May 7, 1935. R. HEINRICH 2,000,020

METHOD OF ELECTRICAL PRECIPITATION OF SUSPENDED PARTICLES FROM GASES

Filed May 26, 1932

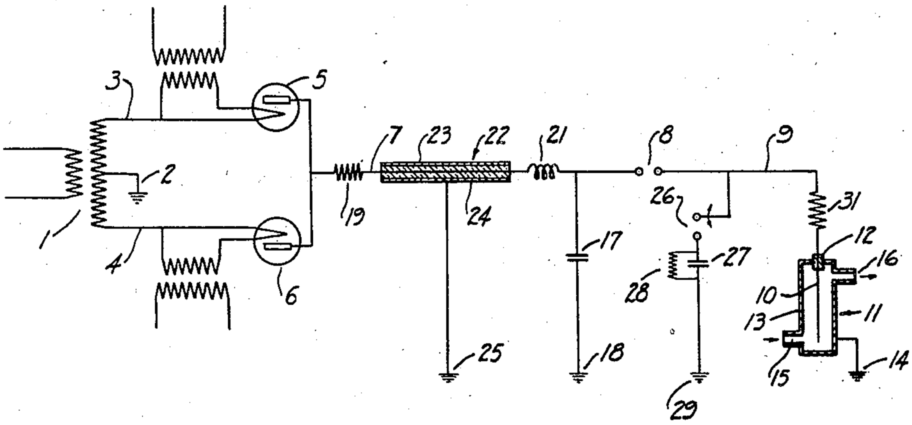

Fig. 1

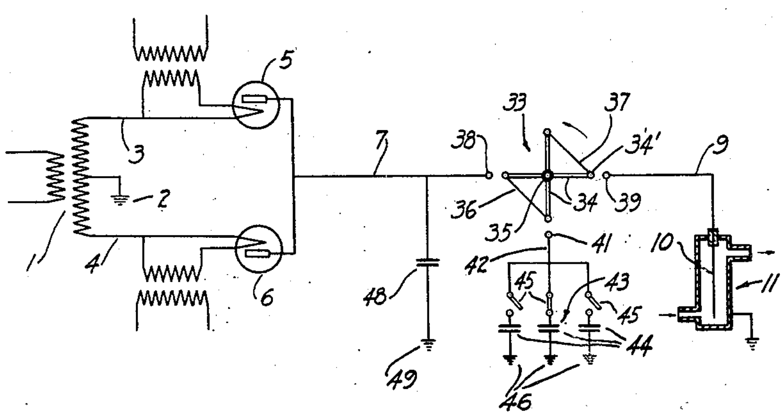

Fig. 2

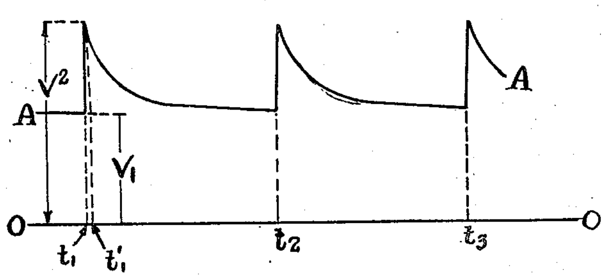

Fig. 3

INVENTOR
RICHARD HEINRICH
BY Arthur P. Knight and Alfred W. Knight
ATTORNEYS

Patented May 7, 1935

2,000,020

UNITED STATES PATENT OFFICE

2,000,020

METHOD OF ELECTRICAL PRECIPITATION OF SUSPENDED PARTICLES FROM GASES

Richard Heinrich, Berlin-Sudende, Germany, assignor to International Precipitation Company, Los Angeles, Calif., a corporation of California

Application May 26, 1932, Serial No. 613,783
In Germany June 2, 1931

8 Claims. (Cl. 183—114)

This invention relates to electrical precipitation processes, that is, to processes for the electrical treatment of gases for the purpose of removing suspended particles therefrom.

The principal object of the invention, in general, is to improve the efficiency of operation of such methods by applying relatively high electrical potential impulses, of extremely short duration and steep wave front, to opposing electrodes between which the gas is passed, whereby the potential between the electrodes may be momentarily raised to a sufficiently high value to produce intense ionization in the gas without causing objectionable arcing or short-circuiting between the electrodes, through said gas.

In the operation of electrical precipitators it has been found that the precipitation efficiency depends very materially upon the ionization density within the gas being treated, and that an increase in the production of ions therein increases the efficiency of electrical precipitation. In ordinary electrical precipitation methods, using either continuous direct current or intermittent unidirectional current such as obtained by rectification of alternating current of commercial frequency, the gas is maintained substantially continuously in an ionized condition, or is subjected to a close succession of ionizing periods of relatively long duration, which causes paths of relatively high conductivity to be established between the electrodes, so that there is a definite limit imposed upon the potential which may be applied between the electrodes, for a given electrode spacing, without serious danger of arcing or disruptive discharge therebetween, along these conductive ionized paths. This in turn limits the ionization density obtainable, since such arcing or disruptive discharge must be substantially eliminated if the electrical field intensity between the electrodes is to be kept sufficiently high to effect electrical precipitation, and if the current flow is to be kept within reasonable limits. For this reason, the maximum density of ionization heretofore obtainable in such methods is about 10^8 to 10^9 ions per cm^3.

A particular object of the invention, therefore, is to provide a method in which a potential materially greater than that which can normally be used, is applied to the electrodes between which the gas is passed, but in which this abnormally high potential is applied in intermittent impulses of such short duration and steep wave front as to prevent the creation of an arc or short-circuit between the electrodes during each impulse, while the potential is permitted, between successive impulses, to fall below the ionization potential and such intervening periods are made sufficiently long to permit substantial dissipation of the ions from the gas during such intervals.

According to the preferred embodiment of this invention, the duration of each potential impulse applied to the electrodes is equal to or less than the time required for the formation of an ionized condition across the entire distance between the opposing electrodes, so that ions formed at or adjacent the discharge electrodes will be permitted to migrate only to about, or somewhat in front of, the surface of the opposing electrodes, so that by the time any ionized path of gas might be set up extending across the entire distance between the electrodes, the potential between the electrodes is reduced sufficiently to prevent arcing or disruptive discharge along such path. In most cases, with the spacing between electrodes on the same order as ordinarily employed, the time required for formation of any such complete ionized path is on the order of about 10^{-3} seconds, and I therefore prefer to use potential impulses of shorter duration than this and preferably of 10^{-5} seconds or less. I also prefer to use potential impulses in which the voltage, during each impulse, rises quickly to its maximum or peak value, preferably in about 10^{-6} seconds or less, and then falls to a sufficiently low value to prevent arcing. It has been found that, by the use of impulses of this type, the voltage between the electrodes may be instantaneously raised to a value at least 30% greater than under previous methods of energization without any danger of flash-over between the electrodes, and consequently a more intense and uniform corona discharge may be produced, with a correspondingly greater degree or density of ionization.

Another objectionable phenomenon that is encountered in electrical precipitation, particularly when the material to be precipitated is of a non-conducting or poorly conducting nature, is that the surface of the layer of precipitated material on the collecting electrodes tends to accumulate an electrical charge of a different potential than the collecting electrode itself, due to the fact that the ions of opposite sign, which are driven by the electrical field to this surface, either with or without carrying suspended particles therewith, are prevented from passing immediately to the electrode itself, due to the relatively high resistance of the layer of precipitated material therebetween. The electrical potential thus created between the surface of this layer of material and the collecting electrode tends to produce ionization in the gas within this layer, and thus causes flow of ions into the gas stream from this surface also, so that the tendency to formation of complete ionized paths through the gas between the electrodes, and consequently the production of arcing or disruptive discharge therebetween, is further increased.

For this reason, it is a further object of the invention to prevent the accumulation of an electrical charge at the surface of the precipitated material on the collecting electrodes, and thus further minimize the tendency to arcing or disruptive discharge, and this object is accomplished by substantially interrupting the supply of electrical energy to said electrodes between successive impulses so as to provide a sufficient period of relatively low potential to permit ions formed during any one high potential impulse and reaching said surface, to be substantially entirely dissipated through the layer of precipitated material and reach the collecting electrode, before the next high potential impulse is applied. As described more fully hereinafter, the intervals of relatively low potential are relatively long as compared to the duration of the high potential impulses.

The accompanying drawing illustrates the forms of apparatus suitable for carrying out this invention, and referring thereto:

Fig. 1 is a diagrammatic view illustrating one form of such apparatus, and

Fig. 2 is a diagrammatic view showing a modified form of apparatus.

Fig. 3 is a graph showing the relation between voltage and time, in an electrical precipitator operated in accordance with this invention.

In Fig. 1, the numeral 1 indicates a transformer which steps up the supply voltage to the desired value. The middle of the secondary winding is grounded, as indicated at 2, while the terminals thereof are shown as connected through leads 3 and 4 and thermionic rectifiers 5 and 6 or any other suitable rectifying means to a common lead 7, which leads to one side of a spark gap 8, the other side of which is connected by lead 9 to the discharge electrode means 10 of an electrical precipitator 11, or to other suitable means for treatment of gases or liquids. Said discharge electrode means 10 is shown as insulated at 12 from the collecting electrode means 13 thereof, which is electrically grounded as at 14, and suitable means such as inlet 15 and outlet 16 are provided for passing gas or other fluid through the apparatus. Rectifiers 5 and 6 are preferably so connected as to permit passage of electric current to lead from each terminal of transformer 1 during only the alternate half waves when that terminal is at a negative potential with respect to ground.

Immediately before the spark gap 8, the lead 7 is connected to a charging condenser or capacitance 17, the other side of which is grounded at 18. Lead 7 is shown as including resistance 19 and inductance 21 for the purpose of suppressing high frequency oscillations and preventing such oscillations from reaching the rectifying and transforming apparatus. A portion of lead 7 is also shown as covered by a cable 22 provided with an insulating layer 23 and having its covering 24 grounded as at 25, so that said cable also acts as a charging condenser to augment the capacity of condenser 17.

It is also advantageous to provide another discharge path, connected in parallel with the precipitator, between the spark gap 8 and ground, and such discharge path is shown as comprising an adjustable spark gap 26 having one side connected to the lead 9 and the other side connected through condenser 27 and leaking resistance 28 to ground as indicated at 29.

In carrying out this invention with the apparatus above described, the unidirectional high voltage supplied by transformer 1 and rectifying means 5 and 6 serves to charge the charging capacity connected to lead 7, including not only condenser 17 but also the capacity of cable 22, until the voltage at the spark gap 8 becomes sufficient to break down said gap, whereupon the energy stored in said charging capacity is suddenly discharged across said gap and causes a high unidirectional potential impulse of extremely steep wave front and short duration to be applied between discharge electrode means 10 and the grounded collecting electrode means 13. This results in a uniform and intense corona discharge from all parts of the discharge electrode, accompanied by a high degree of ionization of the gas, and the ions thus produced cause suspended particles in the gas to become electrically charged and to be precipitated toward and upon the surface of collecting electrode 13. However, the discharge across gap 8 is of extremely short duration, and the supply of electrical energy is then interrupted. Furthermore, before any disruptive discharge can occur in the precipitator, the spark gap 26 also discharges, to charge the condenser 27 and reduce the voltage at the precipitator sufficiently to prevent such disruptive discharge. The charge on condenser 27 then gradually leaks off to ground through resistance 28. If desired, a retarding resistance 31 may also be connected in lead 9 between the point of connection of the auxiliary discharge gap 26 and the precipitator, for the purpose of further preventing disruptive discharge in said precipitator.

During the interval between each impulse and the next, the discharge electrode remains at a certain gradually diminishing potential with respect to the grounded collecting electrode, but this residual potential is insufficient to cause ionization, although it is still effective in causing migration of charged particles in the gas toward the collecting electrode and precipitation thereof on said electrode. During this interval, the ions are largely removed from the gas stream, and any electric charge which may have been built up on the surface of the layer of precipitated material on the collecting electrode is also permitted to leak off through such layer to said electrode.

It will be observed that by suitably selecting or controlling the constants of the above described circuits, and particularly the size of the charging capacity 17 together with the capacity of cable 22, in relation to the energy output of the transformer and rectifying means, and the break-down voltage of spark gap 8, as well as the relation between the auxiliary discharge means including gap 26 and the remaining parts of the circuit, high voltage impulses of any desired duration may be obtained, and any desired interval between successive impulses may also be maintained. According to this invention, the voltage at which the charging capacity, including condenser 17 and cable 22, is charged, and consequently the maximum potential of the relatively short impulses applied to the precipitator, is preferably from 30 to 100% greater than the voltage which could be maintained in an electrical precipitator of the same dimensions and electrode spacing if constant direct current or ordinary rectified alternating current were directly applied thereto. For example, with gases of ordinary composition, and a spacing of say 3 or 4 inches between the discharge electrode means and the collecting electrode means, the maximum voltage which could be applied, when using continuous direct current or ordinary rectified alternating current of commercial frequency, without causing disruptive discharge, would be about 40,000 to 70,000 volts, while, according to this invention, I prefer to employ a voltage, under the same conditions, of say 80,000 to 110,000 volts. Furthermore, the circuit is so adjusted as to cause each impulse delivered to the precipitator to have a duration no greater than the time required for establishment of a complete ionized path across the electrical field within the precipitator, and preferably a duration less than about 10^{-5} second, the voltage increasing to its crest value, for example, in 10^{-6} seconds or less, and then decreasing to a sufficiently low value to prevent arcing. Also, the adjustment of the system is preferably such as to provide an interval between successive impulses of sufficient duration to permit substantially complete dissipation of any electric charge through the precipitated material on the collecting electrode means, such interval being preferably not less than about 0.01 second. The length of these intervals between successive impulses may, for example, be increased to 1/50 or 1/25 second or longer.

In Fig. 3 time is plotted horizontally and voltage vertically. The voltage between the discharge and collecting electrode means is indicated by the line A—A, while the line O—O represents zero voltage. The time t_1 represents the start of an energy impulse caused by breakdown of the spark gap 8, and the sudden discharge of energy from the condenser 17 causes the voltage between the electrodes to rise sharply from the voltage V_1 existing prior to such impulse to a peak voltage V_2. As above stated, the constants of the circuit are preferably so selected and adjusted that the time required for the voltage to rise from V_1 to V_2, namely, the time interval t_1—t_1', is 10^{-6} seconds or less, and the peak voltage V_2 may advantageously be made at least 30% greater than the voltage which could be maintained between the electrodes of the precipitator if said electrodes were energized by impulses of ordinary commercial frequency. Due to the rapid discharge of energy from the condenser, the voltage across the spark gap 8 falls almost instantaneously to a sufficiently low value to break the spark, whereupon the voltage between the precipitator electrodes falls rapidly, so that the duration of the entire energizing impulse is very short and preferably about 10^{-5} seconds or less. Following this impulse, the supply of electrical energy from the condenser to the precipitator electrodes is discontinued for a relatively long period, and the voltage between said electrodes falls rapidly to a sufficiently low value to prevent formation of an arc discharge in the precipitator and thereafter falls more gradually to approximately the value V_1. At the time t_2 another impulse occurs in the same manner as before, and this is again repeated at the time t_3 and so forth.

In some cases it may be advantageous to provide means whereby the portion of the circuit through which each impulse is delivered to the precipitator is entirely disconnected from the source of high voltage used for charging the impulse condenser, at the time of each impulse in the precipitator. By this means the impulse discharge is positively prevented from producing any disturbing effects in the power supply means, including the main supply circuit, transformers, rectifiers, etc. For carrying out the invention in this manner, the form of apparatus shown in Fig. 2 may be employed. Transformer 1, rectifying devices 5 and 6, and electrical precipitator 11 are shown in the same manner as in Fig. 1. In this case, however, a rotary spark gap commutator 33 is provided between the lead 7 connected to the rectifying means and the lead 9 connected to the discharge electrode means 10 of the precipitator. Such commutator is provided with four insulating arms 34 mounted on a rotating shaft 35 driven at any suitable speed, and each of said arms is provided at its extremity with an electrode element 34'. Said electrode elements are connected in two diametrically opposed pairs, by means of conductors 36 and 37. Diametrically opposite to one another with respect to said commutator, and in sparking relation with respect to the electrode members 34', are provided fixed electrodes 38 and 39 connected respectively to leads 7 and 9. At a point halfway between the electrodes 38 and 39 is provided another electrode 41 connected by lead 42 to suitable impulse capacity means indicated at 42. Suitable means may be provided for varying the capacity of said capacity means. For example, said means may comprise a plurality of separate condensers 44 connected through corresponding switches 45 to lead 42 and electrically grounded as indicated at 46, so that by closing one or more of said switches, any desired number of said condensers may be connected in parallel.

A charging condenser 48 is also provided between lead 7 and a ground connection as indicated at 49. In the operation of this form of the invention, when the commutator 33 is in the position shown, the impulse capacity means 43 is charged by the larger charging condenser 48. When the commutator is turned through 90° in the direction shown by the arrow, said capacity means 43 will discharge through lead 9 to the discharge electrode means of the precipitator and cause a high potential impulse of the type above described to be applied thereto. It will be seen that, during the time of this last-mentioned discharge, the impulse capacity means 43 and the precipitator are entirely disconnected from the power supply means, so that the impulse is prevented from reaching said power supply means. In this case also, the electrical characteristics of the circuit are so adjusted as to provide impulses of the desired short duration and high potential, and the speed of rotation of commutator 33 may be made such as to provide the desired interval between successive impulses.

I claim:

This application is a continuation-in-part of my application Serial No. 593,426 filed February 16, 1932.

1. The method of electrical precipitation of suspended particles from gases which comprises producing unidirectional electrical energy at high voltage, storing said energy in a condenser, intermittently discharging energy from said condenser in an electrical field between opposing discharge and collecting electrodes to provide a series of short unidirectional high potential electrical impulses of steep wave front and sharp peak, substantially interrupting the supply of electrical

energy from said condenser to said electrodes for a relatively long period between each impulse and the next succeeding impulse, and passing gas containing suspended particles through said electrical field so as to subject the same to said electrical impulses and thereby causing precipitation of said suspended particles upon said collecting electrode, the peak voltage of each of said impulses being at least 30% greater than the voltage which could be maintained through said gas between said electrodes if said electrodes were energized by impulses of ordinary commercial frequency, and the duration of each of said impulses being sufficiently short to substantially prevent formation of an arc discharge between said electrodes.

2. The method as set fourth in claim 1, in which the duration of each of said electrical impulses is about 10^{-5} seconds or less.

3. The method of electrical precipitation of suspended particles from gases which comprises producing unidirectional electrical energy at high potential, storing said energy in a condenser, intermittently discharging energy from said condenser in an electrical field between discharge and collecting electrodes so as to provide a series of unidirectional high potential electrical impulses of steep wave front and sharp peak each having a duration of about 10^{-5} seconds or less, substantially interrupting the supply of electrical energy from said condenser to said electrodes between successive impulses for a period materially greater than the duration of each impulse, and passing gas containing suspended particles through said electrical field so as to cause said gas to be subjected to said electrical impulses and thereby cause precipitation of said suspended particles upon said collecting electrode.

4. The method as set forth in claim 5, in which the duration of the intervals between successive impulses is about .01 second or more.

5. The method of electrical precipitation of suspended particles from gas which comprises producing unidirectional electrical energy at high potential, storing said electrical energy in a condenser, intermittently discharging energy from said condenser in an electrical field between opposing discharge and collecting electrodes to provide a series of short unidirectional high potential electrical impulses of steep wave front and sharp peak, substantially interrupting the supply of energy from said condenser to said electrodes between successive impulses, and passing gas containing suspended particles through said electrical field so as to subject such gas to the action of said electrical impulses and thereby cause precipitation of said suspended particles upon said collecting electrode, the duration of each such impulse being no greater than the time required to form a complete ionized path through said gas between said electrodes, and the intervals between successive impulses being sufficient to permit electrical charges which accumulate at the surface of precipitated material on the collecting electrode during each impulse to pass through said material to said collecting electrode before the next succeeding impulse.

6. The method of electrical precipitation of suspended particles from gases which comprises producing unidirectional electrical energy at high potential, storing said electric energy in a condenser, intermittently discharging energy from said condenser in an electrical field between opposing discharge and collecting electrodes so as to provide a series of unidirectional high potential electrical impulses of short duration, substantially interrupting the supply of energy from said condenser to said electrodes between each impulse and the next succeeding impulse during an interval of materially greater duration than each of said impulses, and passing gas containing suspended particles through said electrical field so as to subject said gas to the action of said electrical impulses and thereby cause precipitation of said suspended particles upon said collecting electrode, each of said electrical impulses having an extremely steep wave front in which the voltage between the electrodes rises in about 10^{-6} seconds or less from the voltage existing prior to such impulse to a sharp peak value sufficiently high to produce corona discharge from said discharge electrode, after which the voltage falls to a value sufficiently low to prevent arcing between said electrodes.

7. The method of electrical precipitation of suspended particles from gases which comprises supplying to the opposed discharge and collecting electrodes of a precipitator intermittent unidirectional electrical impulses of steep wave front and sharp peak, the peak voltage of each of said impulses being substantially greater than the voltages which could be maintained through said gas between said electrodes if said electrodes were energized by impulses of ordinary commercial frequency and the duration of said impulses being sufficiently short to substantially prevent formation of an arc discharge between said electrodes.

8. The method of electrical precipitation of suspended particles from gases which comprises supplying to the opposed discharge and collecting electrodes of a precipitator intermittent unidirectional electrical impulses of steep wave front and sharp peak, the peak voltage of each of said impulses being substantially greater than the voltages which could be maintained through said gas between said electrodes if said electrodes were energized by impulses of ordinary commercial frequency and the duration of said impulses being materially less than the period between said impulses.

RICHARD HEINRICH.