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METHOD AND APPARATUS FOR ELECTRICAL PRECIPITATION

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Fig. 1.

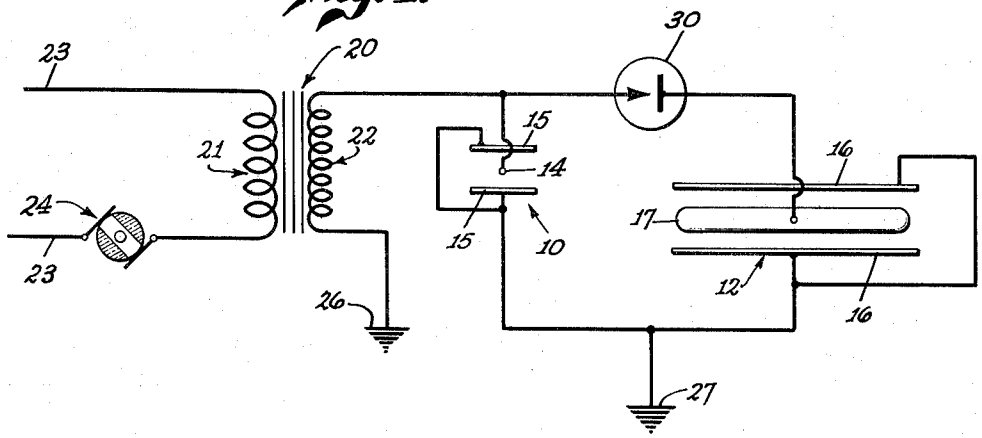
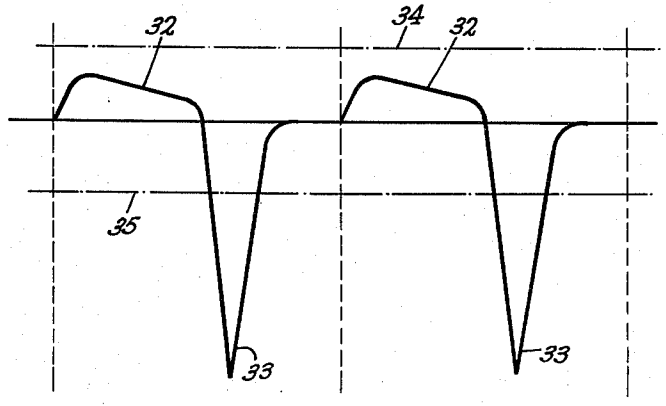


Fig. 2.



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METHOD AND APPARATUS FOR ELECTRICAL PRECIPITATION

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The present invention is generally concerned with the art of electrically precipitating suspended particles from a stream of gas; and it is more particularly concerned with improvements in methods and in apparatus of the type in which the particle laden gas is first passed through a charging field in which corona discharge is produced, in order to electrically charge the suspended particles, and is then passed through a spatially separate precipitating field, which is substantially free from corona discharge, in order to precipitate the charged particles. The gas is subjected successively to two functionally distinct fields, and for this reason a precipitator of this type has been termed a "two-stage" or "separated field" precipitator. In its basic form, a precipitator of this type has a first field maintained between two electrodes of which one is a discharge electrode and the other is a non-discharging electrode, and a second field maintained between two substantially non-discharging electrodes.

In the following description and appended claims, the term "discharge electrode" will be understood to designate an electrode that facilitates corona discharge therefrom, because it has a configuration that establishes a sufficiently high potential gradient at or near its surface to create corona discharge before there is a disruptive discharge or spark-over. For this purpose, the discharge electrode usually takes the form of a member of small surface area, such as a small diameter wire or a rod provided with sharp edges or points, whereby there may be created in the immediate vicinity thereof a sufficiently high electric field intensity to cause ionization and corona discharge. The term "non-discharging electrode" will be understood to designate an electrode that minimizes or prevents corona discharge therefrom because it has a configuration that establishes a sufficiently low field concentration at or near the surface to suppress corona discharge at elevated potentials lower than the voltage required for disruptive discharge or spark-over. For this purpose, a non-discharging electrode is usually one of extended surface area, substantially free from sharp corners or other parts of sharp surface curvature at all portions which are located within the electric field, so as to substantially avoid ionization or corona discharge at that electrode.

The construction and advantages of an electrical precipitator of the two-stage or separated field type are discussed in Patent No. 1,343,285 granted June 15, 1920 to W. A. Schmidt and also in Patent No. 2,192,172 granted March, 1940 to Evald Anderson. Briefly, these advantages are economy of installation and operation; advantageous inherent operating characteristics with certain types of dust; a much reduced tendency to the detrimental phenomenon of "back-corona" in the collecting section; and possibility of maintaining a relatively higher potential gradient between the precipitating electrodes in the collecting section, thus bringing about very effective collection.

The phenomenon of back-corona arises when dust of relatively non-conducting characteristics is being collected in a precipitator. Experimentally, it has been found that when the specific resistance of the collected material is less than approximately 10^{10} ohm-cm., little or no trouble with back corona is encountered; and it is with dusts of greater specific resistance, and which are referred to as having relatively high specific resistance or having relatively non-conducting characteristics, that back corona is most frequently encountered. For the purposes of this disclosure, back-corona may be considered to be corona discharge at or in the immediate vicinity of a non-discharging electrode that is opposing a discharge electrode. The back-corona discharge is consequently opposite in electrical sign to the main discharge and therefore produces ions of an opposite sign to the main supply of ions. Since a discharge electrode usually produces negative ions, the back discharge ordinarily is thought of as producing positive ions. The mechanics of the occurrence of back-corona are not entirely understood, but apparently are as follows:

Particles of non-conducting dust collect upon the surface of a non-discharging electrode opposing a discharge electrode and eventually the collection is sufficient that, even though the layer is very thin, it is substantially continuous and has the effect of insulating the electrode from the space around it. As a result of the presence of this insulating layer, there is an alteration in the potential and field distribution around the electrode in such a way that a relatively larger proportion of the total potential drop between the electrodes occurs across the dust layer. The immediate result is a decrease in voltage across the gas and a decrease in corona current, with a consequent reduction in efficiency of the precipitator. Eventually the voltage drop across the dust layer becomes sufficiently great that the layer breaks down locally, a small hole being formed in the layer into which the gas flows. In

the vicinity of this hole, the gas becomes a good conductor and there is a concentration of the field and the discharge at this hole. The result is either a spark-over between the electrodes or back-corona discharge from the normally non-discharging electrode, whether spark-over or back-corona appears depending upon various factors.

Several undesirable conditions that reduce the precipitator efficiency result from back-corona. The spark-over voltage is greatly lowered and it is necessary that the applied voltage be reduced in order to maintain corona discharge at the discharge electrode. Also, there is a concentration of discharge at the points of local rupture in the dust layer with the result that there may be large sections of the space through which the gas stream flows that have relatively few ions. This means that there is a lower average charge on the dust particles, or in other words that the charging ability of the precipitator is decreased. Probably the most important result of back-corona is that positive ions are produced at the points of back-corona. Not only do the positive ions reduce the charging and collection efficiency of the precipitator by neutralizing the negative ions producing negative charges on the dust particles, but the positive ions produce positively charged dust particles which tend to collect upon the discharge electrode and thus interfere with maintenance of the proper ionizing field.

In a two-stage precipitator, back-corona is not ordinarily present in the precipitating section, even though there is a heavy dust layer present, because of the almost complete absence of current between the electrodes.

However, there is often a very strong tendency toward back-corona in the charging section of a two-stage precipitator. It has been found that in charging sections having non-discharging electrodes upon which dust particles can accumulate, very considerable trouble with back-corona arises when the dust is of a particularly non-conducting nature. The amount of dust collected upon a non-discharging electrode in the charging section can be made relatively small compared with the quantity collected in the precipitating section, but nevertheless an amount which cannot be neglected will always be precipitated.

It is thus a general object of my invention to eliminate back-corona from the charging section of a two-stage precipitator and at the same time to collect the suspended particles in a dry condition.

It is an object of my invention to provide electrical precipitation apparatus of the two-stage type which maintains a relatively high collection efficiency at all times because it is operated and constructed in a manner to prevent the occurrence of back-corona discharge that would reduce the normal collection efficiency.

Electrical apparatus for energizing precipitators has heretofore usually included transformers and rotary rectifiers that receive power from an alternating current source and apply a uni-directional current to the precipitator. Since this type of apparatus must handle high voltages and give uninterrupted service over a long period of time, conventional types of apparatus have been relatively very expensive to construct and also to install; and this expense has, in many cases, been sufficiently great to make the use of precipitators prohibitive from a commercial viewpoint.

It is a further object of my invention to provide electrical apparatus for energizing a two-stage precipitator that is relatively simple and inexpensive to build and install, and which is adapted to energize the charging field of the precipitator in such a manner as to reduce to a minimum any precipitation of particles therein; and more particularly is it an object to provide electrical apparatus that does not include rotary rectifiers.

These objects of my invention are attained according to my improved and novel method, carried on in two-stage electrical precipitation apparatus comprising two spatially separated pairs of electrodes, by establishing the charging field between the first pair of electrodes by applying to that pair of electrodes successive asymmetrical alternating current impulses which comprise two half-waves of opposite polarity. The peak or maximum potential of one half-wave is of sufficient magnitude to create corona discharge at the discharge electrode, while the peak or maximum potential of the other half-wave is insufficient to produce any corona discharge. The charging field is thus alternating in direction or polarity, but effects only a uni-polar charging of dust particles. The field between the second pair of electrodes and in which the charged particles are precipitated, is established preferably by applying to the second pair of electrodes the half-wave of higher potential from said current impulses. The precipitating field is thus uni-directional.

Electrical apparatus energizing a precipitator according to my novel method includes suitable means, connected to the discharge electrode, for generating or forming high tension asymmetrical alternating current impulses of the character described above; and also suitable means, connected to the second pair of electrodes, for supplying thereto uni-directional current, preferably from said impulses.

In a preferred form of apparatus embodying my invention, the first means is an induction coil with an interrupter in the primary circuit to which unidirectional current is supplied from any suitable power source, the secondary of the induction coil being connected to the first pair of electrodes and the characteristics of the coil being such that current impulses are generated in the secondary with one half-wave of sufficiently high peak potential to produce corona discharge at the discharge electrode while the peak potential of the other half-wave, of opposite polarity to the first mentioned half-wave, is not sufficient to produce corona discharge. In a broad view, the means for supplying uni-directional current to the second pair of electrodes may be entirely independent of the means used for generating the asymmetrical wave impulses applied to the discharge electrode; but it is preferred to connect the second pair of electrodes to the secondary of the induction coil, or other equivalent apparatus, through a suitable rectifying means which eliminates one half-wave of current impulses and applies the other half-wave to the non-discharging electrode. Preferably, the half-wave so applied to the non-discharging electrode is the half-wave of higher potential.

How the above objects and advantages of my invention, as well as others not specifically mentioned above, are attained will be more readily understood by reference to the following description and the annexed drawing, in which:

Fig. 1 is a diagrammatic representation of a two-stage precipitator and an electrical circuit for energizing the electrodes; and

Fig. 2 is a graphical representation of a typical asymmetrical electrical impulse.

Fig. 1 illustrates diagrammatically a preferred form of electrical circuit and apparatus for energizing electrodes in a precipitator, and illustrates also the principles involved in carrying out my improved method of removing the suspended particles from a stream of gas. As the characteristic features of the method and the apparatus used for carrying out that method become apparent from the following description, it will be understood that my invention is not necessarily limited to the particular form and arrangement of apparatus shown therein, but that any other suitable apparatus may be used.

Fig. 1 illustrates diagrammatically a two-stage precipitator comprising one or more first pairs of electrodes constituting a charging section indicated generally at 10 and one or more second pairs of electrodes constituting a spatially separated collecting or precipitating section indicated generally at 12. The charging section comprises one or more discharge electrodes 14 each of which is opposed by one or more non-discharging electrodes 15. Likewise, the precipitating section comprises two or more non-discharging electrodes 16 upon which the charged gas particles are collected, and which are opposed by one or more centrally located non-discharging electrodes 17 which are of the same polarity as discharge electrode 14. Although the diagrammatic arrangement illustrates the relative placement and location of electrodes common in horizontal-flow type precipitators in which the gas stream flows parallel to the surface of the electrodes, it will be understood that the invention is equally applicable to vertical-flow precipitators having tubular electrodes and transverse-flow precipitators with fluid pervious electrodes through which the gas flows.

There is indicated generally at 20 an induction coil having a primary winding 21 and a secondary winding 22. Primary winding 21 is connected by leads 23 to any suitable source of unidirectional current, and an interrupter 24 in one of leads 23 intermittently interrupts the primary circuit, as is conventional with induction coils. Although interrupter 24 is here indicated as being of the rotary or commutator type, it will be understood that any other mechanical or electrolytic type that is suitable may be used, as may be dictated by the requirements of electrical design. The number of turns in the secondary winding is many times that in the primary, in order to provide the desired high ratio of secondary voltage to primary voltage.

One side of secondary winding 22 is grounded, as at 26, while the other side of the secondary winding is connected to discharge electrode 14 to impress thereon a relatively high voltage. Discharge electrode 14 is insulated from other portions of the precipitator, and opposing non-discharging electrodes 15 are grounded, as at 27, in order to establish a high potential difference between electrode 14 and electrodes 15.

Collecting electrodes 16 are also grounded, as at 27. It is the usual practice to have electrodes 15 and 16 electrically connected together, as they are both maintained at ground potential. High tension non-discharging electrode 17 is maintained at a relatively high potential with respect to electrodes 16 by connecting it to the side of secondary winding 22 which is connected to discharge electrode 14. However, in the circuit connecting electrode 17 to the secondary winding, there is placed suitable rectifying means 30 that operates to pass to electrode 17 only one half-wave of the alternating current impulses generated in secondary 22, thus maintaining electrode 17 always at the same polarity with respect to the grounded electrodes 16. Typically, the rectifying means 30 may be a thermionic vacuum tube.

When the precipitator is in operation, unidirectional current is applied to induction coil 20 through leads 23, and interrupter 24 is placed in operation to make and break the circuit to primary winding 21 at any desired frequency. Each time the circuit is completed and broken by interrupter 24, there is produced in secondary winding 22 an electrical impulse which has two portions of opposite polarity. Since this impulse has portions of opposite polarity, it may be considered as being an alternating current impulse; and the portion of each polarity is herein termed a "half-wave" although it will be understood that the two half-waves are not thereby indicated to be similar in shape, duration, or potential. On the contrary, the impulse is an asymmetrical impulse, as may be seen by reference to Fig. 2 which illustrates a typical impulse having the desired characteristics. During the interval of time when the primary circuit is completed by interrupter 24, there is formed in secondary 22 the positive half-wave 32 of the electrical impulse; and as may be seen from Fig. 2, this positive half-wave 32 preferably has a relatively low, flat wave-form. When the primary circuit is broken by interrupter 24, there is produced in secondary 22 the negative half-wave 33 of the alternating current impulse; and it will be seen from Fig. 2 that the negative half-wave has a steep, peaked wave-form such as is characteristic of induction coils.

If the horizontal lines 34 and 35 represent respectively the positive and negative potentials at which corona discharge appears at discharge electrodes 14, it will be noticed that the maximum potential of the positive wave 32 is lower than the potential indicated by 34 and that consequently during this portion of the electrical impulse corona discharge is not produced at electrode 14. On the other hand, the maximum negative potential of the half-wave 33 exceeds the potential indicated at 35 as necessary to produce corona discharge, and consequently during the existence of the negative wave 33, corona discharge occurs at discharge electrode 14. As a result of applying to discharge electrode 14 an asymmetrical alternating current impulse of the character described, the electric field between electrodes 14 and electrodes 15 is continually alternating in direction or polarity; but since the corona discharge occurs only when electrode 14 is negative, the only corona discharge produced in the charging section 10 is of one polarity. Negative corona discharge at electrode 14 is preferred for various technical reasons; but it will be seen that, by connecting the electrode to the other side of secondary 22, positive corona can be produced if desired.

The alternating current impulse of Fig. 2 cannot be applied in that form to electrode 17, as in the precipitating section it is necessary to have a uni-directional field between electrode 17 and the collecting electrodes 16; and in order that the precipitating field be in one direction, it is neces-

sary that electrode 17 have but one polarity This is accomplished by means of the half-wave rectifier 30 interposed in the circuit between electrode 17 and the terminal of secondary winding 22. During the initial or positive portion of the impulse, no current passes. But during the latter or negative portion of the impulse, half-wave 33 passes current through the rectifier and electrode 17 is placed at a relatively high negative potential with respect to grounded electrodes 16. There is thus established between electrodes 16 and 17 an electrostatic field which is substantially non-discharging since both electrodes 16 and 17 are designed to be non-discharging electrodes.

The frequency of the impulses should be sufficiently high that several impulses are applied to electrode 14 during the time that any one dust particle is subjected to the action of the charging field. For example, if the particle is in the field for .1 second, the frequency of the impulses would preferably be 100 per second or greater, but not less than say 50 per second. The spacing between electrodes 14 and 15 also influences the minimum frequency, as a closer spacing of the electrodes makes a higher frequency admissible. On the other hand, very high frequencies of several thousand impulses per second make the duration of the negative wave so short that inefficient charging of the particles results, with consequent low collection efficiency.

From the foregoing, it will be seen that my novel improvements in methods of removing suspended particles from a stream of gas in a two-stage precipitator include establishing the field in the charging section of the precipitator by applying to the pair of electrodes in that section successive asymmetrical alternating current impulses, each impulse comprising two half-waves of opposite polarity. As a result of the opposite polarity of the half-waves, the electric field between the electrodes alternates in direction or polarity and as a consequence any tendency of the field to cause charged particles to become precipitated upon grounded electrodes 15 is very greatly reduced, and in some cases substantially eliminated. As a consequence, the charging section operates to effect charging of the suspended particles and is substantially unhampered by collection upon the grounded electrodes of non-conducting particles that cause back-corona discharge, as previously explained.

Another advantage of my improved method of applying asymmetrical alternating current impulses is that during the time in which the discharge electrode is charged positively at a potential such that no corona discharge occurs, the accumulated charges upon the non-conducting particles that may have collected upon the grounded electrodes can leak away and thus the tendency towards production of back-corona is materially reduced.

By supplying to the discharge electrode asymmetrical impulses of which the two half-waves have substantially different peak potentials and only one half-wave is of sufficient peak potential to create corona discharge at the discharge electrode, particles in the gas stream are always charged with the same polarity. These particles are then collected in the precipitating section of the precipitator by applying to the high tension electrode in that section only the half-wave that produces corona in the charging section. Application of the half-wave of higher potential to the high tension electrode in the collecting section maintains between the non-discharging electrodes an electric field which is in the proper direction to move the charged particles toward the grounded electrodes 16.

The foregoing description of my novel method and apparatus is intended only to illustrate the general principles and characteristics of my invention, for it will be understood that the invention is not necessarily limited thereto. It is an advantageous feature of my invention that expensive mechanical rectifiers usually used in conjunction with precipitators are dispensed with and replaced by the induction coil and interrupter supplied with uni-directional current. This latter is particularly simple and inexpensive equipment to install and operate. However, it will be understood that, where an induction coil is not satisfactory because of the power requirements, other types of electrical apparatus may be used to supply asymmetrical current impulses. For example, a motor-generator set may be used having an alternating current generator adapted to produce suitable asymmetrical waves. Likewise it is possible to replace the induction coil and interrupter with an alternating current transformer of the saturated core type producing asymmetrical waves in the secondary winding; or electrical circuits employing vacuum tubes may be used, as will be understood by those skilled in the art.

For the rectifier 30, a vacuum tube may be used; but this particular piece of apparatus may be replaced by other types of rectifiers such as a point-to-plate spark gap or, in the event that a rotary interrupter 24 is used, a rotary rectifier synchronized with the interrupter.

For the purposes of simplicity it is preferred that both electrodes 14 and 17 be connected to the same secondary winding 22; but it will be understood that it is within the scope of my invention to energize electrodes 17 from any suitable source, which may if desired be independent of high potential applied to electrode 14. In this connection, the only requirement is that electrode 17 be maintained at a sufficiently high potential of the proper polarity to cause charged suspended particles to migrate towards collecting electrodes 16 which are grounded through the connection at 27.

Having set out a preferred form of my invention and described the essential characteristics of my novel method and the apparatus preferred for carrying out that method, it will be understood that various changes may be made in my invention without departing from the spirit and scope thereof; and it is therefore to be understood that the foregoing description is to be treated as illustrative of rather than limitative upon the claims appended hereto.

I claim:

1. In the method of removing suspended particles from a stream of gas by flowing the gas stream past a first pair of electrodes of which one is a discharge electrode and between which is maintained an electric field in which the particles are charged by corona discharge, and then past a second pair of electrodes between which is maintained a substantially non-discharging field in which charged particles are precipitated, the improvement that comprises establishing the first field by applying to the first pair of electrodes successive asymmetrical alternating current impulses comprising two half-waves of opposite polarity to maintain between said electrodes a field of alternating polarity.

2. In the method of removing suspended par-

ticles from a stream of gas by flowing the gas stream past a first pair of electrodes of which one is a discharge electrode and between which is maintained an electric field in which the particles are charged by corona discharge, and then past a second pair of electrodes between which is maintained a substantially non-discharging field in which charged particles are precipitated, the improvement that comprises establishing the first field by applying to the first pair of electrodes successive asymmetrical alternating current impulses comprising two half-waves of opposite polarity of which one half-wave only is of sufficient maximum potential to create corona discharge at the discharge electrode to maintain between said electrodes a field of alternating polarity.

3. In the method of removing suspended particles from a stream of gas by flowing the gas stream past a first pair of electrodes of which one is a discharge electrode and between which is maintained an electric field in which the particles are charged by corona discharge, and then past a second pair of electrodes between which is maintained a substantially non-discharging field of single polarity in which charged particles are precipitated, the improvement that comprises establishing the first field by applying to the first pair of electrodes successive asymmetrical alternating current impulses comprising two half-waves of opposite polarity and unequal potential to maintain between the first pair of electrodes a field of alternating polarity, and maintaining the second field by applying to the second pair of electrodes only the higher potential half-wave of said current impulses.

4. In the method of removing suspended particles from a stream of gas by flowing the gas stream past a first pair of electrodes of which one is a discharge electrode and between which is maintained an electric field in which the particles are charged by corona discharge, and then past a second pair of electrodes between which is maintained a substantially nondischarging field of single polarity in which charged particles are precipitated, the improvement that comprises establishing the first field by applying to the first pair of electrodes successive asymmetrical alternating current impulses comprising two half-waves of opposite polarity of which one half-wave only is of sufficient maximum potential to create corona discharge at the discharge electrode to maintain between the first pair of electrodes a field of alternating polarity, rectifying said impulses, and applying only one half-wave of said current impulses to the second pair of electrodes to establish the second field.

5. The method of removing suspended particles from a gas stream which comprises subjecting the gas stream to the action of a first electric field of alternating polarity maintained between a pair of electrodes of which only one is a discharge electrode at which unipolar corona discharge takes place and in which field the suspended particles are charged; and subsequently passing the gas stream with the charged suspended particles through a second electric field of single polarity and substantially free from corona discharge, in which field the charged particles are collected.

6. Apparatus for energizing from a source of electric current an electric precipitator of the separated field type having a first pair of opposing electrodes of which one is a discharge electrode and a second pair of opposing non-discharging electrodes spaced from the first pair, comprising means connected to the first pair of electrodes and supplying thereto high tension asymmetrical alternating current impulses comprising two half-waves of opposite polarity.

7. Apparatus for energizing from a source of electric current an electric precipitator of the separated field type having a first pair of opposing electrodes of which one is a discharge electrode and a second pair of opposing non-discharging electrodes spaced from the first pair, comprising means connected to the first pair of electrodes and supplying thereto high tension asymmetrical alternating current impulses comprising two half-waves of opposite polarity of which one half-wave only is of sufficient maximum potential to produce corona discharge at the discharge electrode.

8. Apparatus for energizing from a source of electric current an electric precipitator of the separated field type having a first pair of opposing electrodes of which one is a discharge electrode and a second pair of opposing non-discharging electrodes spaced from the first pair, comprising means connected to the first pair of electrodes and supplying thereto high tension asymmetrical alternating current impulses comprising two half-waves of opposite polarity, and means connected to the second pair of electrodes and supplying thereto unidirectional current impulses.

9. Apparatus for energizing from a source of direct electric current an electric precipitator of the separated field type having a first pair of opposing electrodes of which one is a discharge electrode and a second pair of opposing non-discharging electrodes spaced from the first pair, comprising an induction coil of which the secondary is connected to the first pair of electrodes and which supplies thereto high tension asymmetrical current impulses comprising two half-waves of opposite polarity of which one half-wave only is of sufficient maximum potential to produce corona discharge at the discharge electrode.

10. Apparatus for energizing from a source of direct electric current an electric precipitator of the separated field type having a first pair of opposing electrodes of which one is a discharge electrode and a second pair of opposing non-discharging electrodes spaced from the first pair, comprising an induction coil of which the secondary is connected to the first pair of electrodes and which supplies thereto high tension asymmetrical current impulses comprising two half-waves of opposite polarity and unequal potential, and rectifying means connecting the secondary of the induction coil to the second pair of electrodes to rectify the current impulses and apply to the second pair of electrodes only the impulses of higher potential.

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