Aug. 8, 1961 S. CHARP 2,995,393

METHOD AND APPARATUS FOR INCREASING THE COEFFICIENT OF FRICTION BETWEEN METAL SURFACES

Filed Oct. 30, 1957 2 Sheets-Sheet 1

FIG. 1

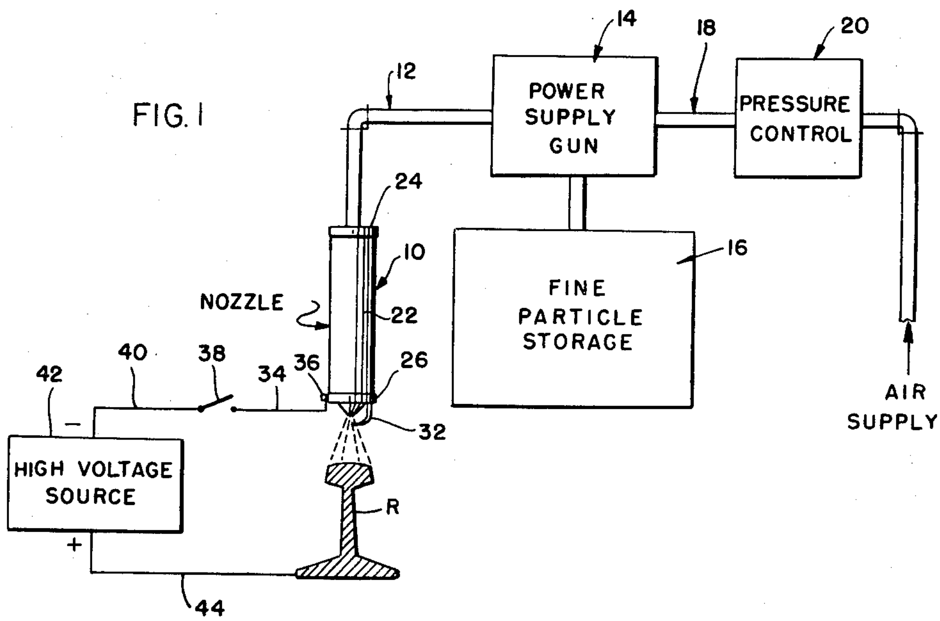
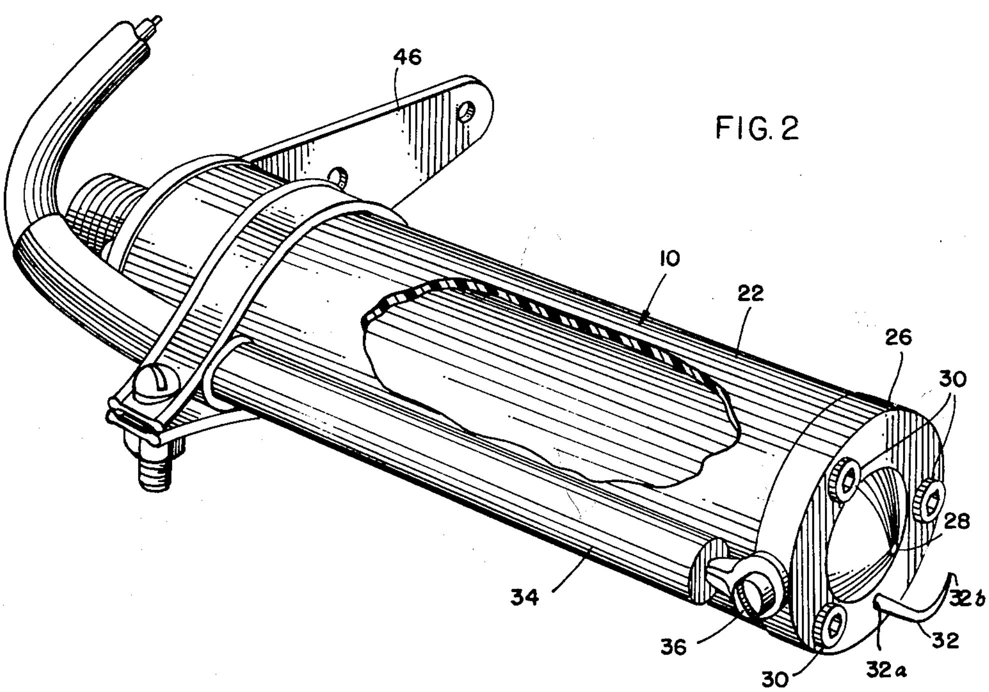


FIG. 2



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Filed Oct. 30, 1957 2 Sheets-Sheet 2

FIG. 3

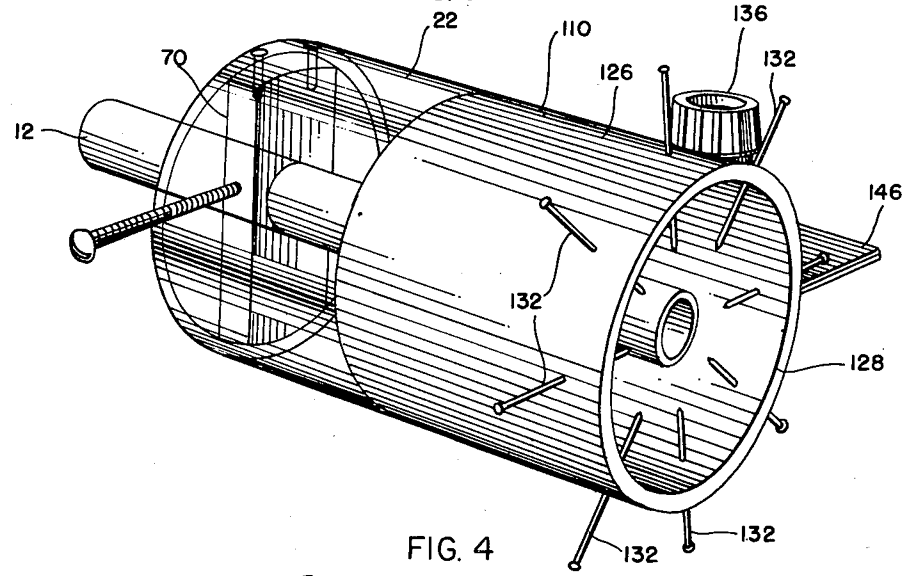


FIG. 4

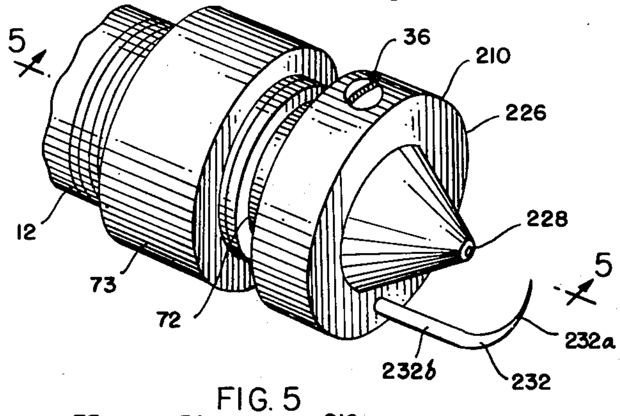
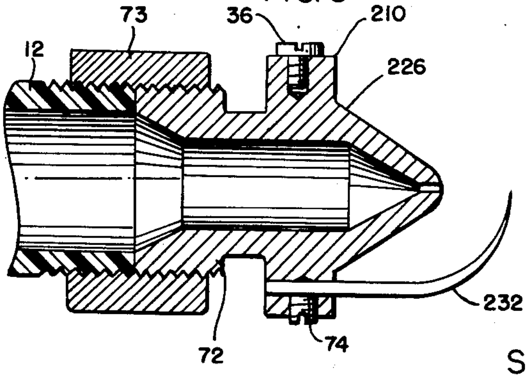


FIG. 5



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METHOD AND APPARATUS FOR INCREASING THE COEFFICIENT OF FRICTION BETWEEN METAL SURFACES

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Filed Oct. 30, 1957, Ser. No. 693,360
9 Claims. (Cl. 291—11)

This invention relates to a new and improved method for increasing the coefficient of friction between metal surfaces capable of movement relative to each other, and to apparatus for doing so, and, more specifically, to a new and improved method of, and apparatus for applying anti-slip material which is particularly well adapted for increasing the coefficient of friction between locomotive wheels and the rails on which they run.

It is a primary object of the present invention to enable dry, or substantially dry anti-slip material to be applied to relatively movable metal surfaces, such as, for example, locomotive wheels or railroad rails, or both, in a novel and expeditious manner.

The past several decades have produced railway locomotives possessing great power and weight, thus enabling long, heavily laden trains to be pulled by single engines. With the advent of the extremely heavy locomotive it was felt that driving wheel slip would be eliminated. It was soon discovered, however, that the increased static weight carried on the driving wheels did not solve the problem to any great extent. Track sanding techniques were developed but this only partially alleviated the condition. Wheel slippage has proved to be an erratic condition which has not in all cases been satisfactorily explained.

In one explanation of the problem rail slip is said to result from a tough invisible oil film on the wear band of the rail. Traffic and heat destroy this film and high adhesion results. When a light rain occurs or when the rails reach the dew point as the result of relatively high humidity, a water vapor film forms across the wear band where it may contact oil deposits on the edge of a rail with the result that a film of oil creeps through and replaces the water film. The oil deposits on the rail surface act as reservoirs for the formation of new oil films and water acts as the transporting agent. The oil deposits on the rail come from journal box oil leakage by way of the outside face and outer portion of the tread of the car wheels. There are other sources of contamination such as road crossings, rail lubricators, and the like.

The importance of solving the problem is strikingly illustrated when it is realized that only 15% of the engine's weight can be utilized as tractive force when the rails are greasy and moist, and 30% when the rails are clean, dry and sanded. Even a small improvement in these figures, as expressed in the terms of increased coefficient of friction, would enable railway locomotives to operate more efficiently and economically as well as providing improved braking for railway locomotives and rolling stock.

It is an important object of this invention to enable the coefficient of friction between railway car wheels and rails, and the like, to be raised in a novel and expeditious manner.

Another object is to raise the coefficient of friction between railway car wheels and rails having a film of oil thereon.

Yet another object of the invention is to enable an anti-slip material to be applied to rails in a novel manner whereby it is relatively easy to apply and will remain stable over prolonged periods of time.

A further object of the invention is to enable a rail treating material to be applied to railroad rails, and the like, in a novel manner whereby it is stable and effective at temperatures below the freezing point of water.

Another object of the present invention is to enable the frictional contact between metal surfaces, or between non-metal surfaces backed by metallic layers, to be improved in a novel and expeditious manner.

An additional object is to provide a novel method for depositing anti-slip materials in dry, or substantially dry powdered form to a railway wheel or rail, or both, in such a manner that the material is immediately effective to perform its anti-slip function.

Another object of the present invention is to enable a novel rail or wheel treating system to be afforded, which may be mounted immediately in front of the main driver wheels of a locomotive, or other wheels of a train, or the like, and which will be effective, in a novel and expeditious manner, to apply anti-slip material to the rail or wheel, or both, at such times, and in such quantities, as may be required to effectively increase the coefficient of friction between the rail and the wheel.

Yet another object of the present invention is to provide a novel method for substantially preventing slippage between a railway rail and a locomotive wheel, or the like, by coating the wheel or rail, or both, with a dry slip-inhibiting material in a novel and expeditious manner.

Another object of the present invention is to enable anti-slip material to be electrically deposited in a novel and expeditious manner on metal surfaces capable of movement relative to each other.

Another object is to afford a novel method of coating metal surfaces with dry anti-slip material by depositing such material, which may be electrically charged, on the surfaces in the presence of an electrostatic field.

A further object of the present invention is to enable dry anti-slip materials, in extremely fine powdered form, to be effectively deposited and retained, in a novel and expeditious manner, on metal surfaces capable of movement relative to each other, such as, for example, railroad wheels and rails.

An ancillary object is to enable such fine dry anti-slip materials to be so deposited and retained on relatively movable metal surfaces even in winds of relatively high velocity.

Other and further objects of the present invention will be apparent from the following description and claims and are illustrated in the accompanying drawings which, by way of illustration, show preferred embodiments of the present invention and the principles thereof and what I now consider to be the best mode in which I have contemplated applying these principles. Other embodiments of the invention embodying the same or equivalent principles may be used and structural changes may be made as desired by those skilled in the art without departing from the present invention and the purview of the appended claims.

In the drawings:

FIG. 1 is a diagrammatic view of apparatus embodying, and operable in accordance with, the principles of the present invention;

FIG. 2 is an enlarged detail perspective view of the nozzle forming a portion of the apparatus shown in FIG. 1, with certain parts broken away;

FIG. 3 is a perspective view, somewhat similar to FIG. 2, but showing a modified form of nozzle;

FIG. 4 is a perspective view somewhat similar to FIG. 2, but showing another modified form of nozzle; and

FIG. 5 is a sectional view taken substantially along the line 5—5 in FIG. 4.

In FIGS. 1 and 2 of the drawings apparatus constructed in accordance with the principles of the present invention is shown to illustrate one form of apparatus embodying the principles of the present invention, and the manner of practicing the present invention.

In general, the apparatus shown in FIGS. 1 and 2 embodies a nozzle **10** to which a supply of dry powdered anti-slip material may be fed for application to a suitable metal surface, such as a railroad rail R. The anti-slip material may be fed to the nozzle **10** through a suitable conduit **12** and a suitable feed mechanism **14** from a suitable source of supply **16** of the anti-slip material. The feed mechanism **14** may be of any suitable type of mechanism capable of effectively spraying dry, powdered anti-slip material from the supply source **16** into the conduit **12**, through which it may be borne, by a suitable working fluid such as, for example, air, passing through the conduit **12**, into the nozzle **10**. Such suitable feed mechanism includes any suitable type of powder spray gun or flock gun commercially available on the market capable of feeding powdered material therethrough. The outlet end of the gun **14** is directly connected to the end of the conduit **12** opposite to that end to which the nozzle **10** is connected. An air line **18** is connected to the air inlet end of the gun **14** for feeding a suitable working fluid such as, for example, compressed air thereto through suitable pressure controls **20** from a source of supply of compressed air, not shown.

In the operation of the apparatus shown in FIGS. 1 and 2, the powdered material will be deposited on and adhered to a suitable metallic surface such as, for example, the rail R, FIG. 1, as will be discussed in greater detail presently.

The nozzle **10** embodies a tubular-shaped housing **22** having a rear end wall **24**, through which one end of the conduit **12** extends, and a nozzle tip **26** at the front end thereof having a centrally disposed discharge orifice **28** therein, FIGS. 1 and 2. The body portion **22** may be made of any suitable, electrical insulating, dielectric material such as, for example, rubber, a suitable plastic, or the like, and the nozzle tip **26** may be made of any suitable electrically conductive material such as, for example, aluminum, or the like. The nozzle tip **26** may be secured to the front end of the tubular member **22** by suitable means such as screws or bolts **30**.

A substantially L-shaped needle or pointed wire **32** made of suitable electrically conductive material such as, for example, aluminum, copper, or the like, is mounted on the nozzle tip **26** in good electrical contact therewith by suitable means such as, for example, being threaded thereinto. One end portion **32*a*** of the needle **32** is directly attached to the front of the nozzle tip **26** below the orifice **28**, and the needle **32** projects forwardly from the tip **26**, and curves upwardly in such position that the free end **32*b*** of the needle **32** is disposed on the longitudinal axis of the orifice **28**. The needle **32** tapers to a sharp point at its free end **32*b*** for a purpose which will be discussed in greater detail presently.

One end of an electrical conductor **34** is connected by a suitable connector post or terminal **36** to the nozzle tip **26**, and the other end of the conductor **34** is connected through a switch **38** and a conductor **40** to a suitable source of high voltage **42**, FIGS. 1 and 2. The other side of the high voltage source **42** is connected by a suitable conductor **44** to the metal member on which the anti-slip material is to be deposited, which in the showing of FIG. 1 is the rail R, for a purpose which will be discussed in greater detail presently.

In the practice of the preferred form of the present invention, a suitably dry, or substantially dry, anti-slip material is deposited on either one or both of two metal surfaces, capable of movement relative to each other, in the presence of an electrostatic field. Materials which have been found to be particularly useful in the practice of this invention include finely powdered sand, silica and $CaCO_3$, and various types of dry colloidal silica commercially available on the market such as, for example, colloidal silica sold on the market under the trade names "Cab-O-sil," "Hy-Sil," and "Syloid." However, it will be appreciated by those skilled in the art that other anti-slip materials, which can support an electric charge, may be used without departing from the purview of the present invention.

An important aspect of this invention is that by the practice thereof, finely divided sand, silica, or other suitable anti-slip materials may be effectively applied to the contacting surfaces of relatively movable metal members in a dry or substantially dry state, to thereby immediately afford effective anti-slip materials of high efficiency between the two members.

Stated in a simple manner, the present invention contemplates applying dry powdered anti-slip materials to the bearing surfaces of either one or both of two relatively movable metal members such as, for example, a locomotive wheel and the rail on which it runs, through the medium of a novel electrostatic electrode system. The powder deposited on the surface of the metal member, or members, by the electrostatic process embodied in this invention, results in a strongly adherent dry coating which has effective anti-slip characteristics.

The size of the anti-slip materials which have been found particularly useful for the purposes of this invention are particles as small as five millimicrons and as large as the largest particles which will pass through a No. 100 sieve (U.S. sieve series), or, in other words, approximately one hundred and forty-nine microns, with the range of particle sizes which it is preferred to use being between fiften and forty-five millimicrons.

The method of applying anti-slip material to metal surfaces which is embodied in this invention comprises depositing dry, or substantially dry, solid particles of the anti-slip material on metal surfaces by a process in which the increased force and adhesive properties necessary for depositing are imparted to the solid particles. These forces and properties are impressed upon the air-suspended particles by the interaction between an electric field maintained with an electrode system and a charge induced on the surface of each particle. In essence, each particle of the anti-slip material acquires an electric charge by its passage through a field in which ions of proper polarity are present. The charged particles then drift or are impelled to a collector electrode under the influence of an electric field. The collector electrode is the metal member on which it is desired to deposit the particles of anti-slip material such as, for example, a railroad wheel, or a rail, such as the rail R, FIG. 1.

The two above mentioned basic steps in the present novel method, namely, (1) the charging of the particles of the anti-slip material, and (2) the depositing thereof on a collector electrode, may be performed in the practice of the present invention by a single electrode system such as is shown in the drawings, or by two separate electrode systems, not shown. In the single electrode system, the electrode for charging particles and the source of the electric field for impelling the charged particles to the collector electrode are the same. In the two electrode system, the particles may first be charged, and then transferred to a second electrode system for attracting them toward the collector electrode. The present invention contemplates the charging of fine particles of anti-slip material and adhering the materials, by an electric field, to either one of two metal bearing surfaces, or both, such as, for example, a railroad wheel and the rail on which it bears, by either a single electrode system or a multiple electrode system.

In the practice of this invention, the particles of anti-slip material are first mixed with air so that the particles become airborne. This may be accomplished in the apparatus shown in FIG. 1 by passing compressed air from a suitable source of supply through the pressure control mechanism **20**, the conduit **18**, and the spray gun

14, into the conduit 12 and then into the nozzle 10. The passage of air through the gun 14 is effective to pick up the powdered anti-slip material from the storage supply 16 and to bear it through the conduit 12 into the nozzle 10, from whence it is discharged through the orifice 28 of the nozzle tip 26.

Charging of the particles of anti-slip material, in accordance with the present invention, is caused by the passage of the particles through ionized gas generated by an incipient corona-discharge or by a corona-discharge. The effectiveness of the charging of the particles is dependent upon the production of a large number of ions by the corona and the effective transfer of electrical charge from the ions to the particles.

When an increasing potential difference is applied between electrodes, such as a pointed wire and a plate, the voltage gradient at the wire attains a critical value resulting in an electrical breakdown of the gas surrounding the wire. When the voltage gradient attains the aforementioned critical value, sparking results. If the gas is air at atmospheric pressure, the air so breaks down at approximately 30 kv./cm. The breakdown is caused by the high field strength near the point of the corona wire and results in a bluish glow surrounding the tip, which is a corona discharge.

In order that many ions may be produced in such a gas in the vicinity of such a corona wire, a high field strength is required. Hence, in the practice of this invention it is desirable that as high a field strength as is possible be used without causing continuous arcing. However, it has been found that in the practice of this invention, excellent depositing of anti-slip materials can be achieved with voltages applied between the pair of electrodes which are only a small fraction of the voltages necessary to cause a corona discharge. Hence, it will be seen by those skilled in the art that field strengths which are considerably less than that necessary to cause arcing between the pair of electrodes may be used in the practice of the present invention without departing from the purview of the invention.

In the apparatus shown in FIGS. 1 and 2, the needle or wire 32 is the aforementioned "corona wire" thereof, and affords one of the two electrodes between which the aforementioned increasing potential is applied. The rail R is the other of the two aforementioned electrodes, namely, the "collector" electrode, in the apparatus shown in FIGS. 1 and 2 of the drawings.

In the practice of the present invention, either a positive potential or a negative potential may be used for the corona wire, such as, for example, the wire 32, the choice being dependent, to some extent, upon the characteristics of the particles of the specific anti-slip materials used. In most instances, however, a negative potential applied to the corona wire is more efficient for the purposes of this invention, because a negative corona may be normally operated at a higher potential before the aforementioned breakdown of the gas occurs, and, hence, such operation is normally accompanied by a stronger electric field than if a positive corona were used. Furthermore, a negative corona wire has a higher potential gradient near its surface than does a positive corona wire.

The minimum voltage at which a corona discharge may be formed, and which provides sufficient ions to charge the particles of anti-slip material in accordance with the present invention, is dependent upon the size and shape of the corona wires, such as the wire 32, and the spacing between the electrodes, such as the wire 32 and the rail R, as well as the configuration of the electrode system.

When the corona wire, such as the wire 32, has a negative potential with respect to the collector electrode, such as the rail R, positive ions in the gas surrounding the wire bombard the wire and liberate free electrons. The free electrons, which are so liberated, are repelled from the wire by the field and form negative ions by attachment to the gas molecules. These negative ions move toward the collector electrode, such as the rail R, as a unipolar space charge. The motion of these ions causes a charging current to flow in the electrode system. The extent to which negative ions form is a function of the type of gas and the temperature and the pressure thereof. It is to be noted that the cloud of ionized gas is the same polarity as the corona wire.

In accordance with the theory of operation which is believed to be correct in connection with the present invention, when solid particles of anti-slip material such as sand, silica, and the like, are present in the gas at the same time as the negative ions, a small proportion of the ionized gas molecules collide with and attach themselves to the particles of anti-slip material. The particles of material then acquire an electric charge of the same sign as the corona wire, such as the wire 32, and are thereby propelled or attracted to the collector plate, such as the rail R, to which they then adhere.

After the particles are thus deposited on the collector plate, the charge previously acquired by the particles tends to leak off. If the collector plate, such as the rail R, were absolutely clean, such leak-off would be accelerated. However, in the practice of this invention the bearing surfaces which normally are treated are not normally absolutely clean, and, in fact, in most instances are quite dirty. Thus, for example, a railroad rail, which is particularly well adapted for treatment in accordance with the present invention, is normally covered with a film of moisture, oil, dirt, or the like. In such instances, the charged particles which are propelled toward the collector electrode, such as the aforementioned rail, do not touch the metal and the leak-off of their charge to the ground is retarded. The finite separation of the charged particles from such a normal collector electrode causes image charges below the surface of the rail which provide an attractive force to the particles deposited on the rail by the electrostatic system in the practice of the present invention. The particles so deposited are attracted to the image charges singly and in clusters. The efficiency of the adhesion of the anti-slip materials so deposited on a rail, or the like, depends on several factors, including the ability of the particles to retain their charge, the electric polarization, and the moisture which is present in the gas and in and on the particles.

Two processes can effect electrical charging of fine particles of material. These are known as (1) bombardment charging and (2) ion diffusion charging.

In bombardment charging of particles, ions of gas, moving rapidly under the influence of an applied field, collide with the solid particles and attach themselves to the surfaces of the particles. The strength of the charge which is acquired is dependent upon the strength of the charging field, the surface area of the particles, the dielectric properties of the material, and the time the particles are subjected to the charging action of the field. Thus, in general, it may be said that, everything else being equal, the charging of such particles is more efficient with large size particles. However, smaller size particles have several distinct advantages in the practice of the present invention, such as, for example, affording more efficient action as an anti-slip material and, also, saving less tendency to ricochet or bounce from the collector electrode to which they are being applied. It has been found that the present invention affords a highly effective method of coating a metal surface, and the like, with anti-slip material of powdered form wherein the particles sizes are very small, as well as with larger size particles.

In the process of charging by ion diffusion, thermal motion of the ions causes diffusion through the gas. Charging of solid particles in such a process is dependent upon collisions of such ions with the particles irrespective of the presence of an electric field. The amount of charge acquired by such particles in this process depends upon the particle size, the characteristics of the gas, the gas temperature, and the time available for charging. An example of ion diffusion charging is the charge acquired by finely divided particles of material held in a container, with the container then being agitated.

Charging of the particles of anti-slip material in accordance with the present invention is a combination of both ion diffusion charging and bombardment charging, although ion diffusion charging has an effect only on the smaller particles, and the greater part of the charging is accomplished by bombardment charging.

As the charge on a particle increases in its passage through the charging field, the repulsive force between it and the oncoming ions of the same sign increases until a limiting charge is acquired. The number of elementary charges acquired in the charging process is given by Equation 1.

$$n=\frac{3E_c a^2}{\epsilon}\,\frac{t}{\left(t+\frac{1}{\pi N\epsilon k}\right)} \qquad (1)$$

where

n=number of elementary electronic charges
ϵ=elementary electronic charge
t=time
a=particle radius
E_c=field strength
N=ion concentration
k=ion mobility

All units are in E.S.U. system. If the particles travel a short distance, the limiting charge is acquired rapidly and it can be assumed that this charge is given by Equations 2 and 3.

$$q=pE_c a^2 \qquad (2)$$

where $p=3$ for a conducting particle.

$$p=\frac{3d}{d+2} \text{ for a non-conducting particle of dielectric constant } d \qquad (3)$$

For the latter an average for p is between 1.5 and 2. It is seen that the charge acquired by the anti-slip particle is proportional to the surface area and to the strength (voltage gradient) of the charging field. For a field strength of 10,000 volts per inch, and for a particle having a radius of 30 millimicrons, the charge is approximately 0.4 elementary charge.

For the case of the anti-slip particle acquiring a charge by the ion diffusion process, caused only by the presence of the thermal motion of ions, the number of elementary charges is given in Equation 4.

$$n=\frac{aKT}{\epsilon^2}\ln\left[1+\frac{\pi asN\epsilon^2 t}{KT}\right] \qquad (4)$$

where the symbols are the same as in Equation 1 with the addition of the following:

T=absolute temperature
K=Boltzmann's constant
s=R.M.S. velocity of ions

The rate of acquiring the number of elementary charges is given by Equation 5.

$$\frac{dn}{dt}=\pi a^2 sN \exp.\left[-\frac{n\epsilon^2}{aKT}\right] \qquad (5)$$

It is seen that the rate decreases as the number of charges acquired increases.

Investigation of Equations 1 and 4 for various conditions shows that for particles near 1 micron diameter the bombardment charging and ion diffusion charging yield approximately the same limiting charge. For particles less than 1 micron diffusion charging may predominate and for particles much greater than 1 micron bombardment charging predominates. To some extent the particles which become charged in the electric field disturb the uniformity of the field. The total charge per unit volume which is acquired by the stream of particles acquiring the charge from the ionized gases is given approximately by the total charge as given by Equation 2 summed over the total number of particles in a unit volume of the gas.

It was noted earlier that an electrostatic depositing system such as that to which this invention relates, can make use of a single-stage or a two-stage electrode system. The second stage is used to accelerate the charged particles toward the collector electrode. If the field strength in this part of the system is designated E_p, then the force on the particle which is being impelled toward the collector electrode is given by Equation 6.

$$F_1=qE_p=pE_cE_pa^2 \qquad (6)$$

If the corona producing system propels the charged particles of anti-slip material vertically toward the collector plate, such as the rail R, FIG. 1, there is a vertical velocity due to the electric field which is counteracted by the viscous drag acting on the particle.

Equation 7 represents this viscous drag.

$$F_2=6\pi a\mu w \qquad (7)$$

where μ is the belocity of the gas in poises and w is the drift velocity of the particle. For steady state conditions the two forces given by Equations 6 and 7 are equal, hence, the drift velocity is given by Equation 8.

$$w=\frac{pE_cE_pa}{6\pi\mu} \qquad (8)$$

where

$$w=0.16\frac{E_cE_pa}{\mu} \text{ for a conducting particle} \qquad (9)$$

$$w=0.095\frac{E_cE_pa}{\mu} \text{ for a non-conducting particle} \qquad (10)$$

Thus it is seen that the drift velocity is not much affected by the electrical properties of the charged particles but it is materially affected by the size of the particles and particularly by the voltage gradient in the charging and accelerating electrode systems. For a single-stage system, where the same electrode system is used to produce the ionized gas and to provide the accelerating field, $E_c=E_p$, thus emphasizing that, for high efficiency in depositing anti-slip material, high voltage gradients are desirable.

If the charged particles are emitted from an electrostatic nozzle system a distance h above a rail of width H, and if a crosswind of W units is present, then in order that the charged particle never be deflected more than the width of the rail, if the particle drops initially at one edge of the rail, then it is necessary for Equation 11 to hold.

$$\frac{w}{W}\geq\frac{h}{H} \qquad (11)$$

In an actual situation, h may be two inches, and the width of the rail may likewise be two inches. Therefore, the condition to be achieved is for the drift velocity to be equal or greater than the wind velocity.

In actual practice while optimum deposition and adherence for a wind velocity of one mile per hour theoretically requires a field strength of approximately 54 kv./in. and a wind velocity of 60 miles per hour theoretically requires approximately 425 kv./in., effective deposition and adherence of fine colloidal silica and other types of finely divided discrete non-electrically conductive particles can be obtained on a railway rail by applying the said particles to a rail from an electrostatic nozzle system as herein described mounted on a diesel electric locomotive with the nozzle opening 1.5 inches from the rail, using 30 kilovolts.

In an actual installation on a railroad train, or the like, the apparatus shown in FIG. 1, with the exception, of course, of the rail R, may be mounted on and carried by the train. The air supply to the pressure control **20** may be from any suitable source, such as, for example, the source of compressed air used to actuate the brakes of the train. The pressure control **20** is preferably such that it will effect adjustment of air pressure at the outlet thereof from zero pounds per square inch to thirty pounds per square inch. The power supply **14** and the supply **16** of anti-slip material may be mounted in the train and the conduit **18**, connecting the power supply **14** to the pressure control **20** may be of any suitable type such as, for example, a rubber hose.

The nozzle **10** may be mounted outside the train in suitable position to discharge the anti-slip material through the orifice **28** directly onto the metal surface such as the rail R a short distance in front of the wheel which it is intended to prevent from slipping. Thus, for example, when the wheel which it is desired to prevent from slipping is one of the driver wheels of a locomotive, the nozzle **10** may be secured to the framework of the locomotive by suitable means such as a bracket **46** and bolts, not shown. Preferably, the nozzle **10** is so disposed on such a locomotive that the orifice **28** is disposed forwardly of the wheel, with which it is associated, a distance of from two to six inches.

The high voltage source **42** may be any suitable type of generator which may be carried by the train, and the negative terminal thereof is connected by a line **40** and the switch **38** to the nozzle **26** and, thereby to the corona needle **32**. The positive terminal of the high voltage source **42** is connected by the line **44** to the rail R. This, in effect, is the ground connection and on a locomotive, this connection may be made to the rail R by connecting the positive terminal of the voltage source **42** to the axle or framework of the locomotive and thus through the locomotive wheel to the rail R.

It has been found that to insure good depositing and adherence of anti-slip materials on the rail R, the potential at the corona needle **32** should not be substantially less than ten thousand volts per each inch of distance that the needle **32** is spaced from the rail R.

The best mode contemplated for the practice of the present invention will be illustrated by the following examples and the results obtained by its use in actual tests.

Example I

A dry colloidal silica powder having a maximum particle size of fifteen millimicrons was sprayed through a nozzle **10**, of the general type shown in FIGS. 1 and 2, with a pressure of five pounds per square inch at the nozzle discharge. The corona needle and rail were spaced from each other a distance of two inches. A voltage of twenty-four kv. was used, and the silica was fed from the nozzle at the rate of one-half a gram to five grams per minute. Excellent depositing and adherence on the collector electrode were realized even in crosswinds up to sixty miles per hour.

Example II

In this test electrostatic spraying or dry colloidal silica powder having a particle size of approximately thirty millimicrons was carried out in the laboratory inside a humidity chamber using a single-stage nozzle system of the general type shown in FIGS. 1 and 2. The air pressure at the nozzle was maintained at approximately two and one-half pounds per square inch and the silica powder was discharged from the nozzle at the rate of from one-half a gram to five grams per minute. The corona needle was spaced from the collector electrode a distance of approximately one inch, and a voltage of twelve kv. was used. During the test, the relative humidity was varied from ten percent to seventy-five percent, and the temperature was varied from 84° F. to 114° F. The test was run both without any crosswind and with crosswinds up to approximately forty miles per hour, such winds being created by air emitted from a hose. There was no difficulty encountered in the operation of this process and method and the depositing and adherence of the silica powder on the collector electrode was good under all the test conditions.

Example III

Tests were also conducted under the conditions set forth in Example I above, with the only variations being that the material deposited was finely powdered sand, the largest particles of which were of such size that they would pass through a No. 100 sieve, but would not pass through a No. 200 sieve, and the sand was discharged from the nozzle at a rate of approximately, but somewhat less than, one pound per minute. The depositing and adherence of the material in this test was good.

Example IV

In this test, sand, which would pass through a No. 100 sieve, but would not pass through a No. 200 sieve, was used and a potential of twenty-four thousand volts applied to the corona needle, which was spaced from the rail a distance of two inches. The sand was discharged from the nozzle at a rate of approximately one pound per minute and with an air pressure at the outlet of the nozzle of from five pounds to fifteen pounds per square inch. The depositing and adherence of the sand particles on the collector electrode was satisfactory, although not as efficient as the depositing and adherence of the particles in Examples I to III, inclusive, some of the larger particles of the sand apparently recocheting from the collector electrode.

Example V

In this test, experiments were conducted in the field, with the nozzles being mounted in front of the driver wheels of a locomotive. The nozzles were disposed approximately two inches above the rails, and ground sand, having a maximum particle size of 44 microns, was fed from each nozzle at the rate of three grams per minute, with an air pressure at the outlet of the nozzle of from five to fifteen pounds per square inch with the train moving at approximately six miles per hour. A voltage of thirty thousand volts was applied to the corona needle. The depositing and adherence of the sand to the rails was satisfactory, although the adherence was not as efficient as in Examples I to III, inclusive, above. The larger particles of sand apparently ricocheted to a certain extent from the rails.

Example VI

Another test was conducted under the same conditions as set forth in Example V with the exception that dry colloidal silica of finely powdered form having a particle size of approximately fifteen millimicrons was used instead of the 44 micron sand. Depositing and adherence of the silica to the rails was good, and was more efficient than in Example V.

In the making of these tests, depositing of the anti-slip material has been accomplished with and without an electric field being present. When there was no electric field, the powder deposited on the rail could be readily blown off immediately with a crosswind of not more than forty miles per hour. When an electric field and the electrostatic process of this novel invention was used, the particles deposited on the rail were not materially blown off from the rail with a crosswind of up to sixty miles per hour, even after the electrostatic field had been removed. This demonstrates the importance of the image charges in causing good adherence of the charged particles to the rail surface.

In FIG. 3, a modified form of nozzle **110** embodying the principles of the present invention is shown, and parts which are the same as parts embodied in the nozzle **10** shown in FIGS. 1 and 2 are indicated by the same reference numerals, and parts which are similar to parts embodied in the nozzle 10 but differ somewhat therefrom are indicated by the same reference numerals with the prefix "1" added thereto.

The nozzle 110 embodies a substantially tubular-shaped body member 22 having a brace 70 mounted in the rear end thereof. A nozzle tip 126 is mounted on the front end of the body portion 22, and the tube 12 is mounted in and extends through the brace 70 in such position that it extends forwardly through the body portion 22 into the nozzle tip 126, and terminates at its front end in rearwardly spaced relation to the front end of the nozzle tip 126. The nozzle tip 126 is tubular in shape, and has an open front end 128 which is substantially the same in diameter as the body portion 22. A plurality of elongated straight corona needles 132 are mounted in the nozzle 126, forwardly of the front end of the tube 12, and extend radially through the side walls of the nozzle tip 126, with their inner ends disposed in spaced relation to each other. A connector post or terminal 136 is attached to the nozzle tip 126, by means of which a conductor, such as the conductor 34, FIGS. 1 and 2, may be attached to the nozzle tip 126.

The nozzle 110 may be mounted in position of use in a manner similar to the manner heretofore described with respect to the nozzle 10, a bracket 146 being provided for this purpose, and the potential between the corona needles 132 and the collector electrode, not shown, which may be of any suitable metallic member which it is desired to coat with particles of dry material, such as the rail R shown in FIG. 1, is effective to afford the necessary electrostatic field for charging the particles to be so deposited.

In FIGS. 4 and 5, another modified form of nozzle 210 is shown, and parts which are the same as parts of the nozzle 10 shown in FIG. 1 are indicated by the same reference numerals and parts which are similar but somewhat different from the corresponding parts of the nozzle 10 are shown by the same reference numerals with the prefix "2" added thereto.

The nozzle 210 embodies a nozzle tip 226 having an elongated shank 72, the nozzle 210 being directly mounted on the end of the conduit 12 by a suitable coupling member such as the sleeve 73, threadedly engaged with the conduit 12 and the shank 72, FIGS. 4 and 5. The nozzle 210 is made of suitable electrically conductive material such as, for example, aluminum, and is electrically insulated from the train, or the like, on which it is mounted, such as, for example, by having the section of the conduit 12 to which it is attached constructed of rubber, a suitable plastic, or other suitable dielectric material.

One end of the corona needle 232 is mounted in the tip 226, below the orifice 228, and is held therein by a screw 74, FIG. 5. The needle 232 curves upwardly from this one end, as viewed in FIG. 5, and the other end, or free end, of the needle 232 is sharply pointed and the point thereof is disposed on the axial center line of the discharge orifice 228 of the nozzle tip 226. A connector post or terminal 36 is threadedly engaged in the rim of the nozzle tip 226 to afford means for connecting a conductor such as the conductor 34 shown in FIGS. 1 and 2 to the nozzle tip 226, and the nozzle 210 may be operated in the same manner as that heretofore discussed with respect to the nozzle 10 in the present invention.

From the foregoing it will be seen that the present invention affords a novel method of increasing the coefficient of friction between two relatively movable metal surfaces, and that novel apparatus has, also, been afforded for carrying out the aforementioned novel method. While the invention is especially useful in the railroad field to improve frictional contact between rails and the wheels of a diesel electric locomotive, it is also useful in other fields as, for example, for improving the frictional contact between guide rails and wheels on overhead crane apparatus and for improving frictional contact between other mating surfaces which normally tend to move one with respect to the other.

In field tests of the type described in Examples V and VI some of the specific finely divided solids which were successfully applied to rails were Dow Corning fine silica having an average particle size of about 15 millimicrons, spray dried Nalcoag having a particle size of about 30 millimicrons, and Flufsil 255 having a particle size of about 30 millimicrons. Other types of fine silicas suitable for the practice of the invention are disclosed in U.S. Patent No. 2,787,967. These fine silicas are usually characterized by having a specific surface area of at least 25 square meters per gram and preferably within the range of 25 to 400 square meters per gram. The ultimate particle size usually varies from 1 to 150 millimicrons when these silicas are dispersed in water.

While the powdered discrete particles of colloidal silica and other finely divided electrically non-conducting solids are referred to herein as dry or substantially dry, it will be understood that the presence of moisture in these particles, so long as they remain discrete, does not substantially affect the practice of the invention. Some particles tend to adsorb or absorb moisture more than others and even finely ground gels of the silica gel type or alumina gel type or silica-alumina gel type containing substantial quantities of moisture can be used for the practice of the invention.

The rate of application is subject to considerable variation. In general, the slower the application the better the adhesion of the particles, but good results are obtained over a relatively wide range, for example, up to 120 grams of particles per minute, or higher. The size and weight of the particles being applied is also a factor in the rate of application. For example, fine sand might be applied at a rate of 1 pound to 4 pounds per minute per nozzle whereas fine silica might be applied at a rate of 3 to 6 grams per minute per nozzle.

In general, the higher the electrostatic field the more focused is the application of the particle. The charge on the particle is proportional to the voltage gradient. The larger the size of the particle, the more the charge. In some instances, effective application has been obtained at voltages of six kilovolts, or less, per inch of distance from the nozzle to the surface to which the material is applied, but higher voltages are preferred. Many other variations and modifications will be apparent to those skilled in the art.

I claim:

1. Apparatus for improving the coefficient of friction between two metal surfaces comprising means for supplying dry solid material in powder form, and means for feeding and adhering said material to one of said surfaces, said last named means comprising nozzle means for spraying said material through the open atmosphere toward said one surface, an electrode disposed between said nozzle means and said one surface, and means for applying a selected potential difference between said electrode and said one surface.

2. Apparatus for improving the coefficient of friction between two metal surfaces comprising means for discharging air-borne particles of dry material in powder form through the air along a path of travel onto one of said surfaces, an elongated electrode having a pointed end disposed in said path of travel, and means for applying a selected potential difference between said electrode and said one surface during movement of said particles along said path of travel toward said one surface.

3. Apparatus for improving the coefficient of friction between two metal surfaces comprising means for discharging air-borne particles of dry material in powder form through the air along a path of travel onto one of said surfaces, an elongated electrode having a pointed end disposed in said path of travel, said electrode being spaced from and insulated from said one surface, and means for applying a potential difference between said

electrode and said one surface of not substantially less than ten thousand volts per inch of space between said electrode and said one surface.

4. Apparatus for improving the coefficient of friction between two metal surfaces comprising means for discharging air-borne particles of dry material in powder form onto one of said surfaces, said means including means for feeding such particles, and a spray nozzle having an outlet disposed in position to discharge said particles from said feeding means toward said one surface, corona needle means mounted on said nozzle between said feeding means and said one surface in the path of movement of said particles between said feeding means and said one surface, and means for applying a selected potential difference between said corona needle and said one surface.

5. Apparatus for improving the coefficient of friction between two metal surfaces comprising means for discharging air-borne particles of dry material in powder form onto one of said surfaces, said means including means for feeding such particles, and a spray nozzle having an outlet disposed in position to discharge said particles from said feeding means toward said one surface, a corona needle mounted on said nozzle, said needle having a sharp point disposed in the discharge path of said outlet between said nozzle and said one surface, and means for applying a selected potential difference between said corona needle and said one surface.

6. Apparatus for improving the coefficient of friction between two metal surfaces comprising means for discharging air-borne particles of dry material in powder form onto one of said surfaces, said means including means for feeding such particles, and a spray nozzle having an outlet disposed in position to discharge said particles from said feeding means toward said one surface, corona needle means mounted on said nozzle between said feeding means and said outlet of said nozzle in the path of travel of said particles from said feeding means, and means for applying a selected potential difference between said corona needle and said one surface.

7. Apparatus for improving the coefficient of friction between two metal surfaces comprising means for discharging air-borne particles of dry material in powder form onto one of said surfaces, and an electrically conductive metal spray nozzle connected to said feeding means and having an outlet disposed in position to discharge said particles from said feeding means toward said one surface, corona needle means mounted on, carried by, and electrically connected to said nozzle means between said feeding means and said one surface in the path of travel of said particles between said feeding means and said one surface, and means for applying a selected potential difference between said nozzle and, therefore, said corona needle means, and said one surface.

8. Apparatus as defined in claim 7 and in which said corona needle means comprises an elongated needle projecting from said nozzle and having a pointed end disposed between said discharge outlet and said one surface.

9. Apparatus as defined in claim 7 and in which said corona needle means comprises a plurality of elongated needles disposed radially to the axial center line of said discharge outlet between said outlet and said feed means.

References Cited in the file of this patent

UNITED STATES PATENTS

2,027,308	Schacht	Jan. 7, 1936
2,352,252	Canetta	June 27, 1944
2,618,552	Wise	Nov. 18, 1952
2,758,524	Sugarman	Aug. 14, 1956
2,787,965	Luvisi	Apr. 9, 1957
2,787,966	Lyons	Apr. 9, 1957
2,787,967	Nohejl	Apr. 9, 1957
2,832,511	Stockdale	Apr. 29, 1958

FOREIGN PATENTS

210,109	Australia	Aug. 30, 1957

OTHER REFERENCES

Alexander, Jerome: "Colloid Chemistry," second edition, D. Van Nortrand Co., 8 Warrent St., New York, 1924.

Zsigmondy, Richard & Spear, Ellwood: "The Chemistry of Colloids," first edition, John Wiley & Sons, Inc., New York, 1917.