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CONTROL CIRCUIT FOR ELECTRO-MAGNETIC RAPPERS FOR PRECIPITATORS

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This invention relates to electrical control circuits and more particularly, to an improved circuit for periodically and automatically actuating an electro-magnetic hammer for jarring or rapping the electrode plates of an electrical precipitator to remove layers of dust and the like that have collected on the plates.

Electrical precipitators for cleaning gas streams of impurities, usually comprise a series of oppositely charged electrodes alternately arranged in rows or groups. The gas stream carrying suspended particles to be removed is caused to pass through one or more electric fields maintained between the electrodes where the suspended particles acquire an electric charge of one polarity and are subsequently attracted to and collected upon the electrode or electrodes of opposite polarity.

The collected dust particles, if not removed, build up a thick layer on the collecting electrode, until the dielectric characteristics of the particles impair the collection efficiency of the precipitator. The collecting electrodes are members of extended surface formation, for example plates, to provide a large surface area upon which the dust particles can collect.

It has been common practice, accordingly, to jar or rap the collecting electrodes periodically in order to shake loose the accumulated layer of dust particles. These dust particles drop off the electrodes in relatively large masses which fall by gravity into hoppers below the electrodes. If the precipitator is in operation for a relatively long period, say several hours, between rapping periods and is then continued in operation during these intermittent rapping periods, heavy puffs or dust clouds usually appear above the stack, caused by re-entrainment of a portion of the loosened particles in the gas stream. This condition is undesirable for many reasons and various design features have been introduced into precipitators to overcome or prevent this loss of collected particles by re-entrainment. For example, collecting electrodes are provided that are hollow or formed with pockets to shield the falling dust particles from the gas stream. Also, precipitators have been subdivided into a plurality of units, any one of which may be cut off from the gas stream by suitable dampers during the rapping period. These additional features are not only expensive but sometimes are either ineffective or impractical.

In view of these circumstances, it has been considered desirable to rap the electrodes at relatively long intervals of time. On the other hand, if too much time elapses between rapping periods, the dust layer on the electrodes will build up sufficiently to render operation of the precipitator inefficient. The precipitator ordinarily operates satisfactorily provided the dust layer does not build up to a certain critical thickness; but accumulation of dust beyond this critical thickness results not only in a marked decrease in collection efficiency but in greater re-entrainment losses. Accordingly, there is an optimum time interval between rapping periods for which maximum overall collection efficiency of the precipitator is attained.

Proper rapping of electrodes is of great importance in

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determining overall performance of the precipitator and solution of this problem has been very difficult. With the present trend towards higher efficiencies and the objections raised to the dust clouds or puffs associated with the above-described intermittent rapping, current practice is to rap the electrodes either continuously or at short intervals of the order of one minute. This fast cycle of rapping as well as continuous rapping requires that the intensity of the blows be closely controlled and considerably lighter than the heavy blows which are delivered with the intermittent rapping first mentioned.

The actual rapping is best accomplished by mechanical hammering on the electrode plates. Vibrations of proper intensity established in the plates as a result of each blow, serve to shake loose the accumulated dust. Generally an electrically operated hammer is now used. With regard to the rapping operation itself, it has been found at times that several light blows rapidly repeated on the plates serve to remove the accumulated dust more readily than one or two blows or raps of large magnitude.

The present invention has as its primary object to provide a control circuit for energizing a plurality of electrically operated rappers associated with a plurality of precipitator plates, in a sequential manner and at controlled intervals, whereby units of the precipitator need not be shut down to prevent re-entrainment of dust during the rapping operation.

More particularly, an object is to provide a control circuit for a plurality of rappers which is fully automatic in operation and adapted to time a rapping cycle at proper intervals and thus insure maximum overall efficiency in the operation of an electrical precipitator.

A further object is to provide a control circuit for a plurality of electrically operated rappers which is extremely flexible in its timing of all operations in order to permit the widest possible variation in all time intervals during and between rapping cycles.

These and other objects and advantages of this invention are attained by segregating the precipitator collecting electrodes into a plurality of groups, generally five or so electrodes to a group, and associating with each group an electrically operated hammer or rapping means. When a rapping cycle is to begin, the first group of electrodes is subjected to a series of blows. After the first group has been rapped, timing means automatically de-energizes the rapping means associated with the first group and energizes the rapping means associated with the second group. The rapper for the third and succeeding groups are in turn energized while all other rappers are de-energized. This sequential operation is continued until the several groups of electrodes have all been rapped in series. The next rapping cycle may then be automatically delayed for a predetermined time or a new rapping cycle may be started immediately. The thickness of the dust layer on a given electrode or group of electrodes is approximately proportional to the length of time the precipitator is in operation since the last previous rapping cycle. Therefore, the control circuit is provided with timing means for repeating the rapping cycle of each electrode at an interval of time calculated from the amount of time taken for the dust layer to build up to a selected thickness. Accordingly, removing the dust from the precipitator plates may be accomplished entirely automatically and at suitably timed intervals to insure maximum overall operating efficiency.

A preferred embodiment of the invention will now be described in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic circuit diagram of the electrical control circuit of the invention;

Fig. 2 is a schematic perspective view of one group of

precipitator plate electrodes typical of the groups associated with the circuit of Fig. 1; and

Fig. 3 is a fragmentary circuit diagram showing a variation in a position of the circuit of Fig. 1.

Referring to Fig. 1, there is shown a source of electrical energy 10 connected through a transformer 11 to a power conductor 12 and a grounded conductor 13. The conductor 12 includes a rectifier R-1 and a pair of switches S-1 and S-2 connected in series and, as indicated by the dashed line 14, arranged to be operated by a relay coil 15 shown in the central right hand portion of the drawing. The switches S-1 and S-2 are gang connected for simultaneous operation in opposite directions. Thus, when switch S-1 is closed, switch S-2 is opened, and when switch S-1 is opened, switch S-2 is closed.

The power conductor 12 terminates in a step contact arm S-3 adapted to sequentially engage a series of lead contacts a, b, c, d, e, f, g, and h connected respectively to a series of electrically operated rapper coils A, B, C, D, E, F, G, and H. The other ends of these coils are connected to the grounded conductor 13 as shown.

Connected to conductor 12 between switches S-1 and S-2 and to the grounded conductor 13, is a storage condenser 16. This condenser will be connected across the secondary of the transformer 11 and rectifier R-1 when the switch S-1 is closed, as seen in Fig. 1. On the other hand, when the switch S-1 is opened and the switch S-2 is closed, the condenser 16 will be connected across one of the rapper coils depending upon the position of the step contact arm S-3. In Fig. 1, this step contact arm is connected to the lead contact a, and therefore, the condenser is connected across the rapper coil A.

The electrically operated rappers A through H are identical and description of one will suffice for all. Referring to Fig. 2, the coil A for example, is shown in the form of a solenoid around an iron core 17. Energization of the coil A pulls the core 17 into the coil and strikes a blow on anvil 18 rigidly secured to a cross bar 19 connected to a group of precipitator collecting electrodes 20. Electrodes 20 are shown as being plates, a typical simplified form of electrode; but the invention is in no way limited to this shape of electrode. The cross bar 19 transmits blows on the anvil 18 to all of the electrodes 20 connected to the cross bar. When coil A is de-energized, core 17 is returned upwardly to a normal rest position by spring 17b which bears against head 17a on the core and also on a fixed member 17d, normally a part of the housing enclosing coil A. The upward travel of core 17 is limited by suitable means, for example stop 17c engaging member 17d. The arrangement shown is typical; but the power stroke of core 17 may be delivered upwardly or horizontally by changing the position of the coil and core 17.

Coil A is energized by a surge of current from the condenser 16 of Fig. 1. When the switch S-1 is closed and the switch S-2 is opened, the condenser 16 builds up a voltage charge corresponding to the peak uni-directional voltage across the secondary of transformer 11 and rectifier R-1. When the switch S-1 is open and the switch S-2 is closed, this peak voltage results in a discharge current passing along conductor 12, through the step contact arm S-3, lead contact a, and coil A to grounded conductor 13. This discharge surge energizes the coil A to move the core 17.

The collapse of the magnetic field in coil A will normally generate a back E. M. F. This back voltage is shunted to the power lead 12 by flyback rectifier R-2 connected between the conductors 12 and 13 to provide a low resistance discharge path for the coil. The result is a high current flow, when the magnetic field collapses, that adds substantially (as much as 50%) to the pull of solenoid coil A on the core. Also, the back voltage is dissipated and will therefore not affect the next charge built up on the condenser 16.

A meter 21 is connected between the grounded con-

ductor 13 and the power conductor 12 through a conductor 22 and current limiting resistance 23, for indicating the voltage build up across the condenser 16. Normally, this meter is inoperative as it is shunted out of the circuit by a push-button switch 24. When it is desired to read the meter 21, the push-button 24 is actuated to open the shunt across the meter.

An indicator lamp 25 in series with a voltage dropping resistance 26 is connected in shunt with the condenser 16. When condenser 16 discharges, this light is energized. The meter 21 and the lamp 25 thus serve to indicate to an operator that the build up and discharge of condenser 16 are taking place properly.

As mentioned earlier, it has been found that a series of several light blows on the precipitator electrodes is more effective in removing the dust layer and in preventing subsequent re-entrainment than one or two relatively hard blows. The switches S-1 and S-2 are therefore actuated in opposite directions several times during the time the step contact arm is held on lead contact a. There is thus generated a series of rapid discharge currents for energizing the coil A.

After the electrodes associated with the coil A have been rapped a suitable number of times, the step contact arm is caused to move to lead contact b, as indicated in Fig. 1 by the dashed line 28, upon energization of a step control 29 in the upper portion of the drawing. The step control may be a conventional master control stepping relay coil adapted to step the arm S-3 each time current to the step control is broken and re-established. This stepping movement of the step contact arm S-3 disconnects the arm from lead contact a and connects it to lead contact b to place the coil B across the condenser. The coil B is then similarly energized by a series of discharge surges from the condenser 16. Sequential switching of the arm S-3 from coil to coil is continued until all coils of the rappers have been connected and all of the groups of plates 20 have been suitably rapped.

The control of the switches S-1 and S-2 by the relay coil 15 and the proper stepping of the step contact arm S-3 by the step control 29, is accomplished by a pair of timing circuits shown in the upper portion of Fig. 1.

Referring to the left side of the schematic circuit a pair of leads 30 from the electrical source 10 are connected to the primary of transformer 31 and through the transformer 31 to power conductors 32 and 33. A timing motor 34 is connected through selector switch arm S-4 from conductor 33 to conductor 32 by a lead 35. This motor is arranged to actuate a pair of ganged switch arms S-5 and S-6 both connecting to lead 35. An indicating lamp 36 in series with a suitable voltage dropping resistance is connected between the power conductor 32 and one terminal of the switch arm S-5. The other terminal of switch arm S-5 connects to a transfer lead 37 terminating in one contact 38 of a second selector switch arm S-7 ganged to the first selector switch arm S-4.

One terminal of the switch arm S-6 is open. The other terminal connects through a lead 39 to one side of the step control 29. The other side of the step control is connected directly to the power conductor 32. An indicating lamp 40 and voltage dropping resistance are connected between conductors 32 and 39 in parallel with step control 29 as shown.

Another timing motor 41 is connected across the power conductors 32 and 33 by a lead 42 and is arranged to actuate a pair of ganged switch arms S-8 and S-9. The switch arm S-8 is directly connected to the lead 39. The relay coil 15 is connected between the switch arm S-9 and the power conductor 32.

One terminal of the switch arm S-8 is open while the other is connected to a lead 43 terminating in a contact for the selector switch arm S-4 as shown. One ter-

minal of the switch arm S-9 is also open while the other connects through a jumper lead 44 to the transfer lead 37.

For reasons that will become clearer as the description proceeds, the timing motor 34 is arranged to throw the ganged switch arms S-5 and S-6 back and forth between their solid and dotted line positions in order to move the step contact arm S-3 from any one lead contact to the next at predetermined time intervals. This timing motor operates to terminate the complete rapping cycle and initiate it again after a given interval of time because it controls the stepping of arm S-3 from lead contact *h* to contact *a*. The timing motor 41, on the other hand, continuously operates to throw the ganged switch arms S-8 and S-9 back and forth between their solid and dotted line positions at a given frequency to energize the rappers. The actual control of the switch arms S-5, S-6, S-8 and S-9 by the timing motors 34 and 41 can be accomplished by suitably notched cam wheels rotated at fixed speed by the motors. Such switch control means are so well known in the art, it is not thought necessary to describe them here in detail.

In operation, assume that all of the switches shown in Fig. 1 are initially in their solid line positions. Under these circumstances, a charge builds up on condenser 16 since switch S-1 is closed. Also both timing motors 34 and 41 are operating since the selector switch arm S-4 is closed, completing the circuit through the motors between power conductors 32 and 33 which are connected through the transformer 31 to the electrical source 10. As long as the switch arms S-5 and S-6, controlled by the timing motor 34, are in their solid line positions, the operation of the switch arms S-8 and S-9 by timing motor 41 does not affect the circuit, inasmuch as the leads 43 and 37 connecting to the terminals of these switch arms are open. With the switch arm S-5 in its solid line position, the indicator lamp 36 is energized. This lamp indicates that the timing motor has not yet commenced a rapping cycle. With the switch arm S-6 in its solid line position, the step control 29 is energized through switch arm S-4, lead 35, switch arm S-6 and lead 39. However this step relay control will not actuate the step contact arm S-3 until the step control is de-energized and then energized again.

After a lapse of time during which the dust layers on the precipitator plates, such as the plates 20 of Fig. 2, build up to an allowable thickness, the timing motor 34 throws the switch arms S-5 and S-6 to their dotted line positions. With these switch arms in the dotted line positions, power from conductor 33 passes through normally closed selector switch arm S-4, lead 35, switch arm S-5, and transfer lead 37 to the jumper lead 44 connecting to one terminal of the switch arm S-9. This power is thereby available for energizing relay coil 15 when switch arm S-9 is moved to its dotted line position. Power, formerly supplied through switch arm S-6 and lead 39 to the step control 29 is disconnected when switch S-6 is opened. Also the indicating lamp 36 is extinguished by opening switch S-5. The switch arms S-5 and S-6 are held in their dotted line positions for a predetermined period, the length of which is the interval between step movements of arm S-3 and includes the time during which impulses delivered to the connected one of rapper coils A to H.

When the continuously operating timing motor 41 throws the switch arms S-8 and S-9 to their dotted line positions, the relay coil 15 is energized through switch arm S-9 to open switch S-1 and close switch S-2. Closing switch S-2 completes the condenser discharge path through coil A thereby operating the rapper mechanism associated therewith.

The timing motor 41 is arranged to actuate switch arms S-8 and S-9 several times during the period that timing motor 34 is holding switch arms S-5 and S-6 in their dotted line positions. Each time the switch arm

S-9 is opened and closed, the relay coil 15 is energized to actuate the switches S-1 and S-2. Alternate opening and closing of these two switches provides repeated discharges of the condenser 16 through the coil A.

After the coil A has been subjected to a suitable number of energizing impulses, timing motor 34 momentarily returns the switch arms S-5 and S-6 to their solid line positions to connect power from lead 35 through switch arm S-6 and lead 39 to the step control 29. This step control then, upon re-energization, moves the step contact arm S-3 from lead contact *a* to lead contact *b* connecting coil B across the condenser 16. Movement of the switch arm S-5 to its solid line position energizes the lamp 36. The switch arms S-5 and S-6 are then returned to their dotted line positions disconnecting the circuit through switch arm S-6 to the step control 29 and re-establishing the circuit through switch arm S-5 to the transfer lead 37, jumper lead 44, switch arm S-9 and relay coil 15. Simultaneously, the indicator lamp 36 is again extinguished. A new series of discharges from condenser 16 is then passed through coil B to energize the rapper associated therewith a given number of times.

This sequential stepping of the step contact arm S-3 by the step control 29 and alternate energizing of the transfer lead 37 and jumper lead 44 to enable relay coil 15 to be energized, is continued under the control of the timing motor 34 until all of the rapper coils A through H have been energized. The timing motor 34 may be arranged to hold the switch arms S-5 and S-6 in their solid line positions at the completion of the rapping cycle. Indicator lamp 36 at this time, remains on, indicating the cycle has been completed.

After a preset interval of time a new rapping cycle is again initiated by the timing motor 34, and the above operation repeated. In one preferred timing of the rappers, arm S-3 is actuated at uniform time intervals so that the time delay in moving from contact *h* to *a* is the same as from *a* to *b*. Hence a new rapping cycle is started shortly after completing one, and the inactive time is distributed throughout the cycle between periods of active rapping. On the other hand, my invention is easily adapted to any distribution of time that may be desired, making for maximum flexibility in timing the periods of active rapping and the full cycles, both as to duration and intervals between them. This is possible by setting the time control elements of motors 34 and 41.

In the event it is desired to check the operation of the various rapper coils A through H and it is not desired to wait throughout a normal rapping cycle, the selector switch arms S-4 and S-7 may be manually thrown to their dotted line positions. In these positions, power is supplied from conductor 33 through the switch arm S-4 and the lead 43 to the switch arm S-8 to operate the step control 29 when the switch arm S-8 is closed. Power also is supplied through the switch arm S-7, contact 38, lead 37, and jumper lead 44 to the contact of switch arm S-9. With these connections, the step control 29 is energized and accordingly moves the step contact arm S-3 to the next lead contact. When the continuously operating timing motor 41 throws the switch arms S-8 and S-9 to their dotted line positions, the step control 29 is de-energized and the relay coil 15 is energized by power passing up from contact 38, lead 37, jumper lead 44, and switch arm S-9. The step control 29 is thus de-energized while the condenser 16 is discharging as a result of energization of the relay coil 15, each time switch arms S-8 and S-9 are thrown to their dotted line positions, and the step control 29 will be energized and the condenser 16 charged up each time the switch arms S-8 and S-9 are thrown to their solid line positions. With this arrangement, each of the rapper coils A through H receives only one rap before the step contact arm S-3 is moved to the next lead contact, and this operating cycle continues indefinitely until the selector switch arms S-4

and S-7 are returned manually to their solid line positions.

Fig. 3 shows a modification of the circuit in which separate switches S-1 and S-2 are replaced by a single-pole, double-throw switch S-10. This switch is actuated by relay coil 15 by a connection as at 14. Switch S-10 is of the break-before-make type in order to insure arm S-3 being deenergized when it moves. By preventing current flow at the time of stepping the arm, the contacts are free of pitting and burning and give a long trouble-free life. With a single switch, both conductor 22 and condenser 16 are connected to the central or common contact of the switch arm. Otherwise the circuit is as described.

It will be understood from the above description that the circuit of the present invention provides a fully automatic means for controlling the rapping of various groups of electrodes of a precipitator. It is equally adapted to rapping groups of plates in slow or rapid sequence by the simple expedient of adjusting the time interval between steps of arm S-3 and the time interval between the end of one cycle and the start of the next. Experience demonstrates that when the groups of plates are rapped in comparatively rapid sequence, the precipitator need not be closed down during rapping because the rapping causes very little disturbance in operation. Further, the timing control motor 34 insures that the proper intervals of time elapse between rapping cycles prior to commencement of the next cycle. The timing control motor 41 makes it easily possible to vary within a wide range the number of blows, and the rate of their delivery, received by each individual group of plates.

Various modifications within the scope and spirit of the present invention will occur to those skilled in the art. The rapping control circuit is therefore not to be thought of as limited to the specific embodiment disclosed for illustrative purposes.

What is claimed is:

1. A control circuit for sequentially energizing a plurality of electrically operated rappers associated respectively with a plurality of groups of precipitator electrodes to remove dust layers from said electrodes, said control circuit comprising, in combination: a source of electrical energy; a step contact arm adapted, upon actuation, to be disconnected from one of said electrically operated rappers and connected to another of said electrically operated rappers; circuit means including switch means for applying electrical energy derived from said source to said step contact arm; a first timing control means for operating said switch means at a constant frequency throughout a given period; and second timing control means for rendering said first timing control means operative during said given period and for actuating said step contact arm to place said arm in successive electrical contact with each of said electrically operated rappers throughout said given period.

2. A circuit according to claim 1, in which said second timing control means includes means for initiating and terminating said given period and subsequently initiating and terminating said given period in a repeated manner whereby given intervals of time elapse between the termination of one period and the initiation of the next.

3. A control circuit for sequentially energizing a plurality of electrically operated rappers associated respectively with a plurality of groups of precipitator electrodes to remove dust from said electrodes, said control circuit comprising, in combination: a source of electrical energy; a condenser connected to said source to be charged therefrom; a movable step contact arm connected between said condenser and the rappers and movable to successive positions in each of which it electrically connects one of the rappers to said condenser; switch means having alternate positions for alternately connecting said condenser in shunt with said source and with said rappers whereby the condenser is adapted to be discharged through one of said rappers; a first timing control means

shifting said switch means between alternate positions at a predetermined frequency; and a second timing control means shifting said contact arm to successive positions at a frequency lower than said predetermined frequency, whereby a plurality of alternations of the switch means occur while the contact arm is at each position.

4. A circuit as in claim 3 that also includes a second switch means associated with the second timing control means and actuated by the first timing control means to prevent movement of the first mentioned switch means while the contact arm is being shifted from one position to another.

5. A control circuit for sequentially energizing a plurality of electrically operated rappers associated respectively with a plurality of groups of precipitator electrodes to remove dust from said electrodes, said control circuit comprising, in combination: a source of electrical energy; circuit means connected to said source of delivering energy to said rappers and including a first switch means operable to energize and de-energize the circuit and a second switch means movable to successive positions in each of which it electrically connects one of the rappers to the circuit means; a first timing control means operatively connected to the first switch means to energize the circuit means intermittently; and a second timing control means operatively connected to the second switch means to move it to successive positions, the first and second timing control means operating in timed relation whereby a plurality of actuations of the first switch means occur at each position of the second switch means.

6. A control circuit for sequentially energizing a plurality of electrically operated rappers associated respectively with a plurality of groups of precipitator electrodes to remove dust from said electrodes, said control circuit comprising in combination: a source of electrical energy; a condenser; circuit means adapted to be sequentially connected to said electrically operated rappers, said circuit means including a step contact arm between said condenser and said electrically operated rappers adapted, upon actuation, to be disconnected from one of said rappers and connected to another of said rappers whereby said condenser may be sequentially connected across each of said rappers during said given period; switch means for alternately connecting said condenser in shunt with said source and with said circuit means, whereby a charge built up on the condenser from said source is adapted to be discharged through the circuit means upon operation of said switch means; a first timing control means for operating said switch means at a given frequency; and a second timing control means for rendering said first timing control means operative during a given period and including means for actuating said step contact arm after a given number of condenser discharges have passed through any one of said electrically operated rappers.

7. A control circuit for sequentially energizing a plurality of electrically operated rappers associated respectively with a plurality of groups of precipitator electrodes to remove dust from said electrodes, said control circuit comprising in combination: a source of electrical energy; a condenser; circuit means adapted to be sequentially connected to said electrically operated rappers; switch means for alternately connecting said condenser in shunt with said source and with said circuit means, whereby a charge built up on the condenser from said source is adapted to be discharged through the circuit means upon operation of said switch means; a first timing control means for operating said switch means at a given frequency; and a second timing control means for rendering said first timing control means operative during a given period and including means for initiating and terminating said given period and subsequently again initiating and terminating said given period in a repeated manner whereby given intervals of time elapse between

the termination of one period and the initiation of the next.

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