Sept. 25, 1956 H. KLEMPERER 2,764,254

ELECTROSTATIC PRECIPITATOR CIRCUITS

Original Filed Aug. 17, 1953 3 Sheets-Sheet 1

Fig. 2

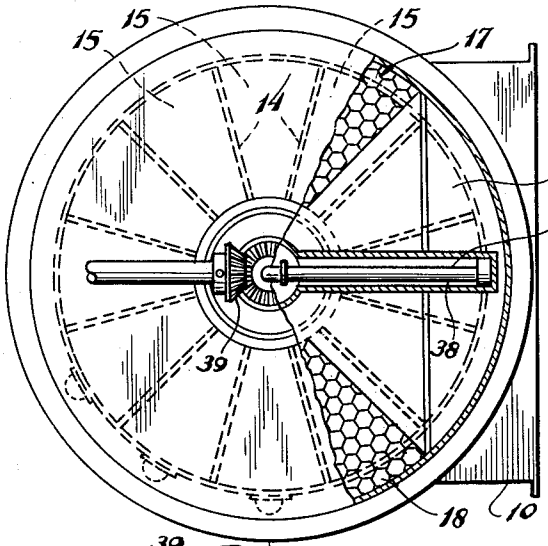
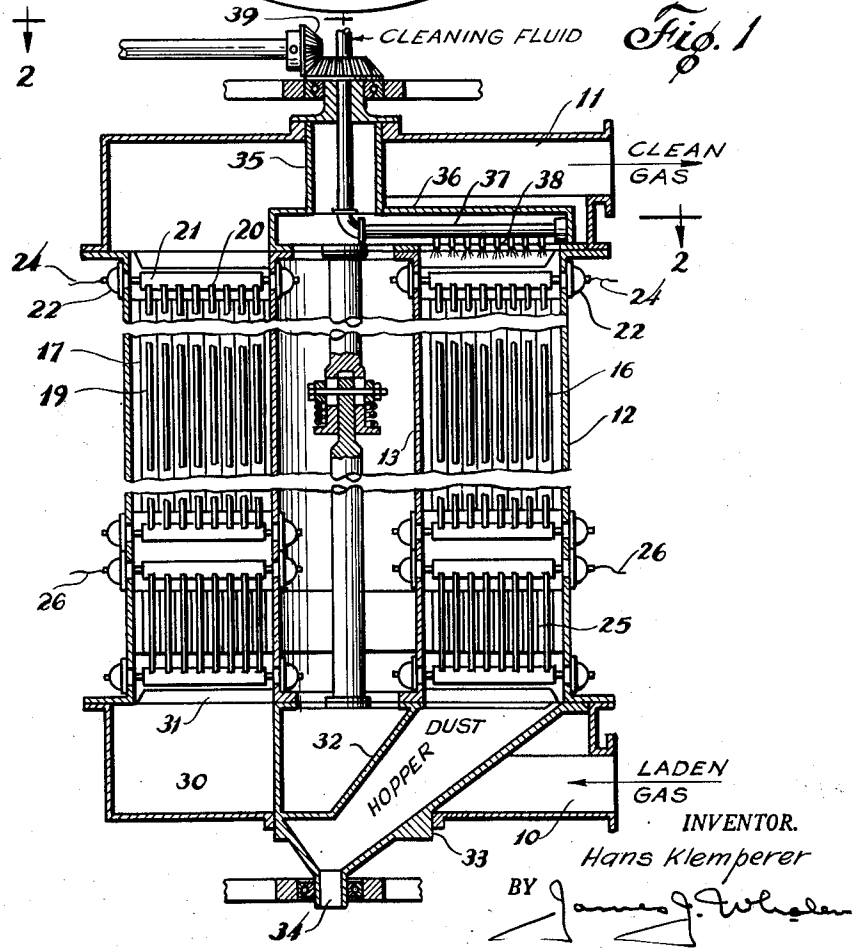


Fig. 1



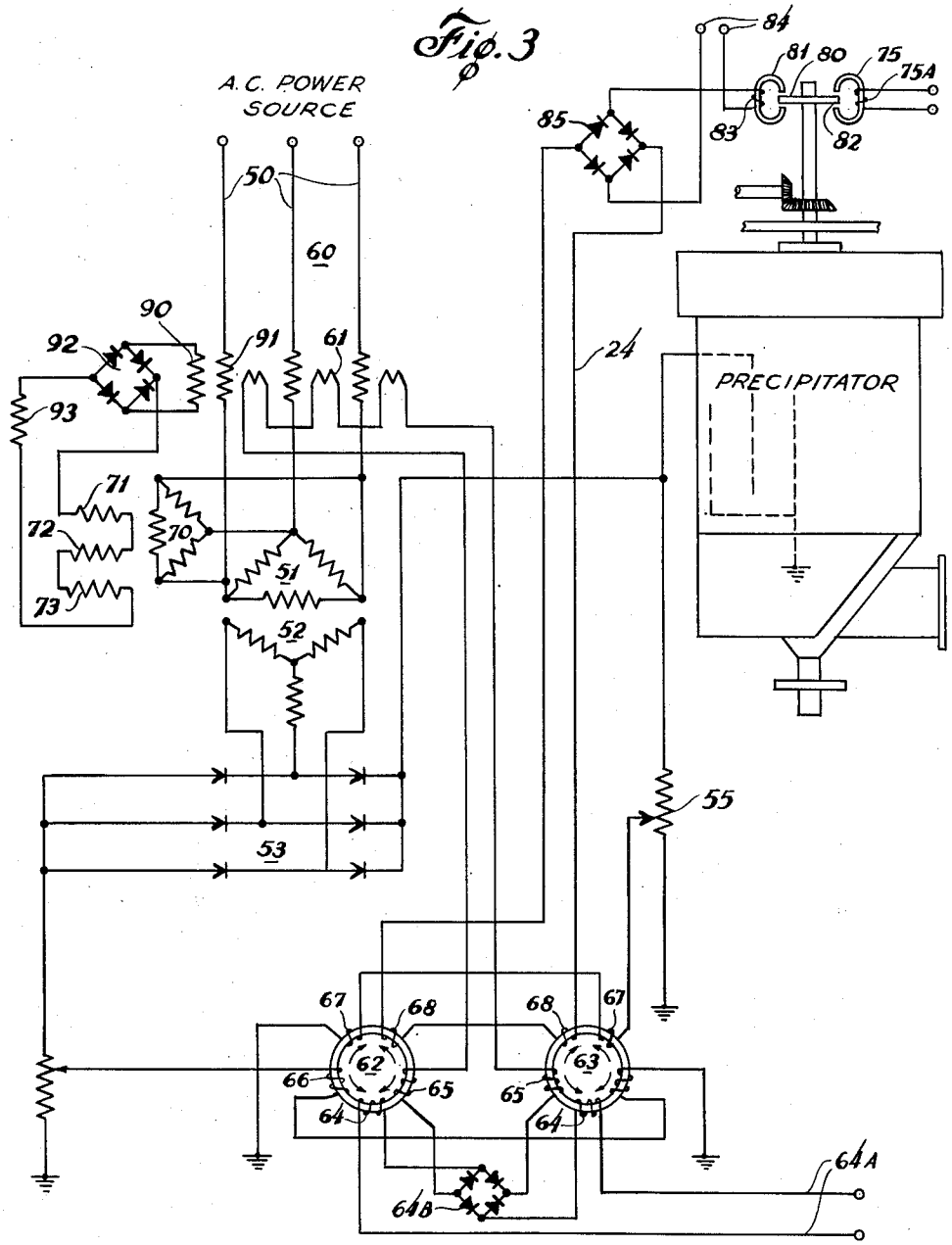
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Original Filed Aug. 17, 1953 3 Sheets-Sheet 2

Fig. 3



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ELECTROSTATIC PRECIPITATOR CIRCUITS

Original Filed Aug. 17, 1953 3 Sheets-Sheet 3

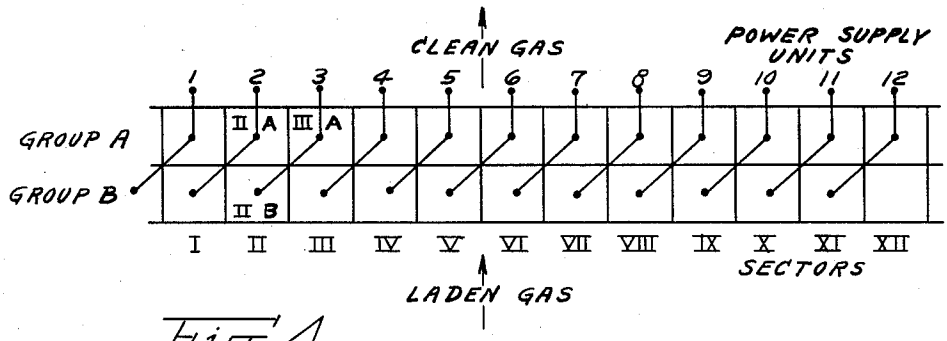


Fig. 4.

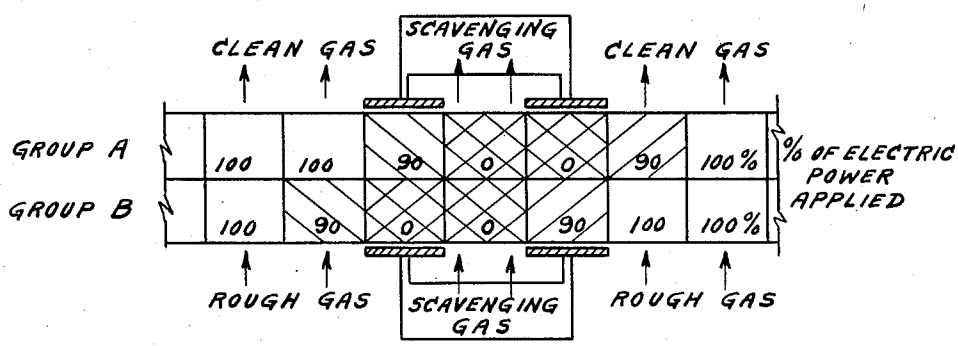
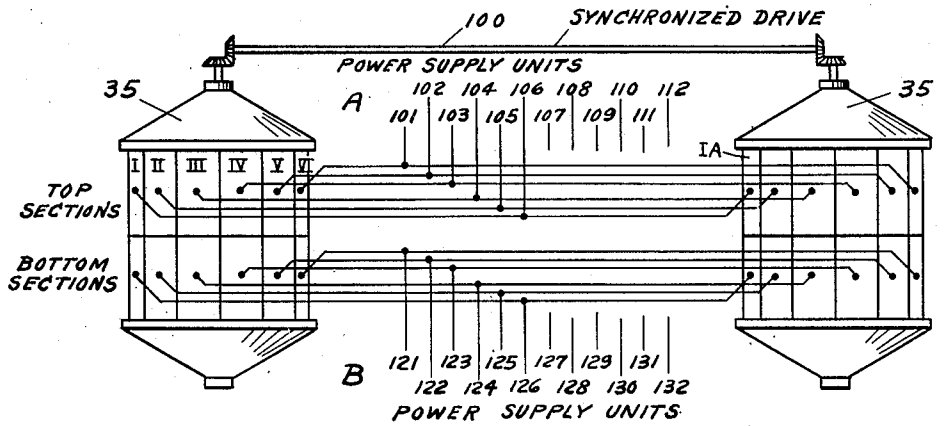


Fig. 5.



FLASHOVER IN ONE SECTION DOES NOT AFFECT OPERATION OF OTHER SECTION IN SERIES WITH GAS STREAM.

Fig. 6.

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2,764,254

ELECTROSTATIC PRECIPITATOR CIRCUITS

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Original application August 17, 1953, Serial No. 374,673. Divided and this application April 11, 1955, Serial No. 500,336

4 Claims. (Cl. 183—7)

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.

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 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 removing 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 electrical 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.

Figures 4, 5 and 6 are schematic views illustrating a preferred arrangement for applying charging voltages to banks of electrodes which are in series in the gas stream.

Referring now more particularly to Figures 1 and 2, the reference character 10 at the lower right 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.

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 a transformer whose secondary 52 feeds a 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.

The individual sections of the precipitator are periodically de-energized during the cleaning period in synchronism with the movement of the cleaning hood of the precipitator. According to the disclosure, the de-energization of the electrodes of each section is effected by magnetic devices using saturable cores within which the level of magnetic saturation is varied. These magnetic elements in turn control the saturable power reactors, series reactors and parallel reactors in the primary A. C. power lines of the precipitator.

Referring to Figure 3, the numeral 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. 62 and 63 are the magnetic loops of a saturable reactor, one preferably consisting of Deltamax material. The magnetic cores 62 and 63 carry five separate windings each designated by numbers 64, 65, 66, 67, 68 as shown in the drawing. Instead of providing single reactor loops with a multiplicity of windings on each one, they could be sub-divided into several pairs of reactor loops, arranged in series or in parallel as the function requires.

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 by, for instance, making use of the well-known D. C. feed-back connections (coils 65) or the well-known self saturating connection could be applied. The rectified output of the reactor 62, 63 leads to the series reactors 60.

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 adjacent resistor 55. The direction of D. C. flow in the respective coils 64 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 flashover 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 electrodes 18 the position of the rotary cleaning nozzle 38 and hopper 32 results in energizing the magnetic pick-up 80, 82.

The energization and de-energization 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. The control of the precipitator as described above

requires two sets of reactors, series and parallel reactors designated **60** and **70**. 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.

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** in receiving its trigger by induction from the control wheel **80**. 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 dependant current of coils **67**. Since **66** and **67** are wound to oppose each other, both effects the decrease in voltage and the increase in current add up and cancel the excitation of the control reactor as received from the magnetic pick up on top of the precipitator. 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 pased through the excitation windings **71, 72, 73** of the parallel rectors **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.

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 ½ second. During this clearing 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 would escape the precipitator during the time of flashover if both sections **16, 25** (which are in series with respect to the gas stream), should be connected to the same power supply.

It is the object of this invention to arrange the connection of power supplies to the precipitator sectors in such a manner that successive sections **16, 25** with respect to the gas stream are supplied by different power supplies without increasing the number of power supplies needed and without appreciably reducing the efficiency which the precipitator would develop in case no flashovers occur. It should be noted that even in an efficiently operated precipitator, the frequency of flashovers may be expected to occur at the average rate of 50 flashes per section per minute.

Figure 4 shows the proposed connection for the single precipitator consisting of two banks A and B of twelve sections each being supplied by a set of twelve power supplies. It will be noted from the sketch that the bottom bank IIB of each sector is connected in parallel to the top bank IIIA of the adjoining sector. Therefore, if the lower section IIB is temporarily inactive due to flashover, the top section IIA stays in operation being supplied from a different power supply. A peculiarity of this connection appears during the scavenging period. In the old way when top IIA and bottom IIB were connected to the same power supply two sections were deenergized during this scavenging period while the adjoining sections were operated in the reduced transition voltage. In the proposed connection as shown in Figure 5, one section of each transition position is completely de-energized, while the other section in this position operates at reduced voltage. In addition, one section in each further adjoining position operates at reduced voltage. The corresponding efficiency figures show a slight loss which, however. will more than compensate the fact that the loss in efficiency during flashovers are minimized.

The new connection lends itself easily to such installations where two precipitators are operated on the same boiler. As shown in Figure 6, the cleaning hoods **35** of both precipitators will run in synchronism. This may be effected by means of a long shaft **100** or by an electric Selsyn drive. Corresponding sections IA of the upper bank A of the two precipitators are connected in parallel to the same power supply **101** and the same parallel connection is applied for the bottom sections **10** of both precipitators with respect to a second set of twelve power supplies **121** to **132**. The individual load of each bank A or B supply is not increased compared with the conventional connection where heretofore top and bottom sections of each sector and each precipitator were connected to the same power supply.

This application is a division of the application filed in my name under Serial No. 374,673 on August 17, 1953.

What I claim is:

1. In electrostatic precipitator apparatus having inlet and outlet ducts for laden and clean gases, respectively; banks of electrodes and associated collecting surfaces interposed between said inlet and outlet ducts arranged adjacent each other in a number of groups to form tiers that include a bank from each of at least two groups so that in flowing between the inlet and outlet ducts gases successively traverse at least two banks arranged serially in a tier; electrical power supply packs for charging the said electrodes including one supply pack for one bank of each tier; other power supply packs for the other bank of each tier; means for periodically isolating at least one tier including banks from different groups;

and means for regulating said power supply packs to reduce the voltage supplied to one bank of at least one tier while maintaining voltage in the other bank of said tier and in other adjacent tiers of said groups.

2. In an electrostatic precipitator having a housing, and inlet and outlet ducts for laden and clean gases, respectively; banks of electrodes and associated collecting surfaces interposed between said inlet and outlet ducts and arranged adjacent each other in several groups to form tiers including a bank from each group so that in flowing from the inlet to the outlet duct the gases successively traverse several electrode banks arranged serially; means for periodically isolating at least one tier including one bank of each group for cleaning the electrodes thereof while precipitation continues in other tiers; and means for applying a charging voltage to each bank so connected that the same voltage supply connects with a bank in one group and an adjacent bank in another group not aligned in a tier with the first bank in the direction of gas flow.

3. In an electrostatic precipitator having a housing, and inlet and outlet ducts for laden and clean gases respectively; banks of electrodes and associated collecting surfaces interposed between said inlet and outlet ducts and arranged adjacent each other in several groups to form tiers including a bank from each group so that in flowing from the inlet to the outlet duct the gases successively traverse several electrode banks arranged serially; means for periodically isolating at least one tier including one bank of each group for cleaning the electrodes thereof while precipitation continues in other tiers; and means for applying a charging voltage to each bank so connected that one voltage supply pack connects with one bank of a particular tier while the other bank

thereof is supplied by a different supply pack; and means for regulating said power supply packs independently of each other.

4. In a gas cleaning system; a pair of electrostatic precipitators each having inlet and outlet ducts for laden and clean gases respectively; banks of electrodes and associated collecting surfaces interposed in each precipitator between inlet and outlet ducts with the banks in each precipitator arranged in upper and lower groups to form tiers including a bank from each group so that in flowing from the inlet to the outlet duct in a precipitator the gases successively traverse lower and upper banks arranged serially; a pair of electrical power supply packs for charging the electrodes of said precipitators; means connecting one power supply pack to the electrodes in the lower banks of each tier of both precipitators; means connecting the other supply pack to the electrodes of the upper bank in each tier in both precipitators; means in each precipitator for periodically isolating at least one tier including one bank of each group for cleaning the electrodes thereof while precipitation continues in other tiers, means associated with each precipitator for cleaning the isolated tiers, and means for operating the isolating means and the cleaning means of the two precipitators in synchronized relation.

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