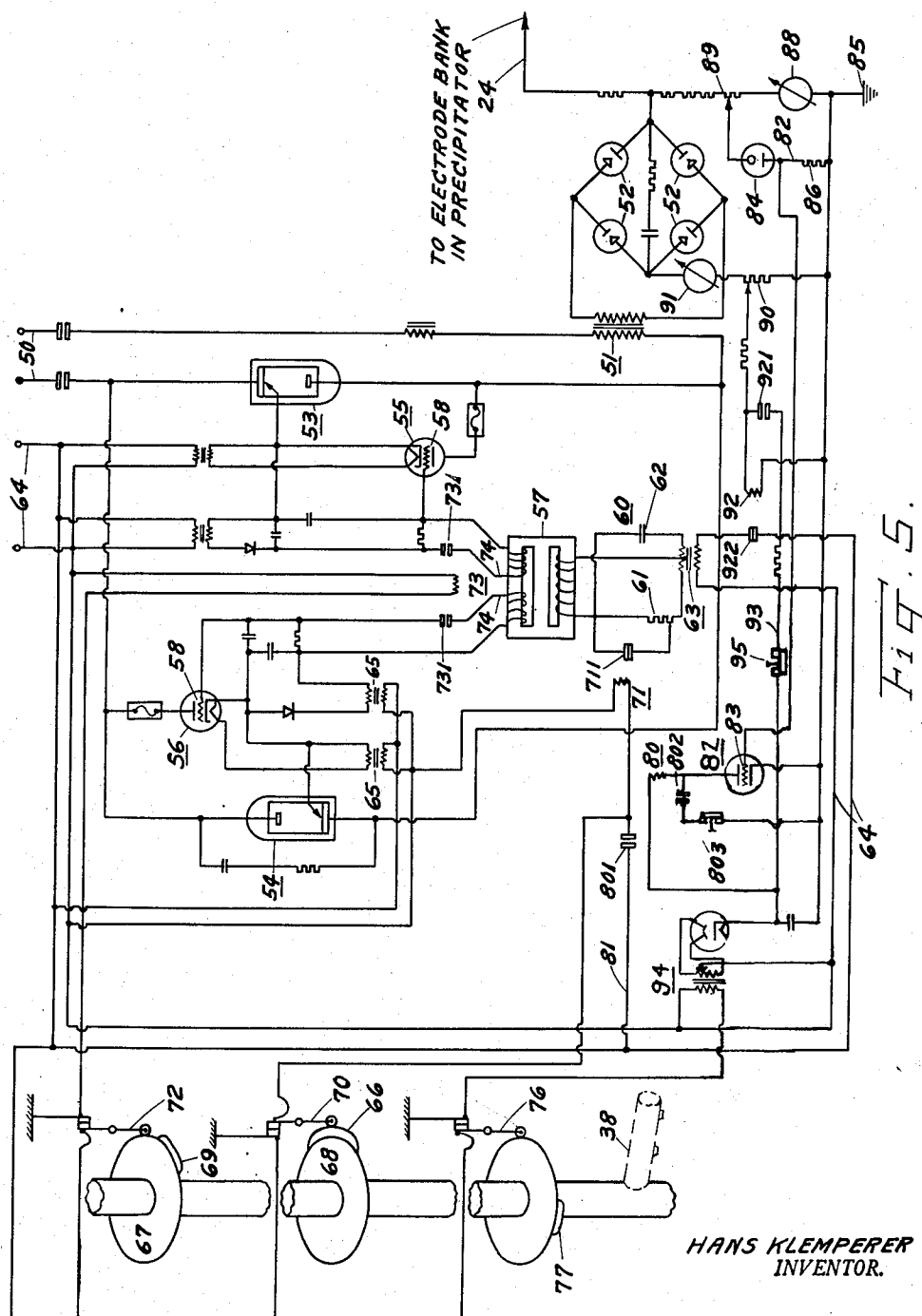
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VOLTAGE CONTROL IN PRECIPITATORS

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3 Sheets-Sheet 3



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VOLTAGE CONTROL IN PRECIPITATORS

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8 Claims. (Cl. 183—7)

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This invention relates to electrostatic precipitators for the removal from combustion or other impure gases of fine solid particles or impurities and particularly to an improved automatic control of the particle collecting and cleaning or discharge cycles of such precipitators.

It is a general object of the invention to provide apparatus for removing impurities so as to provide for the discharge to atmosphere of relatively clear stack gases substantially free from the fine smoke producing particles within the size range of say 15 microns down to sub-microscopic size, which particles for convenience will hereinafter be referred to as "fines." The invention contemplates removal of the fines without interruption from a continuously flowing column of any impure gases by electrostatic means incorporated in apparatus providing an ionizing section or zone followed by a collecting section or zone in which the particles previously electrostatically charged in the ionizing zone are deposited and collected on a suitable collecting surface. The invention contemplates provision of collecting sections having a total cross sectional area for flow of gases greater than that required for flow of the gas column to be treated. Less than the total number of gas channels provided are utilized at a given time and the remainder of the channels are in a cleaning zone outside the path of flow of the gas column so that the collecting surfaces may be cleaned without interrupting the gas cleaning function of the apparatus as a whole. In particular the invention contemplates apparatus of the kind described in which means are provided for automatically reducing the voltage applied to the charged elements of the precipitator prior to the cleaning period at which time the voltage is completely cut off. The voltage is partially restored in a transition period and the charged elements have the full voltage again applied thereto as they fully resume their collecting function.

A salient feature of the invention is the provision of electronically controlled device operative to reduce, cut off and subsequently first partially and then fully restore the charging voltage, all with the object of avoiding the excessive wear of electrical contacts and related mechanical parts that would be entailed if conventional switches of adequate size were utilized directly to repeatedly and frequently reduce and cut off etc. the relatively high voltage utilized for charging the elements of an electrical precipitator.

For a better understanding of the more detailed nature of the invention and the manner

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in which its several objects are attained, reference is made to the ensuing portion of this specification taken in conjunction with the accompanying drawings in which by way of example; but without limitation, an embodiment of apparatus for carrying the invention into effect is disclosed. In the drawings:

Figure 1 is a more or less schematic central longitudinal section through a gas cleaning apparatus embodying the invention;

Figure 2 is a section taken on the line 2—2 of Fig. 1;

Figure 3 is a section taken on the line 3—3 of Fig. 1;

Figure 4 is a diagrammatic view illustrating the electrical arrangements for applying an electrical voltage to the various sections of the precipitator; and

Figure 5 is a schematic wiring diagram showing the electronically controlled devices for applying a high tension charging voltage to elements of the precipitator together with cyclically controlled means for reducing the voltage in a transition period prior to the cleaning operation when the voltage is cut off following which there is a second transition period when the voltage is partially restored prior to the application of full voltage as the collecting cycle is repeated.

Referring now more particularly to the precipitator shown in Figs. 1 to 3, the reference character 10 indicates a duct delivering gases containing fines from a furnace or other apparatus and 11 is a discharge duct for carrying away the cleaned gases. Between ducts 10 and 11 a stationary housing structure 12 is located. The housing 12 includes an inner cylindrical shell 13 spaced from the outer shell and joined thereto by a plurality of radially extending partitions 14 (Fig. 2) to divide the annular space between the shells into a series of sector-like compartments 15 providing the space for the collecting section 16 of the cleaner. The collecting surface is provided by a plate structure 17 forming in each compartment a bank comprising a multiplicity of open ended gas channels 18 of hexagonal cross section. At the upper and lower ends of the plate structure, the marginal spaces between the bank of channels 18 and the shells and partitions of the housing are closed by suitable plates to force all of the gas passing through the housing to flow through the collecting channels 44.

Each of the gas channels 18 is traversed longitudinally by a centrally located electrode 20 which in the embodiment illustrated is in the form of

a solid rod but which also may be a hollow tube or other form. The electrodes 20 are supported by grids 21 of metal plate, there being one such grid for the bank of electrodes in each compartment 15 of the housing. The grids are electrically insulated from the framework of the housing, the grid 21 being supported by insulating connections 22 carried by the outer housing shell 12 and insulating support 23 carried by the inner shell 13.

At the lower or inlet ends of the gas channels other grids similar to grids 21 are provided, these also being supported by insulators. Current is supplied to each compartment through an individual feeder 24 so that through the structure just described the electrodes 20 may be electrically charged.

In the lower portion of the space between the shells 12 and 13 the ionizing section 25 is located, the construction of which is similar to that previously described, the radial partitions that form the compartments being coextensive in length with the shells of the casing structure so that the ionizing section as well as the collecting section is divided and located in a series of compartments, the several parts of the ionizing section being energized through the feed connections 26.

The casing structure is formed to provide a chamber 30 to which the gas inlet 10 leads and communicating through an annular opening 31 with the annular space in which the ionizing and collecting sections 25, 16 respectively are located. Within this chamber there is located a rotatably mounted hopper 32 projecting at its lower end through a suitably sealed opening 33 in the casing structure, being carried by a suitable bearing and having an external discharge outlet 34.

At the upper end of the shell structure a rotatably mounted casing 35 is provided, which comprises a sector-shaped wing 36 providing a chamber 37 housing a cleaning element in the form of a pipe 38 rotatable with the casing 35 by means of the gearing 39. Pipe 38 is connected to a source of high pressure fluid, such as steam or air. The casing 35 operates to isolate a compartment to be cleaned from the compartments through which gas is flowing in the same manner as the hopper effects this separation at the lower end of the apparatus, and it will be evident that as the hopper 32 and casing 35 are rotated electrode banks in different compartments 15 can be successively cleaned without interruption to the flow through the apparatus of the gas to be cleaned.

The foregoing precipitator structure is more fully described in the copending application of Per Hilmer Karlsson Serial No. 747,167 filed May 10, 1947 now Patent No. 2,582,133, issued June 27, 1951 which also discloses forms in which the collecting sections and sometimes the ionizing sections rotate with respect to a stationary cleaning station.

From suitable sources which may be of any appropriate known kind, the electrodes of the ionizing and collecting sections of the apparatus are electrically charged, preferably being given a high negative potential. In actual practice negative potentials of the order of 15,000 volts from a direct current source have been found to be satisfactory in operation, although utilization of the apparatus is not limited to this particular kind or value of electrical charge.

Current is supplied from the 230 or 440 volt 60 cycle line designated 50 in Fig. 5 to the primary of the transformer 51 for the rectifier tubes 52 through the ignitron tubes 53, 54 connected in

back to back relation. The ignitron tubes 53, 54 are controlled by the thyatron tubes 55, 56 which are normally biased off. An impulse transformer 57 periodically overrides the bias to energize the grids 58 of the thyatrons 55, 56 at a phase angle set by a phase shifter 60 comprising a variable resistor 61 and condenser 62 in series and parallel relation, respectively, with the primary of the impulse transformer 57. The resistor and condenser are in series with the secondary of a transformer 63 which is on an auxiliary circuit 64 from which the filament transformers 65 for the thyatrons also are supplied.

With the apparatus thus charged through the various leads 24, the impure gases carrying the fines to be collected flow from the supply duct 10 in a multiplicity of streams through the gas channels of the ionizing section in which section the solid particles acquire a negative charge. The gas carrying the charged particles then flows through the multiplicity of gas channels in the collecting section, and in this section, due to the repulsion of the negatively charged particles from the likewise negatively charged electrodes, the particles travel in oblique paths away from the electrodes until they impinge upon and adhere to the plate structure of the collecting section forming the walls of the channels. As the fines are deposited on the collecting surfaces of the present apparatus, films of solid deposit are built up upon these surfaces, and it has been found that the efficiency of the apparatus falls off relatively rapidly as the thickness of such films or layers of deposits increase. If the apparatus is to operate with a high degree of efficiency from the standpoint of the percentage of fines removed, the collecting surfaces require relatively frequent cleaning.

Voltage reduction prior to cleaning

Preceding the cleaning cycle for each bank of electrodes 13 the position of the rotary cleaning nozzle 38 and hopper 32 results in making the cam 66 of rotary disc 68 effective to close contacts 70 to energize relay 71. This may occur when the cleaning pipe 38 is several compartments or banks of electrodes in advance of the bank to be cleaned. This results in opening contacts 711 that short part of resistor 61 and causes the phase shifter 60 acting through impulse transformer 57 to impose biasing voltage impulses on the grid 58 of the thyatrons 55, 56 which therefore are later in the phase so as to delay the starting phase of the ignitrons 53, 54 and this action results in reducing the voltage impressed on the primary of high voltage transformer 51, and thereby reduces the direct voltage of current supplied by rectifiers 52 through lead 24 to the electrode bank or precipitator section or sections located in the transition zone or period prior to cleaning.

In accordance with the present invention the required cleaning may be intermittently or continuously effected without interruption of the continuous particle precipitating action applied to a continuously flowing column of gases. As will be apparent from the foregoing description of the apparatus, when the cleaning element 37 and hopper 32 are aligned in turn with the several compartments each is temporarily cut off from the gas stream and bank of electrodes then located in the "cleaning zone" and may readily be cleaned of accumulated deposits by means of the jet blast which is arranged so that it can be applied to direct the blast through all of the gas

channels of the bank or compartment as it turns.

When a compartment of collecting surface is to be cleaned, it is desirable that the associated bank of electrodes 18 be de-energized, and it is for this reason that the rotary disc 67 is provided with a cam 69 which is so oriented that the several electrode banks are electrically disconnected from the source of current during the time a bank is in the cleaning zone and aligned with the cleaning element 38.

Current disconnected during cleaning

When the cleaning element is positioned over any electrode bank the rotary cam 69 closes contacts 72 and energizes the related relay 73 to open contacts 731 in the leads 74 from the secondary coil of impulse transformer 57 to the grids 58 of thyratrons 55, 56 and interrupts the supply of starting impulses to these thyratrons so that the ignitrons 53, 54 become completely de-energized and no current passes to the secondary coil of rectifier transformer 51 with the result that during the cleaning cycle voltage is entirely cut off from the lead 24 extending to the precipitator sector being cleaned.

When the cleaning of the electrodes has been completed and the cleaning element 38 moved beyond a particular bank of electrodes, the rotary cam rides beyond the related switch 72 which closes energizing the relay 73 whose contacts 731 engage and restore the biasing voltage to the grids 58 of the thyratrons 55, 56. These in turn cause the ignitrons 53, 54 to function on the part of the cycle permitted by regulation of the impulse transmitter 57 by the phase shifter 60 and restore the charging current. Subsequently as the cleaning element 38 moves away from a particular bank of electrodes the cam 66 of switch 70 moves away and switch 70 closes energizing the relay 71 whose contacts 711 open removing the short circuit around part of the resistor 61 so that the phase shifter 60 causes the impulse transformer 57 to transmit biasing impulses at a later phase in the cycle to the grids 58 of the thyratrons 55, 56. This results in restoring full voltage to the electrodes and the gas cleaning cycle is again fully effective and the electrodes have full voltage applied thereto until the cleaning period is again reached whereupon the voltage imposed upon a bank of electrodes that are to be cleaned is first reduced and then cut off as described above.

Over voltage

An over-voltage relay 80 is provided with normally open contacts 801 in a line 81 connecting the voltage reducing relay 71 directly with the one lead of the auxiliary supply circuit 64. The relay 80 is controlled by the triode 82 whose grid 83 normally has a potential applied thereto that blocks off the tube and prevents its conduction. In ordinary operation of the precipitator a small amount of current drawn from the high voltage line 24 will flow through glow lamp 84 to ground at 85 through resistor 86 in a branch 87 around the k. v. meter 88 and part of its resistance 89 through which the ionizer is shunted to ground. If the high voltage in the ionizer section of the precipitator is momentarily reduced because of flash over or other faulty condition, the voltage tapped by branch 87 is not high enough to keep glow tube 84 ionized. As a result triode 82 loses the bias on its grid 83 and current flows to energize the over-voltage

relay 80. The relay 80 closes contacts 802 locking itself in and the contacts 801 which energize the relay 71 and cause a reduction of the voltage applied to the precipitator as described in detail above. Operation at low voltage could continue indefinitely until relay 80 were reset through manual release button 803. However, since the flashover is of short duration it is safe to restore the ionizer to full voltage after a short interval to permit disruption or disappearance of the flashover. To automatically restore full voltage the rotary contacts 75 are opened once in each cycle of rotation of the precipitator. Consequently if at such time relay 80 is energized and its contacts 802 are closed, the opening of rotary contacts 76 de-energizes relay so that contacts 801 open and in turn result in de-energizing relay 71 and full voltage is restored as described above.

Short circuit lock-out

The high voltage rectifier bridge 52 is grounded at 85 through resistor 90 and ammeter 91. The voltage developed across this resistance in case of a short circuit permits sufficient current to flow in the branch line to energize relay 92 which locks itself in through contacts 921 in line 93 leading to power supply transformer 94.

On energization of relay 92 the contact circuits controlled thereby are opened as contacts 922 open in the primary of transformer 63 associated with the phase shifter 60. This automatically cuts off all control circuits and ignitrons 53, 54 become de-energized so that no power is supplied to high voltage transformer 51.

By manual operation of release button 95 or cyclic opening of contacts 76 by cam 77 once during each rotation of the cleaning element in the precipitator cycle the relay 92 is de-energized thus permitting contacts 922 to close and restart the precipitator cycle. Thus the unit automatically discontinues operation wherever a heavy flash over occurs but it restarts itself again after the cleaning cycle.

What I claim is:

1. In an electrostatic precipitator having separate banks of electrodes located in the path of a stream of particle laden gases, means movable relatively to said banks of electrodes operable to clean collected particles from the electrodes of each bank in succession, and individual power supply means for separately applying a charging voltage to each bank of electrodes; the improvement comprising switching means responsive to and controlled by the position of said cleaning means relatively to each bank of electrodes for reducing the charging voltage applied to the latter electrode immediately prior to the cleaning period.

2. In an electrostatic precipitator having separate banks of electrodes located in the path of a stream of particle laden gases, means movable relatively to said banks of electrodes operable to clean collected particles from the electrodes of each bank in succession and individual power supply means for separately applying a charging voltage to each bank of electrodes; the improvement comprising means responsive to and controlled by the position of said cleaning means relatively to each bank of electrodes for reducing the charging voltage applied to the latter electrode immediately prior to the cleaning period; and means responsive to and controlled by the position of said cleaning means for completely cutting off the voltage during the cleaning period.

3. A precipitator as recited in claim 2 provided with switching means responsive to the position of the cleaning apparatus relative to each bank of electrodes for partially restoring the charging voltage at the end of the cleaning period and for subsequently fully restoring the charging voltage.

4. In an electrostatic precipitator apparatus having electrodes charged from a rectifier connected to the secondary of a transformer whose primary is connected to an electrical power source by a circuit including ignitron tubes controlled by thyatron tubes including grids; means normally effective to bias off said grids; an impulse transformer having its secondary circuit connected to apply starting impulses to the grids of said thyatron tubes for overriding the bias applied thereto; an auxiliary power source; an auxiliary power transformer having its primary circuit connected to said auxiliary power source; a phase shifting circuit connecting the secondary of said auxiliary transformer with the primary of said impulse transformer; a condenser in one side of said circuit; a resistance in the other side of said circuit; a circuit including normally engaged contacts changing the phase of said phase shifting circuit; a relay for disengaging said contacts; means for periodically cleaning said electrodes; a normally open switch controlling said relay; and means synchronously associated with said electrode cleaning means and operative to close said switch a predetermined time before said cleaning means becomes effective to clean said electrodes.

5. In an electrostatic precipitator apparatus having electrodes charged from a rectifier connected to the secondary of a power transformer whose primary is connected to an electrical power source by a circuit including ignitron tubes controlled by thyatron tubes including grids; means normally effective to bias off said grids; an impulse transformer having its secondary circuit connected to apply starting impulses to the grids of said thyatron tubes for overriding the bias applied thereto; an auxiliary power source; an auxiliary power transformer having its primary circuit connected to said auxiliary power source; a circuit connecting the secondary of said auxiliary power transformer in parallel with the primary of said impulse transformer; means for periodically cleaning said electrodes; normally engaged contacts in the grid circuits of said thyatron tubes; a relay connected to be energized from said auxiliary power source; a normally closed switch controlling said relay; and means synchronously associated with said electrode cleaning means and operative to open said switch during the time said cleaning means is effective to clean said electrodes, whereby the de-energization of said relay separates said contacts and opens the grid circuits of said thyatron tubes so as to render said ignitron tubes ineffectual to supply current to said rectifier tubes and precipitator electrodes during the cleaning period.

6. In an electrostatic precipitator having a plurality of separate banks of electrodes located in the path of a stream of particle laden gases; means movable relatively to said banks of electrodes operable to clean collected particles from the electrodes of each bank in succession; individual power supply means including ignitron tubes controlled by thyatron tubes for separately applying a charging voltage to each bank of electrodes; means controlled by the position of said cleaning means relatively to each bank of

electrodes for reducing the charging voltage applied to the latter electrode immediately prior to the cleaning period; and means for completely cutting off the voltage during the cleaning period including normally engaged contacts in the grid circuits of said thyatron tubes, a relay energized from said auxiliary power source, a normally closed switch controlling said relay, and means synchronously associated with said electrode cleaning means and operative to open said second switch during the time said cleaning means is effective to clean said electrodes.

7. In an electrostatic precipitator apparatus having electrodes charged from a rectifier connected to the secondary of a power transformer whose primary is connected to an electrical power source by a circuit including ignitron tubes controlled by thyatron tubes including grids; means normally effective to bias off said grids; an impulse transformer having its secondary circuit connected to apply starting impulses to the grids of said thyatron tubes for overriding the bias applied thereto; an auxiliary power source; an auxiliary power transformer having its primary circuit connected to said auxiliary power source; a circuit connecting the secondary of said auxiliary power transformer in parallel with the primary of said impulse transformer; a resistance in one side of said circuit; a condenser in the other side of said circuit; a circuit including normally engaged contacts shorting part of said resistance; a relay connected to said auxiliary power source and energizable to separate said contacts to disrupt said short circuit; means for periodically cleaning said electrodes; a normally open switch controlling said relay; means synchronously associated with said electrode cleaning means and operative to close said switch a predetermined time before said cleaning means becomes effective to clean said electrodes, whereby the energization of said relay opens said contacts to remove the short circuit of part of said resistance to modify the voltage supplied by said auxiliary transformer to said impulse transformer so as to cause the latter to apply the bias countering impulses to the grids of said thyatron tubes at a later cyclic phase so as to cause said ignitron tubes to act to reduce the charging voltage applied by said rectifier to said electrodes.

8. In an electrostatic precipitator apparatus having electrodes charged from a rectifier connected to the secondary of a power transformer whose primary is connected to an electrical power source by a circuit including ignitron tubes controlled by thyatron tubes including grids; means normally effective to bias off said grids; an impulse transformer having its secondary circuit connected to apply starting impulses to the grids of said thyatron tubes for overriding the bias applied thereto; an auxiliary power source; an auxiliary power transformer having its primary circuit connected to said auxiliary power source; a circuit connecting the secondary of said auxiliary power transformer in parallel with the primary of said impulse transformer; a resistance in one side of said circuit; a condenser in the other side of said circuit; a circuit including normally engaged contacts shorting part of said resistance; a relay connected to said auxiliary power source and energizable to separate said contacts to disrupt said short circuit; means for periodically cleaning said electrodes; a normally open switch controlling said relay; means synchronously associated with said electrode cleaning means and operative to

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close said switch a predetermined time before said cleaning means becomes effective to clean said electrodes, whereby the energization of said relay opens said contacts to remove the short circuit of part of said resistance to modify the voltage supplied by said auxiliary transformer to said impulse transformer so as to cause the latter to apply the bias countering impulses to the grids of said thyratrons at a later cyclic phase so as to cause said ignitron tubes to act to reduce the charging voltage applied by said rectifier to said electrodes; normally closed contacts in the grid circuits of said thyatron tubes; a second relay connected to be energized from said auxiliary power source; a normally closed switch controlling said second relay; and means

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synchronously associated with said electrode cleaning means and operative to open said second switch during the time said cleaning means is effective to clean said electrodes whereby the de-energization of said second relay opens the grid circuits of said thyatron tubes so as to render said ignitron tubes ineffectual to supply current to said rectifier tubes and precipitator electrodes during the cleaning period.

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References Cited in the file of this patent

UNITED STATES PATENTS

	Number	Name	Date
15	2,582,133	Karlsson	Jan. 8, 1952