

Aug. 21, 1962

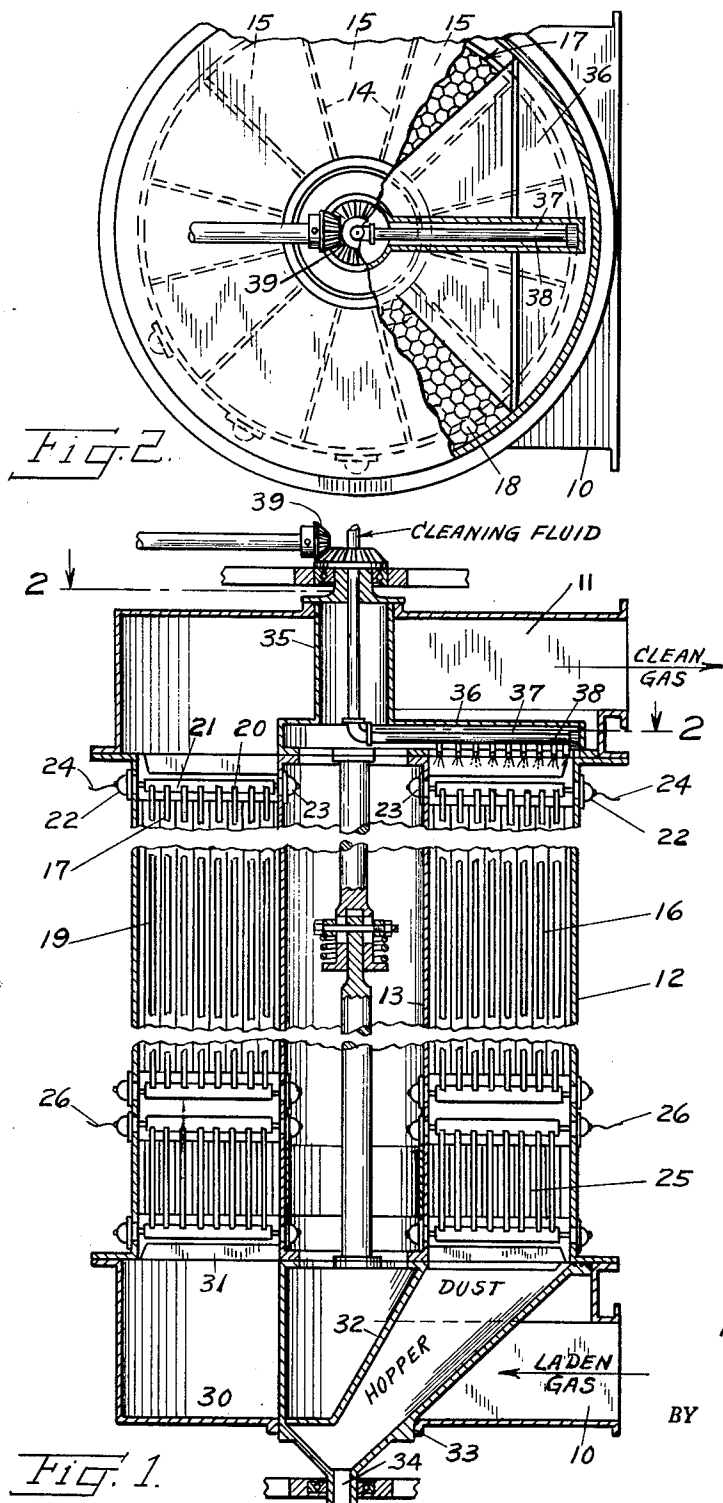
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3,049,848

ELECTROSTATIC PRECIPITATOR CIRCUITS

Filed Aug. 17, 1953

3 Sheets-Sheet 1



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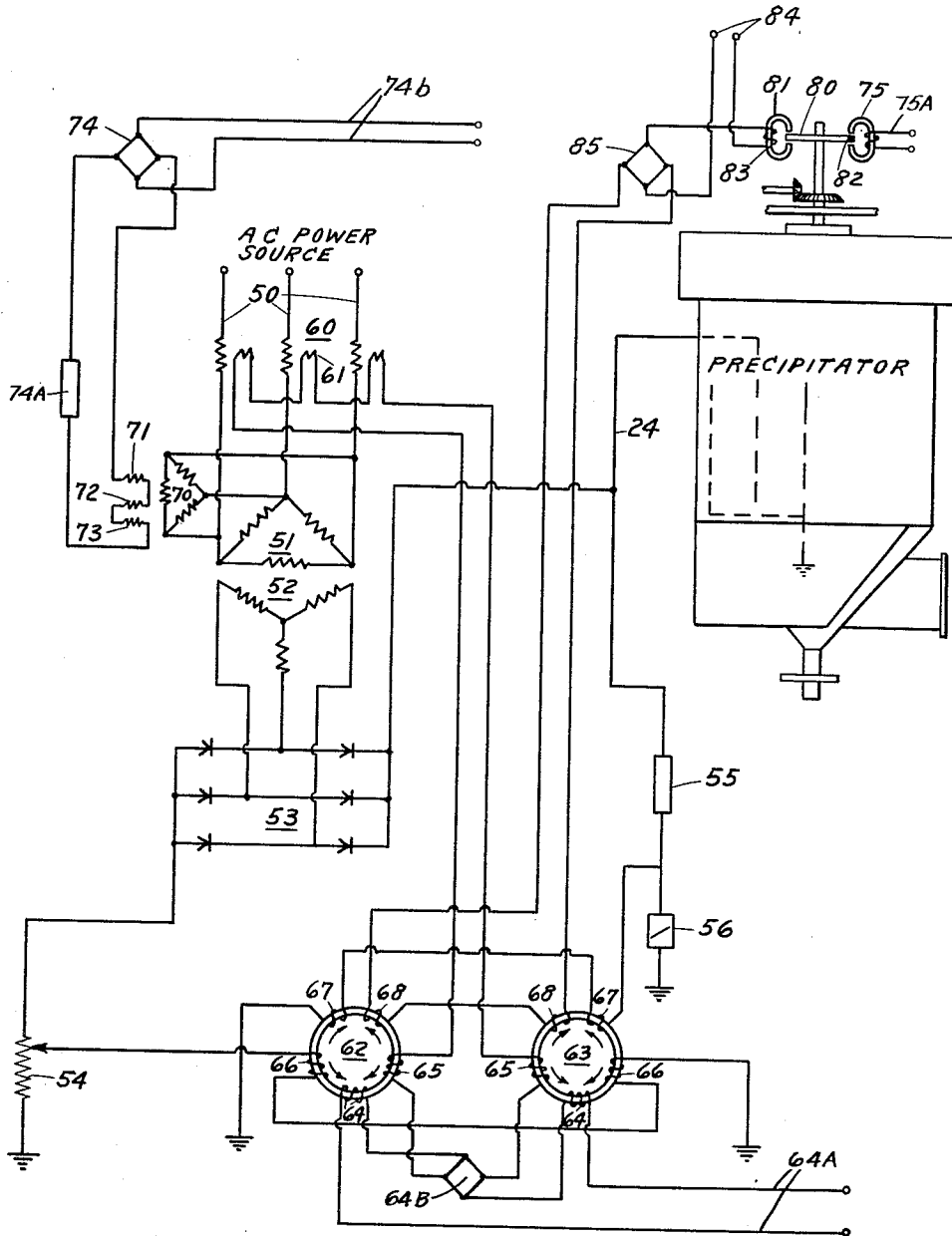


Fig. 3.

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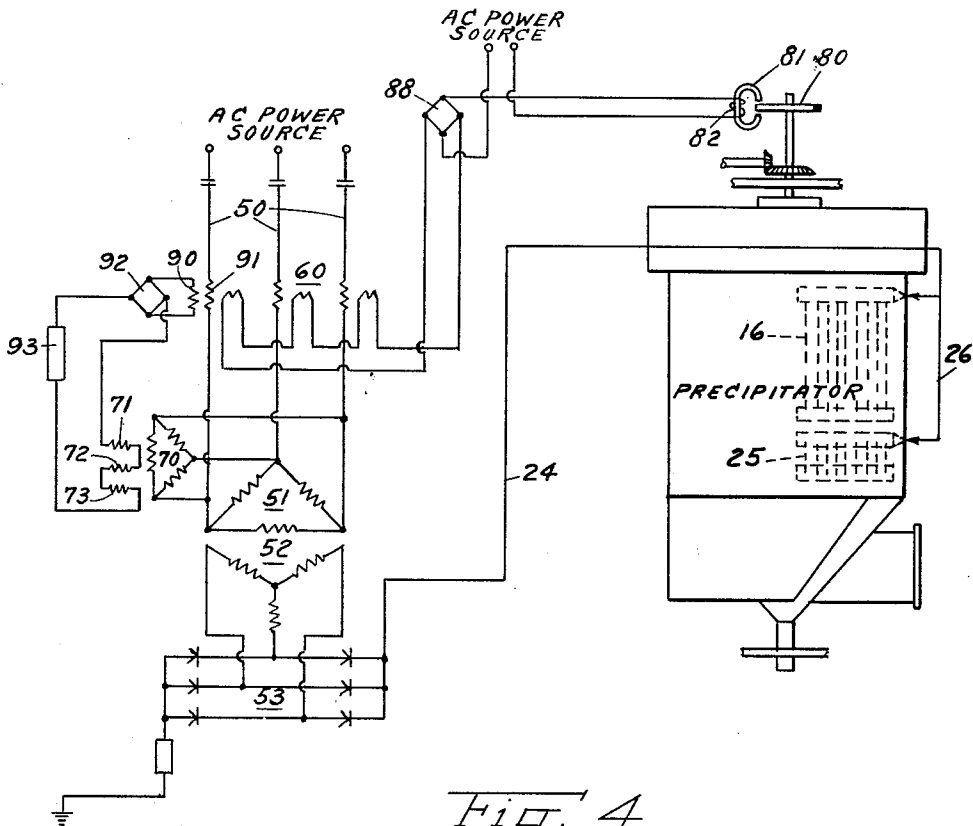


Fig. 4.

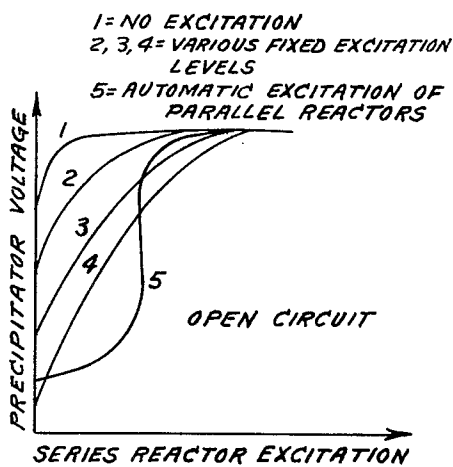


Fig. 4A.

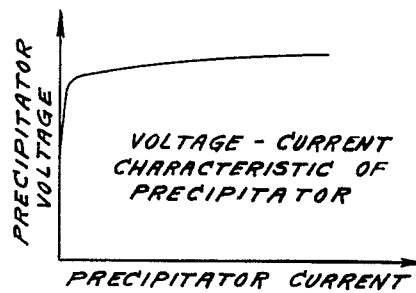


Fig. 4B.

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ELECTROSTATIC PRECIPITATOR CIRCUITS

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4 Claims. (Cl. 55—105)

This invention relates to electrostatic precipitators for the removal from combustion or other impure gases of fine solid particles or impurities and particularly to improved automatic controls of the particle collecting and cleaning or discharge cycles of such precipitators and also to the suppression of "flashovers" before they persist long enough to damage the apparatus.

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. The invention contemplates removal of the particles without interruption from a continuously flowing column of any impure gases by electrostatic means incorporated in apparatus providing 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 the provision of electrical control devices for apparatus of the kind described in Karlsson Patent No. 2,582,133 dated January 8, 1952, in which means are provided for automatically reducing the voltage applied to the charged elements of the precipitator prior to the cleaning period. The voltage is restored at the end of the cleaning period and the charged elements have the full voltage again applied thereto as they resume their collecting function.

A salient feature of the invention is the provision of electronically controlled device operative to reduce and then restore the charging voltage during cleaning periods or when flashovers occur, 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 restore the relatively high voltage utilized for charging the elements of an electrostatic precipitator.

For a better understanding of the more detailed nature of the invention and the manner in which its several objects are attained, reference is made to the ensuing portion of this specification when read in conjunction with the accompanying drawings in which embodiments of apparatus for carrying the invention into effect is disclosed by way of example, but without limitation. 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 FIGURE 1;

FIGURE 3 is a schematic wiring diagram showing the electrical control devices for applying a high tension charging voltage to the electrodes of the precipitator together with cyclically controlled means including series and parallel reactors for reducing the voltage during the cleaning operation and when flashovers occur following which the full voltage is restored as the collecting cycle is repeated. FIGURE 3 also shows controls for reducing voltage to suppress flashovers.

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FIGURE 4 is a wiring diagram illustrating another electrical arrangement for reducing the electrical voltage to the various sections of the precipitator during the cleaning period;

FIGURE 4A and FIGURE 4B are related graphs.

Referring now more particularly to FIGURES 1 and 2, 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 (FIGURE 2) to divide the annular space between the shells into a series of sector-like compartments 15 providing the space for the collecting sections of the precipitator. The collecting surface is provided by a plate structure 17 forming a "bank" or precipitator section in each compartment 15 comprising a multiplicity of open ended gas channels 18 of hexagonal cross section. FIGURE 1 shows an upper bank 16 and a lower bank 25 in each compartment 15.

At the upper and lower ends of the plate structure, the marginal spaces between the banks 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 18. Each of the gas channels 18 is traversed longitudinally by a centrally located electrode 20 which may be of any suitable form. The electrodes 20 are supported by upper and lower grids 21 electrically insulated from the framework of the housing, the grids 21 being supported by insulating connections 22 carried by the outer housing shell 12 and insulating support 23 carried by the inner shell 13. Current is supplied to each compartment through individual feeders 24 for the upper banks 16 and 26 for the lower banks 25, so that through the structure just described the electrodes 20 may be electrically charged.

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 collecting sections 16, 25 are located. Within the chamber 30 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 housing 35 is provided, which comprises a sector-shaped wing 36 providing a chamber 37 enclosing a cleaning element in the form of a pipe 38 rotatable with the casing 35, the movement being effected 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 and hopper 32 operate to isolate a compartment to be cleaned from the compartments through which gas is flowing. It will be evident that as the hopper 32 and casing 35 are rotated electrode banks in different compartments 15 can be successively cleaned by fluid from pipe 38 without interruption to the flow through the apparatus of the gas from which dust particles are precipitated.

The foregoing precipitator structure is more fully described in the Karlsson patent 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 FIGURE 3 to the primary 51 of the transformer whose secondary 52 feeds the rectifier 53 which applies charging voltage to one of the banks 16 (or 25) through the lead 24 (or 26).

With several banks 16, 25 of the apparatus thus charged through the various leads, 24, 26 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.

Flashovers in the precipitator have to be cleared by reduction of power below the level necessary to sustain the flashover arc. This operation is at present performed by relays responsive to increase in current and decrease in voltage at the affected precipitator section. At an average rate of 50 flashovers per minute, these relays perform about 72,000 operations per day.

The individual sections of the precipitator are periodically de-energized during the cleaning period. At present, relays are applied to perform this operation in the control circuit of saturable reactors. At a rate of one cleaning period during every three minutes, 480 relay operations are performed per day.

The operational relays described above are energized by switches operated in synchronism with the cleaning hood of the precipitator. At present, these switches utilize relay contacts that are actuated by means of cams and rods each switch operating at a rate of 480 operations per day. This corresponds to 5760 operations per day for the cam and rod mechanism.

It is the purpose of this disclosure to describe a system which eliminates from the precipitator control all wearing parts and moving contacts, i.e. the flashover clearing relays, the operational relays, and the contacts, rods and cams of the rotary device. According to the disclosure, the mentioned elements are replaced by stationary magnetic devices using saturable cores within which the level of magnetic saturation is varied. These magnetic elements in turn control the saturable power reactors, the series reactors, and the parallel reactors as previously described. (These reactors are presently used in the primary A.C. power lines of the precipitator.)

Referring to FIGURE 3, 60 designates reactors in series with the primary 51 of the transformer. The excitation for the parallel reactors 70 are left off for simplicity, it being understood that they are in a de-energized state while the series reactors are energized and vice versa. 51, 52 is the power transformer, 53 the power rectifier grounded through resistor 54, while the high voltage D.C. output 24, leads to the coordinated precipitator sector, the collecting surfaces of which are grounded. The high voltage line is connected to ground by means of a high ohm resistance 55 and a protecting element 56. 62 and 63 are the magnetic loops of a saturable reactor. The

magnetic cores 62 and 63 carry five separate windings each designated by numbers 64, 65, 66, 67, 68 as shown in the drawing.

The control power for the series reactor 60 is taken from an auxiliary A.C. supply 64A, passed through and controlled by coils 64 of the reactor loops 62 and 63. The dependency of power passed by the reactor loops 62 and 63 as a function of their level of saturation is rendered more sensitive and may be given additional speed for instance by making use of the well-known D.C. feed-back connections (coils 66). The rectified output of the reactor 62, 63 leads to the series reactors 60. The energizing power for the reactors 62, 63 which is taken from the source 64a energizes these reactors by means of coils 64. This energizing power which is controlled by means of the various other coils 66, 67 and 68 is rectified by the rectifier 64B and then flows through reactor coils 65. After passing coil 65 this rectified power is applied to control saturable series reactor 60 by means of coils 61.

The level of power passed by saturable loops 62 and 63 is dependant on the interplay of the control currents of the three other D.C. windings 66, 67 and 68 respectively. Therefore, the respective currents in these windings will determine whether the series reactors 60 are operated at the low or high level as defined by the excitation of the reactor loops 62 and 63.

The three D.C. control windings on the reactor loops 62 and 63 are connected as follows: The current in coils 66 is a fraction of the precipitator current adjustable by means of a tap on resistor 54. The current in 67 corresponds to a fraction of the precipitator voltage; it is supplied by tapping the voltage branch between resistor 55 and protective device 56. The direction of D.C. flow in the respective coils 65 to 68 is indicated by arrows. Therefore, as long as the precipitator is operated at high voltage and normal current, normal excitation will be passed through 64 and 65 to the series reactor 60. However, when a flashover occurs with corresponding increase in current and decrease in voltage, the resultant ampere turns on 62 and 63 in a direction opposing 65 will be greatly increased. Consequently, the saturation of 62 and 63 will "snap-off" to the low level and very little excitation will be provided to the series reactors 60. Thus, the precipitator power will be lowered below the level that could sustain a flashover arc. This flash-over extinguishing action may in some cases of application be performed by the current sensitive winding 66 alone, without further help from the voltage sensitive winding 68.

The rotating device that synchronizes application of power with the operation of a specific precipitator sector is sketched in the upper right hand corner of FIGURE 3. 80 is a disc rotating in synchronism with the precipitator hood 35. 81 is a magnetic pick-up, the reluctance of which is influenced by the rotating disc. A certain sector 82 of the rotating disc 80 consists of a magnetically responsive material like iron. Whenever this sector 82 passes the open gap in the magnetic pick-up 81 the magnetic reluctance of the pick-up will drop considerably. The coil 83 of the magnetic pick-up 81 is energized from an auxiliary alternate current source 84, the output of the pick-up is rectified by 85 and passed through coils 68, in a sense opposing coils 65. Therefore, as long as the reluctance of 81 is high, the magnetic level of 62 and 63 will be high and high power will be supplied to reactor 60. As the magnetic sector 82 passes 83, the reluctance of 83 will decrease with corresponding increase of direct current in coils 68. Since these currents are opposing coils 65, the magnetizing levels of the cores 62 and 63 will snap to "low." As a consequence, the excitation of reactor 60 and therefore the power level of the precipitator sector 16 will be reduced during cleaning period.

Preceding the cleaning cycle for each bank of elec-

trodes 18 the position of the rotary cleaning nozzle 38 and hopper 32 results in energizing the magnetic pick-up 80-82.

The energization and deenergization of the magnetizing windings 71, 72, 73 of the parallel reactors 70 may be controlled through duplicates of the reactor 62, 63 and rectifier 74 with excitation of the parallel reactors 180° out of phase with the series reactors through a pick-up 75 mounted diametrically opposite pick-up 81 with respect to disc 80 which operates in synchronism with the precipitator cleaning device 35, 38.

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" 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.

As described above, when a compartment of collecting surface is to be cleaned, it is desirable that the voltage to the associated bank of electrodes 18 be reduced, and as an alternative to the arrangement of FIGURE 3 the scheme of FIGURE 4 may be employed.

The control of the precipitator as described above requires two sets of reactors, series and parallel reactors designated 60 and 70 respectively in FIGURE 4. The function of the parallel reactor 70 is to suppress the precipitator voltage far enough below the ionization level during the cleaning period to prevent flashovers. In the previously employed control circuits both the series and parallel reactors were controlled by independent sets of relay contacts. These contacts had to be timed accurately with respect to each other, and also required service. It was also necessary for the reactors to be of an unusually large size to take care of short circuit currents which would be drawn from the line if due to faulty operation of the contacts both sets of reactors were excited simultaneously.

According to the present invention automatic means of control for the parallel reactors 70 are proposed dispensing with the need for contacts and making faulty timing impossible. This new circuit will apply preferably in cases where the series reactors are operated by stationary non-wearing electrical means such as the magnetic pick-up 80, 81, 82.

The operation of the control reactors 62, 63, FIGURE 3, is as follows: For synchronization between precipitator cleaning periods and excitation status of coordinated power supply, the control reactor 62, 63 acts as an amplifier, taking its power from the line 64A and receiving its trigger by induction from the control wheel 80 by means of coil 68. To interrupt flashover the control reactor combines the occurrence of an increased current from 54 into control winding 66 with the disappearance of the precipitator voltage dependent current of coils 67. Coils 66 and 67 are wound to increase the excitation of the reactor. Therefore, when a flashover happens during the operation period, the voltage across the precipitator is automatically reduced until the flashover is interrupted.

The excitation level of the parallel reactors 70 should always be inverse with respect to the excitation level of the series reactor 60. Therefore, according to the invention, automatic excitation for the parallel reactors 70 is derived from the voltage build up across the power coils of one of the series reactors preferably by means of a separate coil 90 wound over one of the power coils 91. One of the series reactors is provided with a tertiary winding 90 over one of its power coils. The output of this coil 90 is rectified at 92 and passed through the excitation

windings 71, 72, 73 of the parallel reactors 70. An ohmic resistor 93 may be inserted in order to speed up the response time of the parallel reactors. The voltage of this automatic excitation circuit is the highest when the series reactors 60 are unexcited, at which time the parallel reactors 70 must be excited. This voltage reaches its lowest value when the series reactors are excited, removing the action of the parallel reactors 70 when the precipitator voltage is high.

The operation of the automatic connection of the parallel reactor is as follows: while the precipitator sector is energized there is very little voltage across the series reactor 91. Therefore, very little voltage is built up across winding 90 and the parallel reactor 70 stays deexcited. Therefore, during the operating period the parallel reactors have no active part in the circuit. If a flashover happens in the precipitator sector, the line voltage builds up across the series reactors and considerable power is supplied through winding 90 to the excitation coils 71-72 and 73 of the parallel reactors. The excited parallel reactors deflect current from transformer 51-52, thus facilitating the extinction of the flashover.

During the cleaning period of the precipitator sector, voltage at the precipitator electrodes is considerably reduced by energizing the series reactors 61. With the reduction of precipitator voltage, precipitator current falls off very rapidly and, therefore, the load impedance of transformer 52 goes up very high. Further reduction of precipitator voltage can be achieved only if the load impedance at the precipitator side of the series reactors 61 is artificially reduced. This is done by the automatic excitation of the parallel reactor 70 which, therefore, draws considerable current. By means of this artificial watt-less impedance the precipitator voltage is reduced considerably below the point where ionization current will set in.

Performance curves are shown in FIGURE 4A. The top curve shows how little control is possible without parallel reactors below the ionization level. This may be understood with reference to FIGURE 4B, which shows the well-known voltage current characteristic of an electrostatic precipitator. The other curves of FIGURE 4A apply to different fixed excitations of the parallel reactor, as previously applied and to the described automatic excitation. Experience with this circuit has shown that in addition to savings in control equipment and reactor sizes the control time of the combination is improved because now the operational time constant of the parallel reactors can be adjusted to further speed up whatever action is performed by the series reactors.

Contrary to conventional precipitators, the precipitator described herein is operated with smooth D.C. supply. As a consequence, flashovers have to be cleared by external circuit means. This operation of clearing flashovers takes less than 1/2 second. During this cleaning period the efficiency of all cells connected to the same power supply is very greatly reduced.

The "time of contact," which means the time which a particle is staying inbetween the precipitator electrodes, ranges in full seconds with conventional precipitators. In this precipitator, this time is 0.15 second for each individual bank 16, 25. For this reason a great number of particles escape the precipitator during the time of flashover if both sections 16, 25 (which are in series with respect to the gas stream), would be connected to the same power supply.

What I claim is:

1. In an electrostatic precipitator having an alternating electric current source, a transformer with its primary winding connected to said source, saturable reactor means connected in series with said primary and a rectifier connected to the secondary winding of said transformer for applying a charging voltage to the electrodes of said precipitator, the improvement comprising: a separate alternating current source and rectifying means therefor; a circuit connecting said rectifying means to supply an energizing current to the magnetizing windings of said series

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connected reactor; a saturable control reactor connected in said circuit; separate magnetizing windings for said control reactor, one of said magnetizing windings for said control reactor being connected across the precipitator electrodes to be energized in response to variations in the voltage across the electrodes and another of said magnetizing windings for said control reactor being connected in series with the electrodes to be energized in response to variations in current flow through said electrodes, said magnetizing windings for said control reactor being connected in aiding and opposed relation respectively to the main windings of said control reactor.

2. In an electrostatic precipitator having an alternating electric current source, a transformer with its primary winding connected to said source, saturable reactor means connected in series with said primary and a rectifier connected to the secondary winding of said transformer for applying a charging voltage to the electrodes of said precipitator, the improvement comprising; a separate alternating current source and rectifying means therefor; a circuit connecting said rectifying means to supply an energizing current to the magnetizing windings of said series connected reactor; a saturable control reactor connected in said circuit; separate magnetizing windings for said control reactor, one of said magnetizing windings for said control reactor being connected across the precipitator electrodes to be energized in response to variations in the voltage across the electrodes and another of said magnetizing windings for said control reactor being connected in series with the electrodes to be energized in response to variations in current flow through said electrodes, said magnetizing windings for said control reactor being con-

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nected in aiding and opposed relation respectively to the main windings of said control reactor.

3. In a power supply system for an electrostatic precipitator, a high voltage transformer having its primary winding connected to an alternating current source and its secondary connected through a rectifier to the precipitator electrodes; a saturable reactor in series with the primary winding of said transformer; an energizing winding for said reactor means for cyclically cleaning said precipitator; and magnetic means operating in unison with said cleaning means for controlling the excitation of the said energizing winding of said series reactor.

4. An electrostatic precipitator as in claim 3, said last means comprising a synchronously operated switch with a magnetic pick-up.

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