United States Patent [19]

Gourdine

[11] **3,757,491**

[45] **Sept. 11, 1973**

[54] **APPARATUS FOR SUPPRESSING AIRBORNE PARTICLES**

[75] Inventor: **Meredith C. Gourdine,** West Orange, N.J.

[73] Assignee: **Gourdine Systems, Inc.,** Livingston, N.J.

[22] Filed: **Nov. 5, 1970**

[21] Appl. No.: **87,235**

[52] **U.S. Cl.** ..... **55/107,** 55/138, 55/146, 55/149, 55/152, 55/154, 55/279, 98/50, 239/3, 239/15, 299/12, 317/3, 317/4, 317/262 AE

[51] **Int. Cl.** **B03c 3/00**

[58] **Field of Search** ..... 55/107, 122, 136, 55/137, 138, 150, 151, 152, 146, 155, 2, 5, 10, 149, 154, 279; 98/50; 299/12, 95; 317/2, 3, 4, 262 R, 262 AE; 310/2, 10, 11; 239/3, 15

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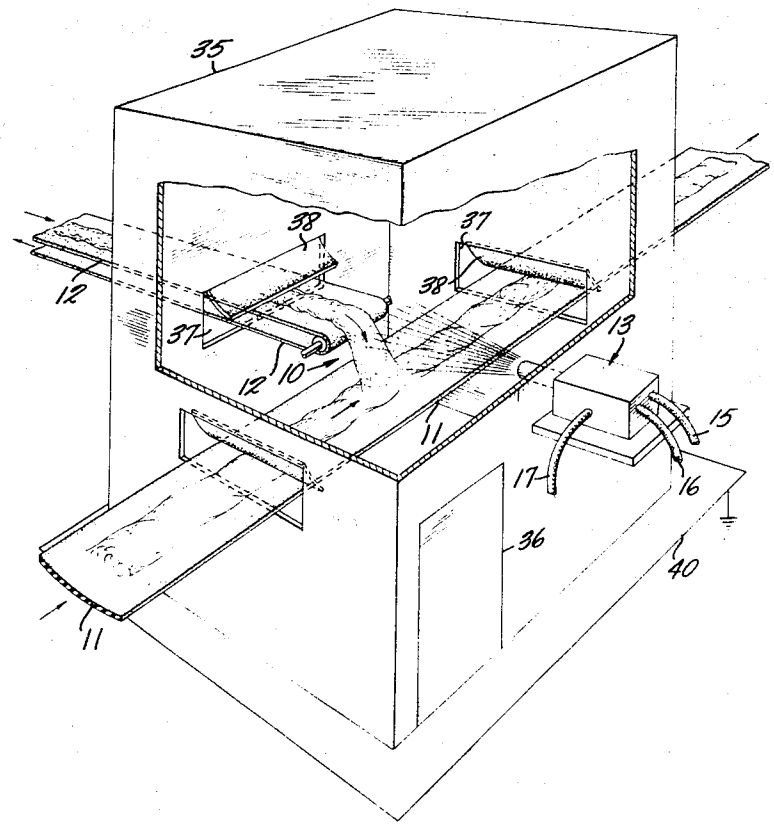
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Primary Examiner—Dennis E. Talbert, Jr.
Attorney—Brumbaugh, Graves, Donohue & Raymond

[57] **ABSTRACT**

Electrogasdynamic apparatus for suppressing airborne particles, dust or the like, by a distribution of charged, minute liquid droplets throughout the zone contaminated by the airborne particles. Passage through a corona discharge region charges the droplets, which then are passed through a channel to the contaminated zone. There, a space charge field is established. As they continue to be forced through the channel, the charged droplets decelerate under the influence of an axial field gradient. An electrogasdynamic exchange occurs, by which the droplets exchange kinetic energy for electrical potential. The droplets disperse, passing among the contaminant particles, attracting, being attracted to, and charging contaminant particles. Now having an associated electrical charge, the particles move to nearby surfaces. An enclosure about the contaminated location reduces the spread of airborne particles and adds additional collection surface area. In mining, dust is suppressed at mine product transfer points, or the dust control apparatus is mounted on a continuous mining machine effectively to isolate the machine's operator station from locations of greatest dust concentration.

1 Claim, 7 Drawing Figures



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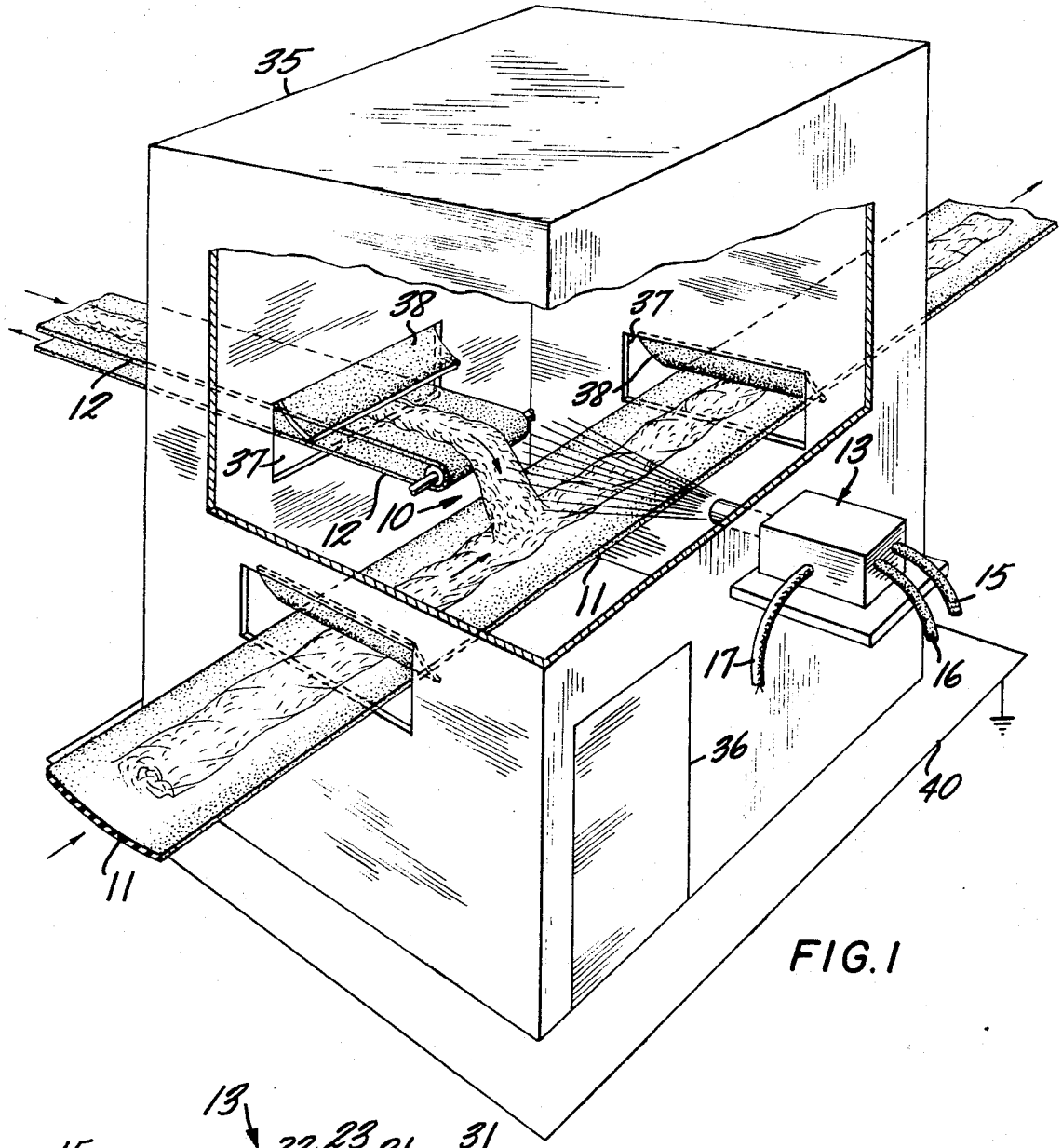


FIG. 1

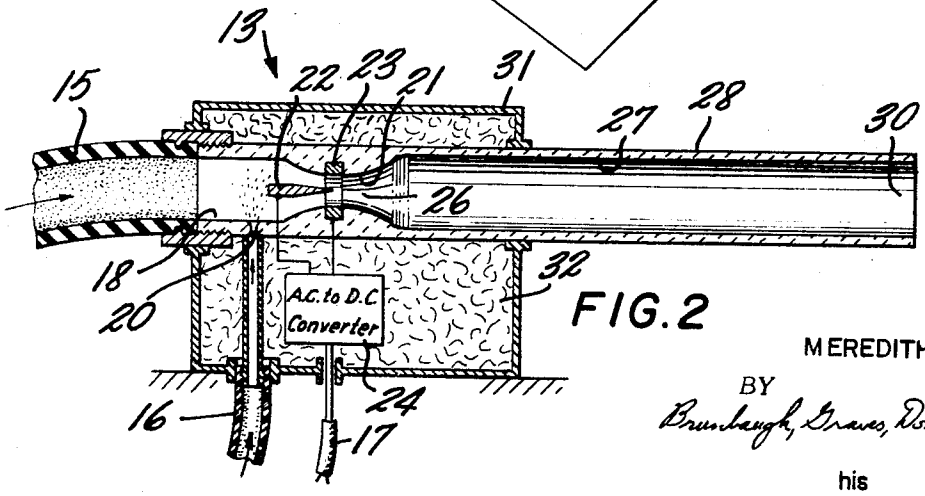


FIG. 2

INVENTOR.
MEREDITH C. GOURDINE

BY
Brumbaugh, Graves, Donohue & Raymond

his ATTORNEYS

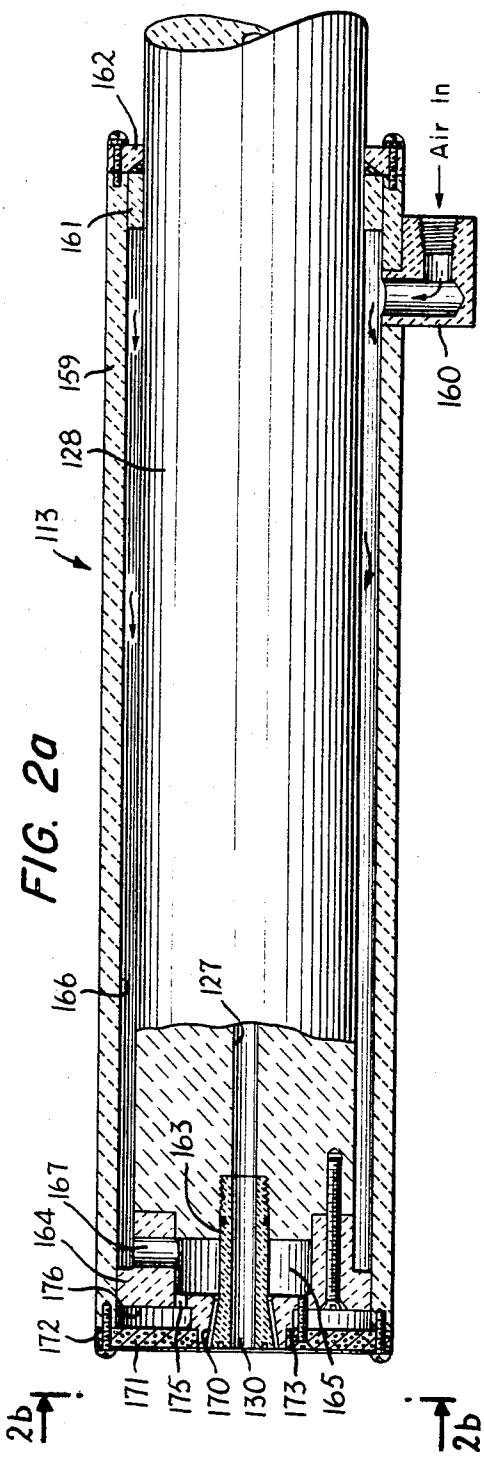


FIG. 2a

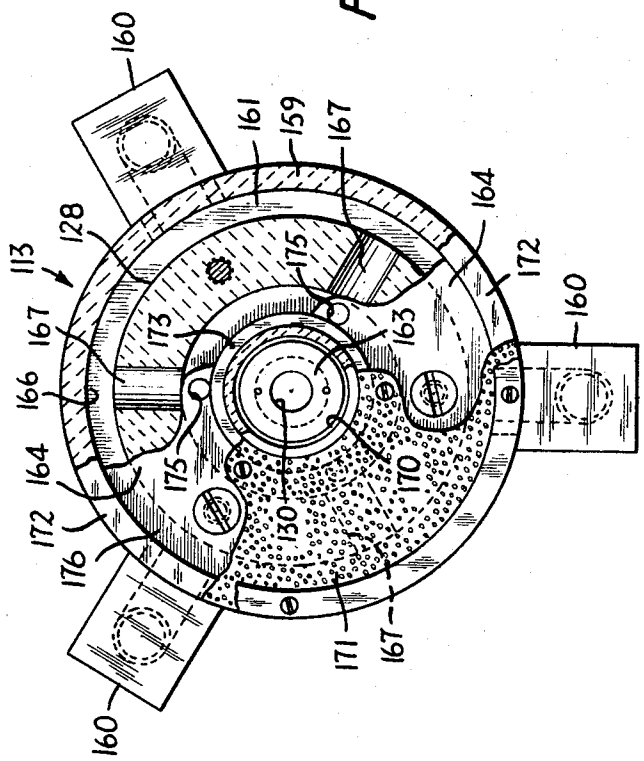


FIG. 2b

INVENTOR.
MEREDITH C. GOURDINE
BY
Brumbaugh, Graves, Donohue & Raymond
his ATTORNEYS

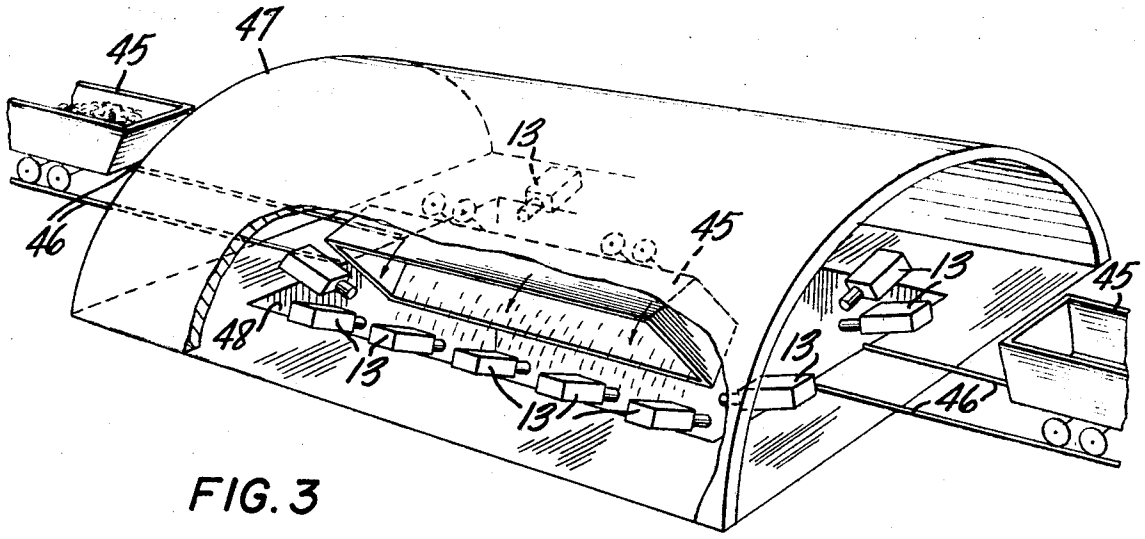


FIG. 3

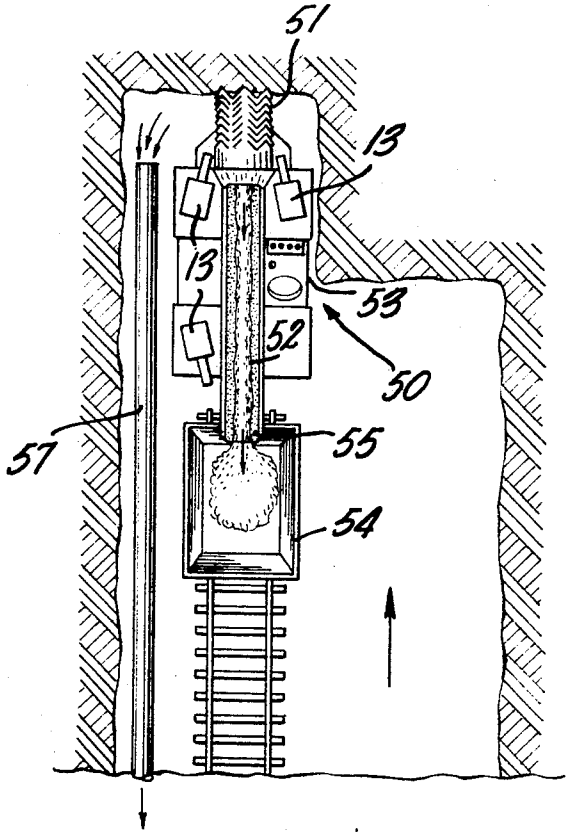


FIG. 4

INVENTOR.
MEREDITH C. GOURDINE
BY
Brumbaugh, Graves, Donohue & Raymond
his ATTORNEYS

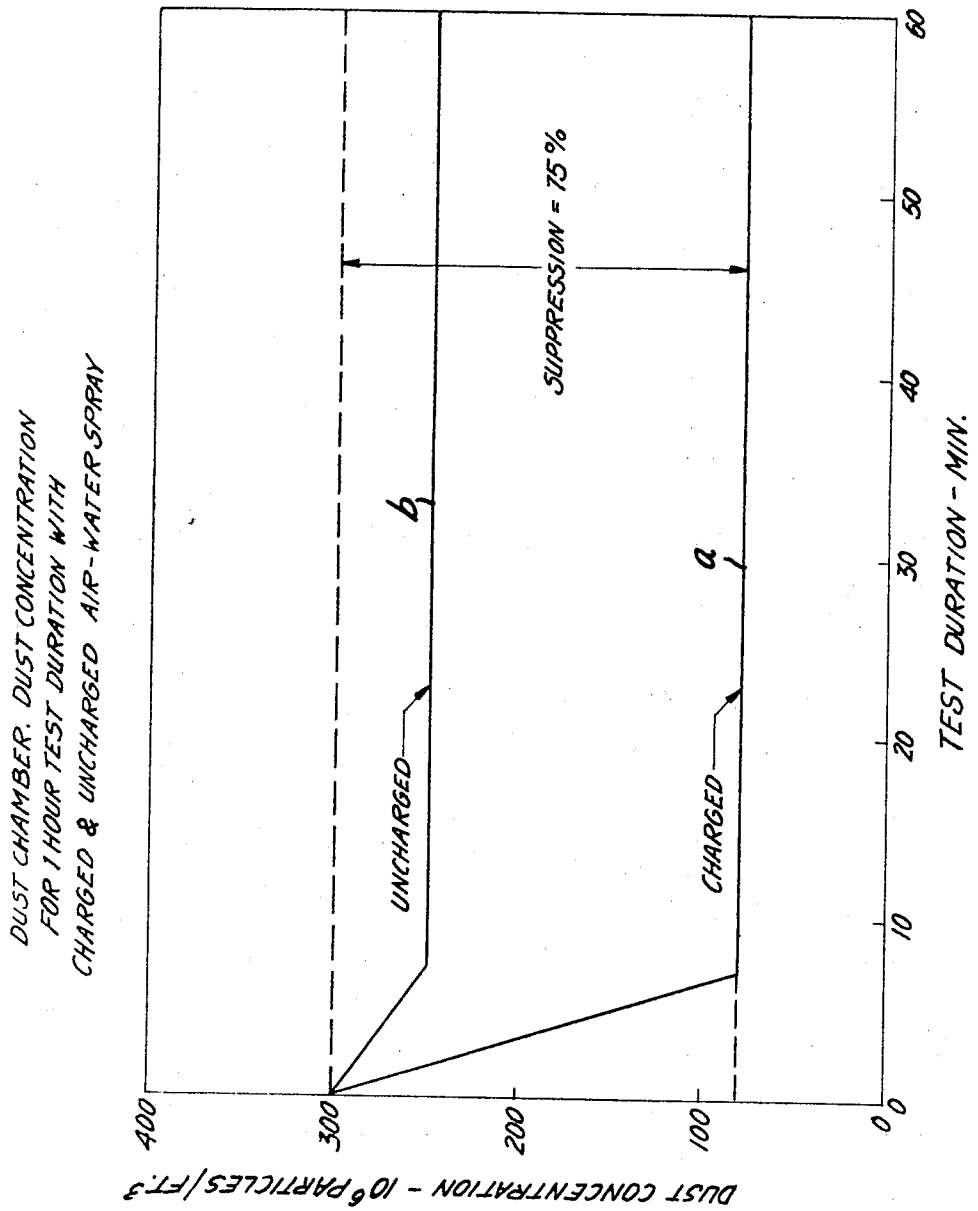


FIG.5

INVENTOR.
MEREDITH C. GOURDINE
BY
Brumbaugh, Graves, Donohue & Raymond
his ATTORNEYS

APPARATUS FOR SUPPRESSING AIRBORNE PARTICLES

BACKGROUND OF THE INVENTION

This invention relates generally to apparatus for suppressing airborne contaminant particles and, more particularly, to the suppression of such particles by distribution of electrical charges throughout the contaminated zone.

The use of water sprays, to suppress airborne dust or other contaminant particles, has long been known. Particularly in mining operations, water sprays have been employed to cleanse the air in an effort to protect mining personnel from respirable dust. Treatment of a contaminated area simply by spraying is less than wholly effective. Chance contact of the sprayed water and the contaminant particles must be relied upon. Further, the mere spraying of water does not insure an even distribution of water droplets throughout the contaminated zone.

For mining sites, another suggestion has been withdrawing or exhausting the dust laden air from adjacent the mine face and passing the withdrawn air through a precipitator unit electrically to remove the dust. The actual suppression occurs in the precipitator, not at the dust source. Hence the air is still dust laden as it moves to the exhaust intake, and this air would appear to limit visibility as it moves, near the mine face, to the exhaust intake. It would also seem that unless tremendous volumes of air were withdrawn, escaping air still would present the danger of high concentrations of respirable dust. Finally, electrostatic precipitation is not practical where combustible methane also is drawn into the precipitator.

Apart from the concern for mine dust suppression, it has been suggested that electrically charged disinfectant spray be introduced into a particular environment to attract bacteria and viruses to disinfectant droplets. This proposal contemplates the use of a charge producing arrangement, effective at the disinfectant spray outlet, to charge the spray as it enters the locale to be disinfected. This proposal does not treat the danger of igniting either combustible dust, or a combustible gas, by the presence of the high voltage charging apparatus in the environment to be cleansed, nor is there proposed enhanced charged particle distribution and outward expulsion by an electrogasdynamic energy exchange. Suggested for cleansing hospital rooms, or like environments where, at most, the usual, everyday amounts of dust are encountered, this proposal does not suggest that the introduction of charged particles, such as water droplets, could effectively suppress airborne dust where, as in mining operations, dust concentration is extremely high.

SUMMARY OF THE INVENTION

In view of the foregoing, it is an important object of this invention to provide improved apparatus for the suppression of objectionable particles.

It is also an object of this invention to provide apparatus in which high concentrations of airborne contaminant particles are suppressed by the introduction of charges into the highly contaminated region.

Another object of the invention is the provision of apparatus employing electrogasdynamic techniques to increase the electrical potential of charges introduced into a contaminant particle containing environment for the suppression of the contaminant particles therein.

It is an additional object of this invention to provide apparatus effective to introduce charges into a contaminant particle carrying environment while reducing the risk of arcing and consequent combustion, resulting from the charge producing apparatus.

Still another object of this invention is the provision of apparatus for electrogasdynamically increasing the electrical potential of charges introduced into a contaminated zone to establish a substantial space charge in the zone, thereby producing an even distribution of charges throughout the contaminated zone for the charging of contaminant particles therein, and also to aid outward expulsion and collection of the contaminant particles.

A further object of the invention is the application of the apparatus of the foregoing objects to particular industrial operations for the suppression of dust, or like airborne contaminants, normally generated there, thereby increasing visibility as well as protecting personnel from attendant dangers such as dust respiration or explosion.

The objects and improvements described above are achieved in accordance with this invention by passing charges through a channel and into the environment to be cleansed. Moving down the channel to the contaminated zone, the charges decelerate under the influence of an opposing axial electric field having a gradient increasing toward the channel outlet. The charges may be applied to seed particles, water droplets for example, by passage of the seed particles through a corona discharge region. The deceleration and forced movement of the charges against the opposing field effects an electrogasdynamic exchange whereby the electrical potential of the charges newly being introduced into the contaminant bearing atmosphere is greatly increased. The charges there are driven away from one another under the influence of the space charge field. A good charge distribution results, and the charges move outward among the contaminant particles, attracting and being attracted to the contaminant particles. The charges applied to the contaminant particles compel movement of the contaminant particles to nearby surfaces.

Establishing an enclosure about the region where contaminant density is greatest reduces the spread of contaminant particles. Furthermore, enclosing this zone into which the charges are supplied, increases the adjacent surface area upon which the charged contaminant particles may be collected. A metal enclosure, connected to ground, aids in the attraction of charged particles. Nevertheless, a partly conductive surface may result, for example, by the collection of charged water droplets and a ground connection may be established through the collected water.

In addition to directing the charge flow, an elongate channel, positioned between the charging electrodes and the point at which charges are to be introduced into the environment, separates the charging electrodes from the contaminated locale. This reduces the possiblity of interelectrode arcing, thus reducing the danger of igniting coal dust or methane gas in coal mines, or other combustible air-powder combinations at other contaminated sites. In fact, the channel may, if desired, be given a configuration preventing flame propagation. Good suppression of dust where it is generated protects

personnel by reducing inhalation. Better visibility promotes the effectiveness of personnel, as well. And in mining, enclosing and suppressing dust at transfer points limits the introduction of dust into fresh air drawn into a mine, promotes mine cleanliness, and may reduce the need for rock dusting throughout the remainder of the mine.

Water, compressed air, and adequate electrical power usually are available in mine shafts. Using fine charged spray to suppress dust at the mine face, where for example, coal is being extracted by a continuous mining machine, requires less water than ordinary water spraying. The water removal problem is thus eased.

Although particularly well suited for mining applications, the methods and apparatus of this invention are not limited in their application to mine dust suppression. Too, by "contaminant particles" no limitation to dust or like solids is intended, and indeed, the methods and apparatus described herein effectively suppress liquid airborne particles forming clouds or mists. Hence, where industrial contaminants are of this nature, the teachings contained herein apply.

The objects mentioned above, the further objects of the invention, and the foregoing discussion will more clearly be understood with reference to the attached drawings and the following detailed description of preferred embodiments of the invention.

IN THE DRAWINGS

FIG. 1 is a diagrammatic illustration, with parts broken away for clarity, of an enclosed coal transfer point and an associated electrogasdynamic (EGD) gun.

FIG. 2 is an enlarged diagrammatic, cross-sectional view of an appropriate EGD gun.

FIG. 2*a* is an enlarged fragmentary cross-sectional view of a modified EGD gun output end.

FIG. 2b is an end view, partly in section, of the arrangement shown in FIG. 2*a*.

FIG. 3 is a further diagrammatic illustration, with parts broken away for clarity, of a coal transfer location, here a rotary dump site, equipped with EGD guns to suppress airborne dust.

FIG. 4 is a top plan view, diagrammatically illustrating a continuous mining machine, located in a mine shaft and equipped with EGD guns.

FIG. 5 is a chart which plots the results of an actual test of dust suppression according to the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

In FIG. 1, a coal, or other granular product, transfer location **10** is illustrated. Here, a main conveyor **11** receives coal from a secondary conveyor **12**. Usually the main conveyor **11** is supplied coal by numerous secondary conveyors **12**, each transporting coal from a branch mine shaft. The secondary conveyor **12** spills the coal it conveys onto the main conveyor **11**, raising clouds of respirable coal dust about the transfer location.

An electrogasdynamic, charged suppressant particle supplying gun **13** is located to direct fine, charged water droplets to the transfer location **10**. The EGD gun **13** is supplied compressed air, and water via supply lines **15** and **16** from sources (not shown) traditionally available at mining sites. Electrical connections to the gun **13** are provided via cable **17** connected with a conventionally available source.

Turning to FIG. 2, the gun **13** is shown here in greater detail. The compressed air line **15** supplies air to the gun through an opening **18**. Adjacent the opening **18**, a restricted fluid inlet **20** opens into the path of air flow. The opening **20** communicates with the water supply line **16** through which water is forced under pressure. As air passes the restricted opening **20**, an aerosol of air and finely divided water droplets is formed. A partial restriction **21** increases the speed of this air-water combination.

Here a needle electrode **22** extends centrally to terminate adjacent an annular electrode **23** seated within the partial restriction **21**. Itself driven from the cable **17** connected with an A.C. source, a high voltage, A.C. to D.C. converter **24** energizes the electrode combination **22, 23**. The converter **24** may be a simple step-up transformer coupled to a suitable rectifier, such combination being well known. The high potential across the electrodes **22** and **23** causes corona emission at the tip of the needle electrode **22**, to establish a corona region **26** about the needle electrode **22**. The finely divided droplets moving through this region are charged.

The partial restriction **21** within the path of air and droplet movement is not necessarily required, but if used, the increase in the velocity of the air and the droplets in the corona region reduces, to a large extent, the deposition of charged droplets on the annular attractor electrode **23**. Once the droplets have been charged, the air bearing the droplets passes down an elongate channel **27** of a dielectric tube **28** opening at its end **30** toward the contaminated zone. A speed of air and droplet flow in the tube near or into the supersonic range increases turbulence at the outlet of the tube **28**. Although not essential, this enhances droplet movement and distribution among the suspended dust or other comtaminant particles.

Initially, as the charged, finely divided droplets are driven into the contaminated or dust bearing zone, transfer location **10** in FIG. 1, the droplets attract and are attracted to dust particles in the zone, and the associated particles and droplets spread outwardly to cling to nearby surfaces. As operation continues, a greater concentration of charged droplets is forced into the dusty zone. A space charged field is established there by the concentration of similarly charged particles.

Within the channel **27** an axial field component operates against the flow of further charges toward the outlet end **30** of the tube **28**. As new charged droplets move down the channel **27** against the opposing axial electric field, they greatly increase in potential until they exit into the contaminated zone. The increased potential of the charged droplets increases the space charge field. Each droplet experienes a relatively high force within the high dust concentration region, this force propelling the charged droplets radially outwardly away from the area of greatest droplet concentration. Two benefits result. Charges are evenly distributed entirely throughout the contaminated region. Charges applied to the contaminant particles force the particles to move away until they meet some nearby surface to reside there.

The increased potential and space charge field characteristic of the electrogasdynamic effect assures dust or contaminant suppression evenly throughout the region being cleansed and provides quick forced movement of contaminant particles to collecting surfaces. If the contaminant is susceptible to explosive ignition, as

are many dusts and powders, the distance down the channel **27** separates the electrodes **22** and **23** from the contaminant region, the electrodes are substantially isolated from spark-inducing contaminant particles, and conversely, the contaminant is not exposed to spark-producing high potential electrodes.

Additional protection may be gained by enclosing the upstream gun area within an isolating arrangement, for example a casing **31** with fibrous insulating material **32.** In this way, the high potential electrodes **22** and **23,** as well as the further electrical connections and components of the converter **24,** are isolated from the contaminant laden atmosphere. The packing material **32** may be selected for its vibration damping characteristics, as well, particularly where the gun **13** is subject to vibration or shock, as on the continuous mining machine discussed below in connection with FIG. **4.**

Where the deposition of contaminant particles on the gun **13,** itself, presents a problem, the improved apparatus of FIGS. **2***a* and **2***b* may be employed. This apparatus, which embodies the inventive methods and apparatus described herein, includes an arrangement for preventing the establishment of an electrical conductive path along the exterior surfaces of a gun **113** to ground or to another reference potential. This is the subject matter described in the copending application Ser. No. 87,253 of Robert W. Seaman and John P. Hanley, assigned to the assignee of this invention now U.S. Pat. No. 3,683,236.

Once an EGD gun has been in use for suppressing airborne contaminant particles, coal dust or the like, charged contaminant and seed particles may accumulate along the exterior surfaces of the gun establishing a continuous electrical path thereon from the output end of the gun to a grounded member or a member at another potential. Charges leaving the gun may be leaked to ground along this path, thus shorting the EGD system to ground. A potential is established near the gun output by the path so produced. A large difference between this potential and that of the passing charged particles may even cause an undesirable secondary corona discharge at the gun output.

The apparatus illustrated in FIGS. **2***a* and **2***b* prevents the formation of a continuous electrical path of this nature. An elongate channel member **128** is similar to the member **28** shown in FIG. **2.** Charged particles, such as the water droplets mentioned, are forced down the channel member **128** from a charging region like the charging region **26** described in connection with FIG. **2.** An exterior jacket **159** extends along the channel member **128,** encircling the member **128** and slightly radially spaced from the exterior surface thereof. A gas input port **160** opens into the jacket **159** and is adapted for connection to a suitably chosen gas or compressed air supply line (not shown).

A pair of closure and support members **161** and **162** support the jacket **159** on the channel member **128** at the jacket end removed from the gun output. At the gun output, a channel extension member or nozzle **163** communicates with the interior channel **127** of the channel member **128.** The nozzle **163** is of smaller outside diameter than the channel member **128.** A generally annular manifold block **164** surrounds the nozzle **163,** supports the jacket **159** near the gun output, and defines an annular chamber **165** about the nozzle **163** at the end of the channel member **128.**

Intermediate the outer jacket **159** and the inner channel member **128,** a gas flow path **166** extends from the port **160** to the block **164.** There, three radially extending ports **167** open into the chamber **165.** An annular restricted orifice **170** encircling the outermost tip of the nozzle **163,** communicates between the chamber **165** and the end face of the gun. Gas forced through the restrictive annular orifice **170** establishes an air shroud encircling the channel end **130** from which charged suppressant particles flow. The air shroud helps prevent the establishment of a continuous conductive path near the gun output **130** by aiding charge flow away from the gun face and limiting the roll back of charged particles across the air shroud to the face.

The prevention of a conductive deposited particle path is assured by a porous end plate **171** supported between the extreme end **172** of the jacket **159** and a mounting shoulder **173** on the manifold block **164,** and defining an annular nonconducting surface. One or more axially extending passages **175** through the manifold block **164** connect the chamber **165** with a further annular chamber **176** formed directly beneath the porous end plate **171,** between the end plate's inner surface and a surface of the manifold block **164.**

Gas forced into the chamber **165,** through the ports **175,** and into the further chambers **176,** escapes outwardly through the pores of the plate **171,** preventing the deposition of a continuous layer of conducting seed and contaminant particles upon the outer face of the plate. Particles will not collect on the face of the plate **171** to leak charges back to ground. No continuous conductive or partly conductive path is established through deposited particles. No undesired potential is established near the output gun end.

FIG. **1** also illustrates an enclosure **35.** This enclosure localizes the dust suppression problem at the transfer point **10,** preventing the spread of airborne dust particles throughout adjacent mine areas. An additional and important function of the enclosure **35** is the provision of increased surface area about the contaminated region. Rather than continuing to more remote locations, charged droplets and dust collect on smooth interior surfaces easily cleaned periodically. Less limestone rock dusting should be needed to suppress dust throughout a mine. Too, fresh ventilating air, drawn down a shaft, is much less subject to contamination while passing a transfer point.

To facilitate periodic interior surface cleaning, by for example, an ordinary industrial vacuum cleaner, enclosure **35** includes a door **36.** Also, to limit the escape of dust as effectively as possible, a series of conveyor facilitating openings **37** are equiped with closure flaps **38** engageable with the upper surfaces of the conveyors **11** and **12.** The flaps **38** limit communication between the interior and the exterior of the enclosure **35** in accordance with the amount of coal passing on the conveyors **11** and **12.**

Preferably, the enclosure **35** is conductive, sheet metal for example, and is connected to ground via a ground plane **40.** In this fashion, the enclosure **35** may drain off the charge applied to its interior surface by the charged droplets propelled thereto. A conductive enclosure thus does not increase in potential as a result of charge storage. Electrical shocks to personnel are avoided. The enclosure **35** may, then, function as a downstream collector electrode for the gun **13.** Although preferred, conductive interior surfaces are not

a necessity. Coating of the interior surfaces of the enclosure **35** by the droplets and contaminant particles does commonly establish a sufficiently conductive charge drain-off path to ground.

In FIG. **3**, the techniques and apparatus of the invention suppress dust at a rotary dump site. Here, coal, or other granular material, rail cars **45** move on tracks **46** into the partial enclosure **47**. Within the enclosure **47**, the cars **45** expel their load into a hopper **48** and then exit. Normally, the sudden release of large quantities of granular material fills the air with dust about the dump site.

As shown in FIG. **3**, however, a bank of EGD guns **13** about the hopper **48** suppresses the dust at its source. The enclosure **47**, like the enclosure **35** of FIG. **1**, increases the available nearby surface area. Any dust-bearing charged droplets escaping the hopper **48** have an available surface close at hand. Dust suppression occurs substantially as described above. Thus where granular material is transferred and dust normally rises, the suppression techniques described are suitable.

Several EGD guns **13** appear in FIG. **4** in combination with a continuous mining machine **50**. The machine **50** is of conventional design with a biting or mine face engaging front end **51** which tears the mine product from the mine face, a central conveyor **52**, and an operator station **53**. As the front end **51** bites into and removes coal from the mine face, the central conveyor **52** conveys the coal rearwardly to transfer the newly re-moved coal to an awaiting car **54**, spilling the coal into the car. Continuous mining machines present a severe respirable dust hazard, since an operator must work in close cooperation with the dust-producing apparatus.

The three EGD guns **13** shown in FIG. **4** have been supported on the machine **51**, substantially to isolate the operator station **53** from two areas of greatest coal dust concentration. These areas are the location at which the front end **51** contacts the mine face, continually removing coal and throwing up dust, and the coal transfer point at the end **55** of the conveyor **52**, where coal is dumped into the waiting car **54**. Because of the severe hazards here, the guns **13** cooperate with an exhaust duct **57**. The duct **57** is connected with an exhaust fan (not shown) to withdraw air from the mine shaft in which the continuous mining machine **51** works. Any methane gas is drawn away and fresh air is supplied down the shaft in the direction of FIG. **4**'s unnumbered arrow. Because fresh air is to be supplied to the machine operator, and because the machine continually moves, the high dust concentration zones cannot be enclosed as they were in the arrangements of FIGS. **1** and **3**. Plural guns are, therefore, supported between the operator station and the front end **51**, as well as one or more guns between the station **53** and rear end transfer point **55**.

Compressed air, electrical power, and water should be made available at the continuous mining machine if the machine is not so equipped. The machine **51**, itself removes much of the dust collecting at shaft walls, since this agglomerates in the presence of the water droplets and is removed with the extracted coal.

In a successful test, the improved suppression of respirable coal dust by spraying charged water particles into a dust-laden environment was shown. The test environment was a 6 foot by 8 foot by 6 foot room into which coal dust particles, approximately ten microns in diameter, were continuously fed in an approximately 400 $ft.^3$/min. airstream. Charged spray was compared with uncharged spray. The results, taken from ten one hour runs, are summarized in FIG. **5**.

As illustrated by curve *a*, the average dust suppression for the 10 1 hour tests was a reduction in dust concentration from approximately 300×10^6 particles/$ft.^3$ to approximately 80×10^6 particles/$ft.^3$. This was a suppression representing approximately 75% of the total number of particles initially in the chamber, using only one gun, and continuously replenishing the dust, as noted. The rate of suppression was 31.5×10^6 particles/$ft.^3$/min. From visual observation, the rate at which dust was introduced into the test environment appear even higher than the rate at which dust is expelled in most mining operations.

For comparison, curve *b*, in FIG. **5** illustrates the degree of suppression, using the same equipment, absent charging of the spray. The coal dust concentration was reduced only from 300×10^6 particles/$ft.^3$ to about 250 particles/$ft.^3$, a percentage suppression of only about 17 percent.

These tests are particularly enlightening since a 6′ by 6′ by 8′ tall enclosure would, in most cases, be sufficient to enclose coal transfer points of the type illustrated in FIG. **1**. An enclosed space having the same volume as that of the test chamber would thus be defined, and similarly successful results should be expected.

The apparatus described above for the suppression of suspended particulate contaminants may be modified, as will be obvious to those skilled in the art, to meet the exigencies of particular uses without departure from the spirit and scope of the invention embodied therein and defined in the appended claims.

I claim:

1. Apparatus for suppressing airborne contaminant particles about a work zone at which the contaminant particles are expelled into the surrounding atmosphere; the apparatus including means for supplying a quickly moving stream of gas, means for entraining fine seed particles in the quickly moving stream of gas, means for establishing a corona discharge region through which the gas and entrained seed particle stream passes and means comprising an elongate channel opening toward and extending toward the work zone and positioned intermediate the work zone and the corona region for directing the gas and seed particle stream toward the work zone against in opposing electric field to electrogasdynamically increase the electrical potential of the seed particles, said corona region establishing means comprising a corona needle, an electrode and an associated attractor electrode, the channel comprising an elongate nonconductive member interposed between the electrodes and the work zone, the distance along said channel from the corona region to the channel exit being sufficient to isolate the corona electrodes from the charge build-up and the contaminant at the exit, thereby substantially reducing the possibility of interelectrode arcing, whereby the contaminant particles are charged by the fine, charge carrying seed particles, and are propelled to surfaces adjacent the work zone, and further including mounting means for the apparatus including means for encasing the corona region, shock damping material within the encasing means and supporting the apparatus therein to substantially lessen jarring of the apparatus.

* * * * *