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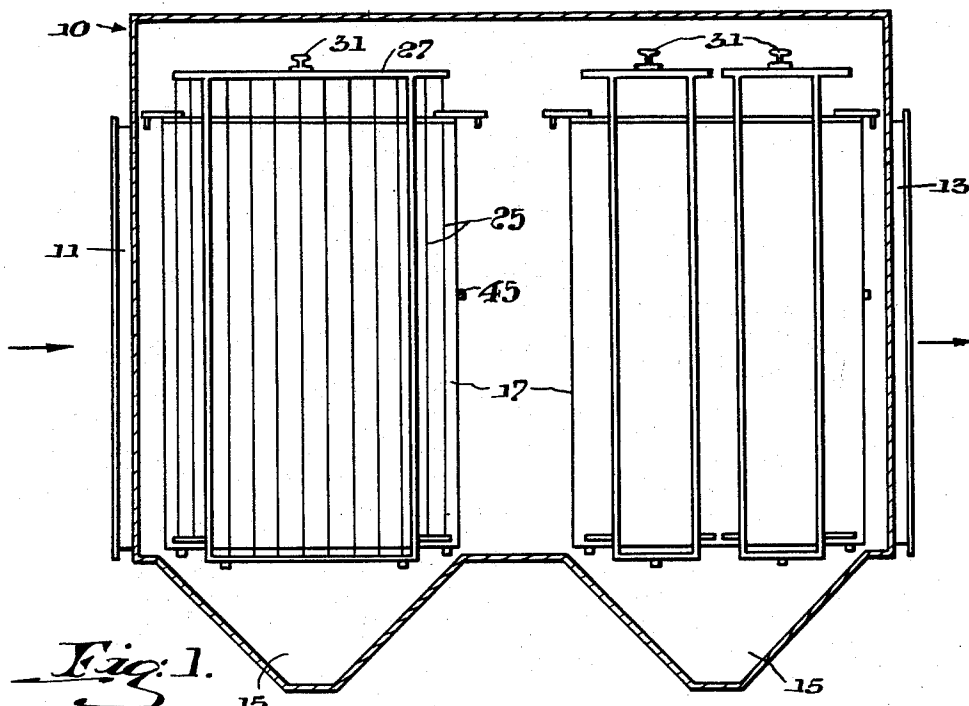
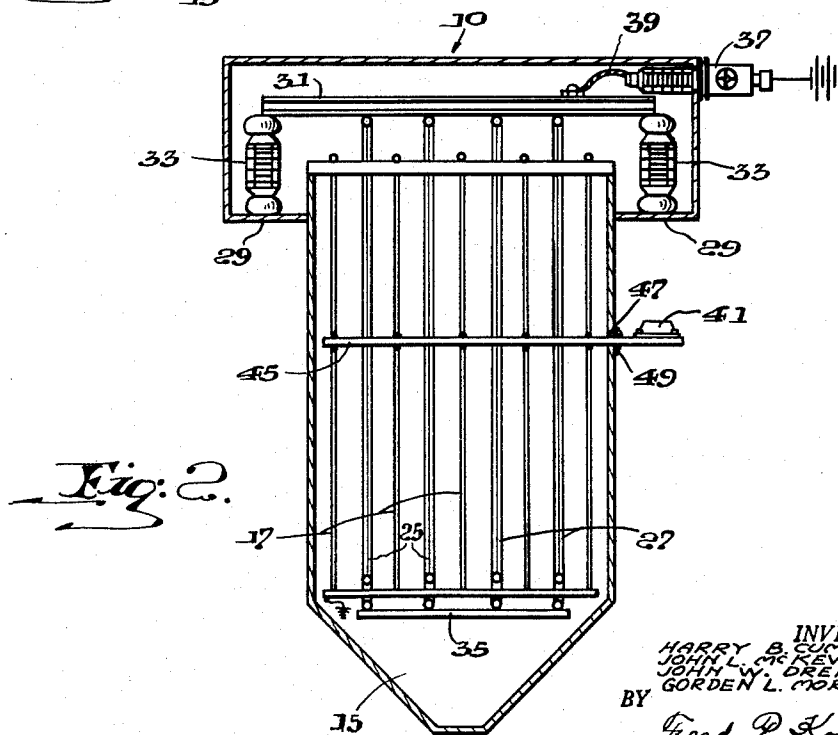
H. B. CUMMINGS ET AL

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ELECTROSTATIC PRECIPITATION

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2 Sheets-Sheet 1



INVENTORS
HARRY B. CUMMINGS,
JOHN L. KREWEN,
JOHN W. DRENNING
GORDEN L. MORGRET.
BY
Fred P. Kootka.
their
ATTORNEY.

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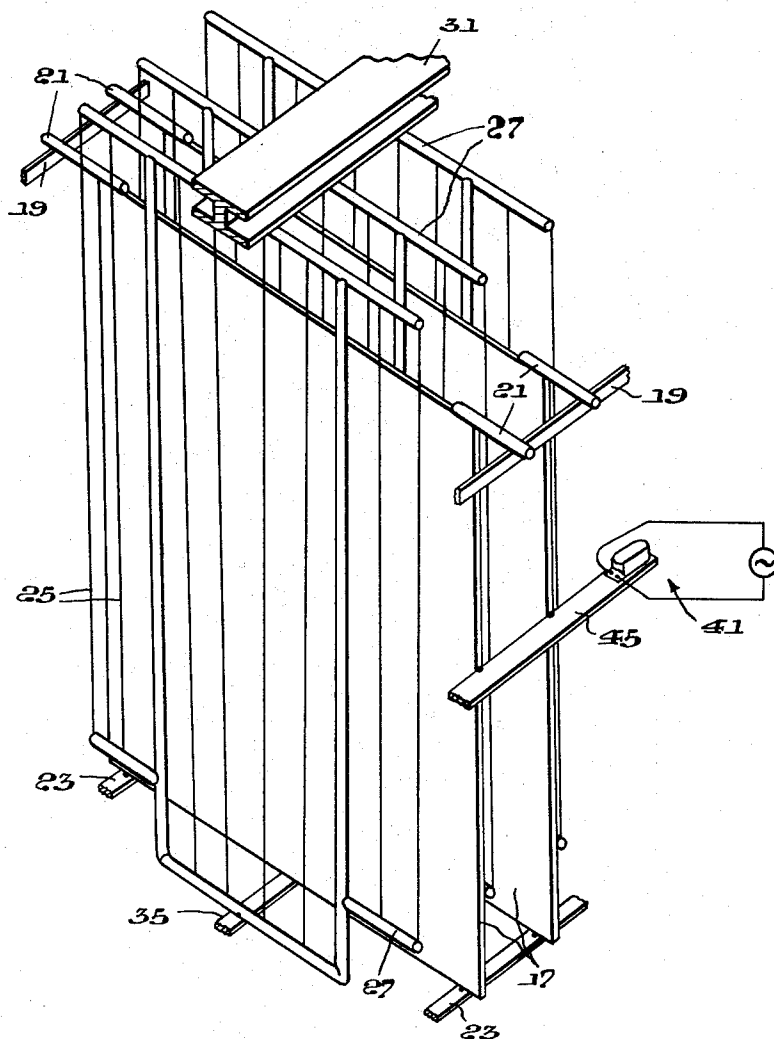


Fig. 3.

INVENTORS.
HARRY B. CUMMINGS,
JOHN L. McKEWEN,
JOHN W. DRENNING,
GORDEN L. MORGRET.
BY
Fred P. Kostka.
their
ATTORNEY.

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ELECTROSTATIC PRECIPITATION

Harry B. Cummings, John W. Drenning, John L. McKewen, and Gordon L. Morgret, Baltimore, Md., assignors to Koppers Company, Inc., a corporation of Delaware

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This invention relates to the removal of foreign particles from a gas stream by electrical precipitation employing electrodes for charging the particles and electrodes to which the particles are attracted and adhered. More particularly it is directed to a new and novel method for removing the precipitated particles from the electrodes.

In the cleaning of foreign particles from a gas stream by the electrical precipitation method the particle containing stream is passed through an ionized gas zone created by a corona discharge of relatively high field strength such that the particles are imparted with a charge of a given polarity. In practice, whenever possible the polarity of the charging zone is negative. The charged particles are then generally collected in a zone outside of the main stream of the gas flow. This collecting zone is generally provided with a charge of opposite polarity usually positive so as to attract the charged foreign particles in the oppositely charged zone.

Conventionally, the structure for carrying out the cleaning or removal of foreign particles from a gas in accordance with the above method comprises a plurality of discharge electrodes and collecting electrodes in spaced relationship. The discharge electrodes are supplied with a high voltage to create a corona discharge for ionizing the gas surrounding the same. The collecting electrodes are generally grounded and serve to attract the particles which are normally adhered thereto.

While considerable effort has been made in recent years to improve the efficiency of cleaning the gas by electrical precipitation by controlling and maintaining a maximum power input to the discharge electrodes so as to impart a high field strength commensurate with the gas characteristics and electrode geometry, the problem of reentrainment of the particles into the gas stream after they are collected on the collecting electrode has not been satisfactorily solved.

Generally, the electrodes are cleaned by one of two methods, either by washing the electrodes with a film such as water or rapping the electrodes so as to knock the particles therefrom. Cleaning by washing is not completely satisfactory inasmuch as it creates problems of discharging the effluent and further problems such as corrosion and the like under some applications. For this reason the rapping method has generally been employed.

There are two rapping methods in general use at the present time. One method employs a high energy output that is about five foot pounds per second, reciprocating (steady state), low frequency 60 cycle per second pneumatic or electric vibration. Under these conditions high amplitude vibrations at accelerations averaging between 8 to 12 g over the surface of the plates at frequencies between 40 to 60 cycles per second are imparted to the electrodes. The dust plates are vibrated violently and the dust is blasted into a gas stream where it can be reentrained and escape with the gas. With this method there is danger of mechanical failure of the equipment because of the relatively large deflections imparted to the collecting electrode and corresponding high stresses produced in the dust plate system. In order to minimize the mechanical failure, the vibrators are operated at intervals of only a few seconds at a time; amounting to a total vibration time of several minutes every hour. Con-

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sequently, a heavy dust layer can build up on the dust plates between the rapping periods thereby preventing the precipitator from operating at peak efficiency. This rapping method is normally used to remove sticky or tenacious dust, for example, found in the paper and in cement industries.

The other rapping method currently in general use employs either a pneumatic or electro magnetic impulse vibrator. The impulse vibrator imparts a shock or transient vibration to the dust plates. The duration of this transient vibration is very short decaying from an initially very high peak force to zero in a few tenths of a second. The dust plates are subjected to only a few hundred useful cycles of rapidly decreasing acceleration. If the impulses of vibration are applied at very close intervals such as once every thirty seconds, such a mode of operation is referred to in the art as "continuous" operation, even though there are intervals during which the vibrating device is not actually imparting vibrations to the electrodes. In the case of "steady-state" excitation, on the other hand, vibrations are imparted to the electrodes throughout the rapping operation. The advantage of the former rapping method over the latter mode of operation as previously practiced in the art resides primarily in the reduction of dust reentrainment and the elimination of mechanical failures. Its area of application has been in the power plant fly ash, open hearth, sintering, and metallurgical industries where normally the precipitated dusts are relatively easy to dislodge from the collecting plate.

From the foregoing discussion of the two rapping methods generally employed it may be concluded that the problem of reentrainment of the particles is dependent to some extent on the physical and chemical properties of the particles being removed from the stream. The electrical charging of the particles also influences the relative tenacity or adhering properties of the particles on the plate. For convenience the particles may be classified into those having high tenacity or high adhering characteristics and those having low tenacity or low adhering characteristics on the plate. In the former class there may be included the particles normally found in the paper or cement industries and in the latter class those particles which are found in the gases resulting from combustion of coal, i.e. fly ash, and the like.

The relative tenacity of the particles determine the methods normally employed. For example, if a low tenacity particle such as fly ash is present in the gas, the second method, described above, of applying impulse or rapidly decaying transient vibration is employed. This method, has heretofore, been used because the collecting plates do not have to be rapped violently at high amplitudes to dislodge the low tenacity ash. However, there is one drawback inasmuch as these non-tenacious particles are not homogeneous such that the plate must be rapped with force sufficient to dislodge the most tenacious of the particles. Therefore, the least tenacious of the particles are thrown back into the main gas stream thereby reducing the efficiency of the precipitator.

When the particles are of the tenacious class having high cohesive, adhesive and resistivity properties, steady-state, reciprocating rapping is generally employed. Such steady-state rapping must be at a high amplitude so as to dislodge the particles from the collecting electrode surface. Under these conditions the particles may break away from the plate in the form of pieces or individual particles. These pieces of agglomerate or individual particles tend to fall back into the main gas stream so as to reduce the cleaning efficiency of the precipitator. High amplitude, steady-state rapping is disadvantageous not only in that it results in structural failure, but also results in low power efficiency because the power input must be of a high order to obtain the high amplitudes.

In accordance with the present invention it is proposed to dislodge the dust or foreign particles from the electrode of an electrostatic precipitator in a manner such that the difficulties of reentrainment of the particles into the gas stream and mechanical failure of the structure created by the high stresses of rapping employed heretofore is substantially precluded.

This is accomplished, generally, by vibrating the electrodes of the precipitator so as to impart high acceleration contiguous to the electrode surface, which vibrations are controlled so as to maintain the amplitudes thereof at values below those which create destructive stresses in the precipitator structure. Normally, a steady-state, low amplitude vibration at high accelerations is employed so that the thickness level of the particles on the collecting electrodes is maintained at a minimum whereby the particles are dislodged by the intensity of vibration rather than by large structural deflections. In this manner the danger of mechanical failures to the plate is minimized and the reentrainment of the particles into particle free stream is substantially reduced. Mechanical failure of the plate is prevented because the amplitudes are maintained at values below those which causes stresses creating mechanical failures. The reentrainment is not as great inasmuch as the plate deflections are minimized and the dust is not knocked into the main gas stream as formerly. Advantageously, because the amplitude is maintained small, the power input required to achieve the frequency of acceleration to dislodge the dust may also be reduced.

It is a further object to impart accelerations to the collecting plate which are of such magnitude as to prevent the substantial formation of an agglomerate layer of foreign particles thereon. In accordance with the method of the present invention in the event it is desired or conditions warrant a minimum concentration of the particles is maintained contiguous to the collecting plate. These particles are continually agitated such that they are displaced along the surface of the plate somewhat in the nature of a flowing stream toward a collecting section or sections provided in or adjacent to the plate. Under these conditions of constant agitation the agglomeration of the particles into a unified mass is minimized such that the amplitude of vibration needed to dislodge the particles from the plate is not as great as employed heretofore.

In effect this invention seeks to approach the performance of an irrigated precipitator with respect to minimizing the reentrainment of precipitated particles during removal thereof. Thus, the application of vibrations in the practice of this invention imparts a force to the particles in a direction to offset the electrostatic force holding these particles against the collecting electrodes only to the degree that the force of gravity can effectively move the particles downward along the plate and yet does not impart enough force to these precipitated particles to overcome entirely the electrostatic force whereby the particles are kept close to the surface of the plate and are not forced out into the gas stream.

For an understanding of the invention one of the more fundamental aspects of the vibrations should be discussed. It is known that the effective root mean square acceleration imparted to a body expressed in terms of the acceleration of gravity g (approximately 32 feet per second²) is equal to

$$(2\pi F)^2 a$$

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where F is the frequency of vibration expressed in cycles per second, a is one-half the amplitude of vibration expressed in inches, and 386 is approximately the acceleration of gravity in inches per second².

From the above relationship, it is evident that the acceleration of a vibrating body varies directly with the

square of the frequency and the amplitude of vibration imparted to the body. As pointed out above, the amplitude of vibration of the plate is maintained below that which causes structural failure. The frequency of vibrations is primarily employed to achieve the required acceleration having an intensity adequate to dislodge the particles from the plate and maintain the particles adjacent thereto in an agitated condition. The frequencies applied are preferably those which are of the fundamental or resonant harmonic frequency of the plate member. It should be apparent, therefore, for any given acceleration g required to dislodge the particles, the frequency will vary in accordance with the geometry of the collecting member.

In accordance with the present invention it has been discovered that a collecting member imparted with steady state vibrations having accelerations at least above 50 g is operative to dislodge the particles into the gas stream. Such accelerations, of course, are obtained at amplitudes below those at which destructive forces are created.

It has further been found that on the typical electrostatic precipitator structure having a substantial collecting surface area that frequencies as low as 3,000 cycles per second may be employed to obtain the required acceleration intensity. As discussed above, the particular frequencies and the accelerations required to dislodge the particles will vary with the relative tenacity characteristics of the particles on the electrode surfaces and the geometry of the plate structure. Under conditions which require that accelerations higher than 50 g be imparted to the plate, it may be vibrated at frequencies which may be in excess of 15,000 cycles per second which is in the range of the ultra-high frequencies.

High frequency vibrations ranging from 3,000 cycles per second into the ultra-high frequency range and corresponding high continuous accelerations in excess of 50 g result in maintaining the particles concentrated in a zone contiguous to the electrodes in a state of agitation. Such agitation tends to prevent the particles from forming a substantially thick agglomerate layer such as occurred in the prior methods. The particles are maintained in more or less discrete or small pellet-like form in a concentrated section contiguous to the electrode. This particle concentrated section is in the nature of a free-flowing stream which under the influence of the vibrating electrode is carried to a hopper or plurality of hoppers provided in the precipitator structure.

Under some circumstances where the particle size is extremely small or the particle loading in the gas stream is light, the steady state vibration at high frequencies and accelerations may be operative at spaced intervals. The period during which the plate is vibrated depends upon the concentration or sum of the mass of the discrete particles adjacent the electrode surfaces. Such interval, steady-state vibration is particularly advantageous when the intensity of the vibrations required to dislodge the particles may be of such a magnitude as to make it unfeasible to continuously vibrate the electrodes. Hence, the electrodes are vibrated at a steady state for extended periods at the required accelerations at time intervals determined by the rate of build-up adjacent to the collector electrode. The time interval rate during which the plate remains undisturbed is maintained just sufficiently long such that the build-up does not form a substantially firm agglomerate layer, but rather forms more or less of a flowing stream.

In carrying out the invention there may be employed various types of collecting electrodes such as solid surface plates, imperforate plates, perforated single and multi-plates, cylindrical chamber, V-member assemblies, and the like. The collecting electrodes are preferably mounted so as to permit relatively free vibration. The vibrating means may be of any type capable of imparting accelerations of at least 50 g on electrodes at frequencies ranging above 3,000 cycles per second. Vibrating devices found to be particularly suitable are sonic

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vibration exciters such as magnetostrictive, piezoelectric, or multipurpose transducers. These sonic electronic vibrators are capable of generating accelerations up to 4,000 g at controlled amplitude and frequency.

For the purpose of illustrating the principles of the invention, a typical embodiment of the invention will be more particularly described with reference to the accompanying drawing in which:

FIG. 1 is a side elevation of an electrical precipitator embodying the principles of the invention with a portion of the precipitator wall broken away.

FIG. 2 is an end elevation of an electrical precipitator embodying the principles of the invention with a portion of the precipitator wall broken away.

FIG. 3 is an enlarged isometric showing a section of complementary discharge and collecting electrode systems of the precipitator of FIG. 1.

Referring to the drawings the precipitator generally designated by the numeral 10 is provided with a gas inlet and outlet 11 and 13 respectively and bottom hoppers or collecting hoppers 15 for receiving the collected particles.

A plurality of spaced and parallel collecting electrode plates 17 are disposed between the inlet 11 and outlet 13. While the plates may be resiliently and loosely mounted, as shown, the plates 17 are attached as by welding to supporting bars 19 and plate brackets 21. To maintain the proper spacing and a parallel relationship of the collecting plates 17, the lower ends are engaged by one or more spacer bars 23 which may be either loosely or rigidly fixed thereto.

Suspended between adjacent collecting electrode plates 17 and parallel thereto are a plurality of vertical high tension discharge electrode wires 25. The discharge electrode wires 25 are maintained in position within high tension frame members 27 which are supported from the precipitator shelf structure 29 by means of I-beams 31 and insulators 33. Spacer bars 35 interconnect the lower ends of the high tension frame members 27 to prevent contact with the spaced collecting plates 17. The high tension discharge electrode system including the supporting beam frame members and discharge electrode wires are maintained at a high potential with respect to the collecting electrode system by means of a coaxial pothead 37 and conductor cable 39 which is connected to the usual high potential power supply unit well-known in the art.

To vibrate the plates 17 at the high accelerations 50 g or above so as to maintain an agitated stream of particles contiguous to the electrode plates there is provided a vibrator mechanism 41. While the vibrator mechanism may be of any type well-known in the art such as mechanical, electro-mechanical or electro-magnetic, in the preferred form of the invention, as shown, the vibrator mechanism is of the sonic generating type. Such sonic generating devices are capable of imparting accelerations up to 4,000 g and frequencies ranging up to 150,000 cycles per second. The sonic device may be of the piezoelectric, magnetostrictive, or a combination of the two former transducer type.

As shown, there is employed a vibrator 41 of the transducer type which is operatively connected at one end to a vibrator bar 45. A transducer found to be suitable is manufactured by Acoustics Associates, Inc. of Mineola, N.Y. under Model No. AT2000.

The bar extends longitudinally through the wall of the precipitator housing and is attached to each of the plates at its edges as by welding or the like. Sealing the bar accommodating openings 47 are packing glands 49 or the like.

Under some circumstances it has been found that the plates 17 are not uniformly vibrated over their entire surfaces such that the particles contiguous thereto are not uniformly displaced toward the collecting hopper. The non-uniform displacement is usually caused by the fact that the nodal patterns of the vibrations are too widely disbursed

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over the plates. To assure a close proximity of the nodal pattern of the vibrations, an additional bar or bars and vibrating assemblies may be employed. In this manner the vibrations are effective to clean uniformly the entire surface of the plates 17. In addition, it has also been found that the particular frequency employed to impart the required particle dislodging accelerations determines the type of nodal patterns of vibrations. Accordingly, frequencies are selected to achieve the most advantageous nodal pattern.

While the arrangement particularly shown and described herein illustrates the principles and the method of the present invention as it may be employed with collecting plate electrode structures of electrical precipitators, it is not intended to define or in any way limit the scope of those principles. For example, discharge electrode structures may also be subjected to vibrations in accordance with the method of the present invention and the specific means and structures shown to impart vibrations to the structures may vary widely without departing from the scope of the claims.

We claim:

1. The method of removing particles from a fluid stream comprising subjecting the fluid stream to an electric charge of one polarity so as to charge said particles, concentrating said particles in a zone contiguous to a member having a charge of opposite polarity, subjecting said member to vibrations having a frequency of at least 3,000 cycles per second and imparting to said particles in said particle-concentrated zone an acceleration of above 50 g.

2. The method of removing particles from a fluid stream comprising subjecting the fluid stream to an electric charge of one polarity so as to charge said particles, concentrating said particles in a zone contiguous to a member having a charge of opposite polarity, applying a steady state vibration having a frequency of at least 3,000 cycles per second to said member and imparting to said particles in said particle-concentrated zone an acceleration of about 50 g.

3. The method of removing particles from a fluid stream comprising subjecting the fluid stream to an electric charge of one polarity so as to charge said particles, concentrating said particles in a zone contiguous to a plate member having a charge of opposite polarity, applying for extended periods a steady state vibration having a frequency of at least 3,000 cycles per second to said plate member and vibrating said plate member at accelerations of at least 50 g.

4. The method of removing particles from a fluid stream comprising subjecting the fluid stream to an electric charge of one polarity so as to charge said particles, concentrating said particles in a zone contiguous to a member having a charge of opposite polarity, applying for extended periods a steady state vibration to said member thereby maintaining said particles in substantially continuous agitation and displacement contiguous with the surface of said member, said steady state vibration being at frequencies in the range from about 3,000 to about 150,000 cycles per second and simultaneously imparting an acceleration of at least 50 g to said member.

5. The process of displacing individual particles along the surface of a solid member in an electrostatic precipitator by overcoming the driving forces tending to agglomerate said particles on said surface comprising imparting to said solid member steady state vibrations having a frequency of at least 3,000 cycles per second, and simultaneously applying to said solid member an acceleration of at least 50 g.

6. The process of removing collected foreign particles from the surface of a solid member in an electrostatic precipitator to which surface said particles are being held by electrostatic, adhesive and cohesive forces comprising:

(a) imparting to said solid member steady state vibrations having a frequency of at least 3,000 cycles per second,

- (b) simultaneously applying to said member an acceleration of at least 50 g,
 (1) said particles thereby being individually excited and displaced along said surface and
 (c) collecting the displaced particles leaving said surface under the force of gravity. 5

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