United States Patent

Watanabe

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[54] **METHOD AND SYSTEM FOR REMOVING PARTICLES OF FLOATING DUSTS PRODUCED UPON AN EXCAVATION OF A TUNNEL**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** .....**55/2**, 55/136, 55/139, 55/146, 55/148, 55/150, 55/154, 98/49, 98/50, 299/2, 299/12, 317/262 R

[51] **Int. Cl.**.....**B03c 3/43**

[58] **Field of Search**....55/2, 101, 136, 137, 139, 146, 55/148, 150, 151, 152; 299/2, 12; 98/50, 49, 51; 317/3, 4, 262 R, 262 AE

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[57] **ABSTRACT**

A method of removing particles of floating dust produced upon excavation of a tunnel including the step of charging the particles by the formation of an electric field between the inner wall of the tunnel and a plurality of electrodes equidistantly positioned within the tunnel and which have a high potential applied thereto. The apparatus for accomplishing this method consists of a system for removing the particles of floating dust produced upon excavation of the tunnel and including a plurality of electrodes equidistantly positioned with respect to the tunnel wall for forming an electric field between the inner wall of the tunnel and the electrodes so as to charge the particles, a plurality of posts provided in the tunnel for supporting the electrodes, and a high voltage supply for applying a high potential to the electrodes whereby the particles are electrically deposited on the inner wall of the tunnel.

7 Claims, 5 Drawing Figures

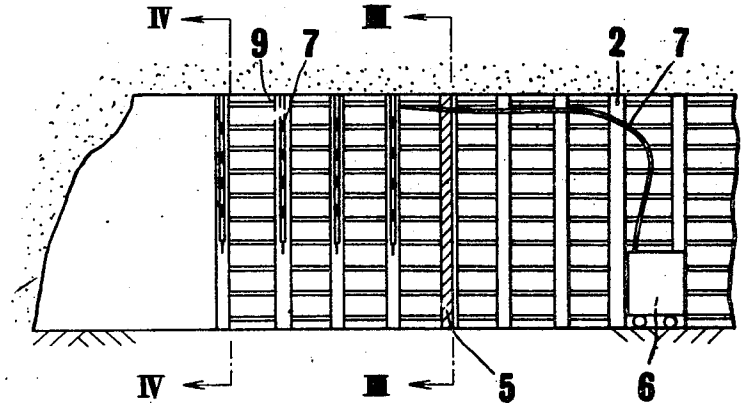

Fig. 1

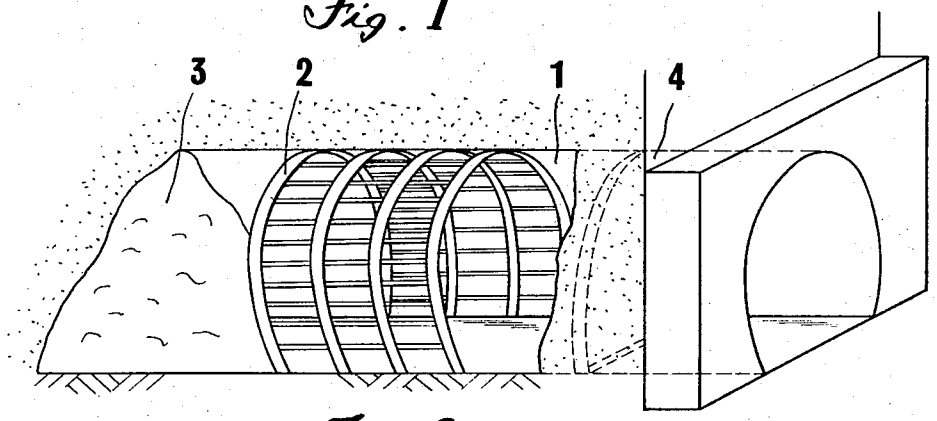

Fig. 2

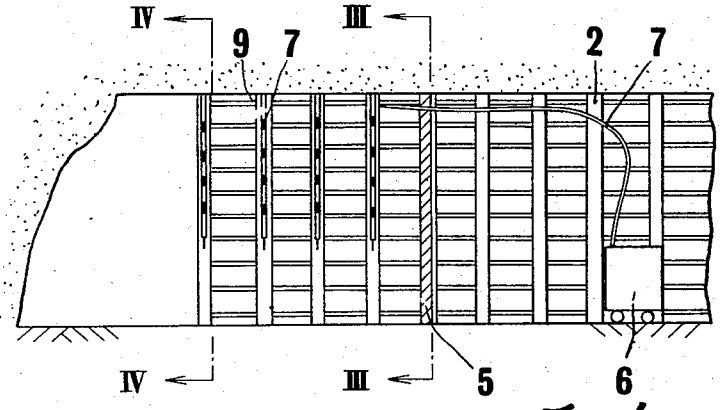

Fig. 3

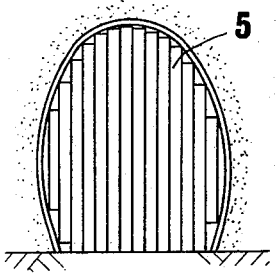

Fig. 4

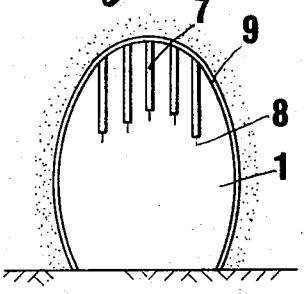

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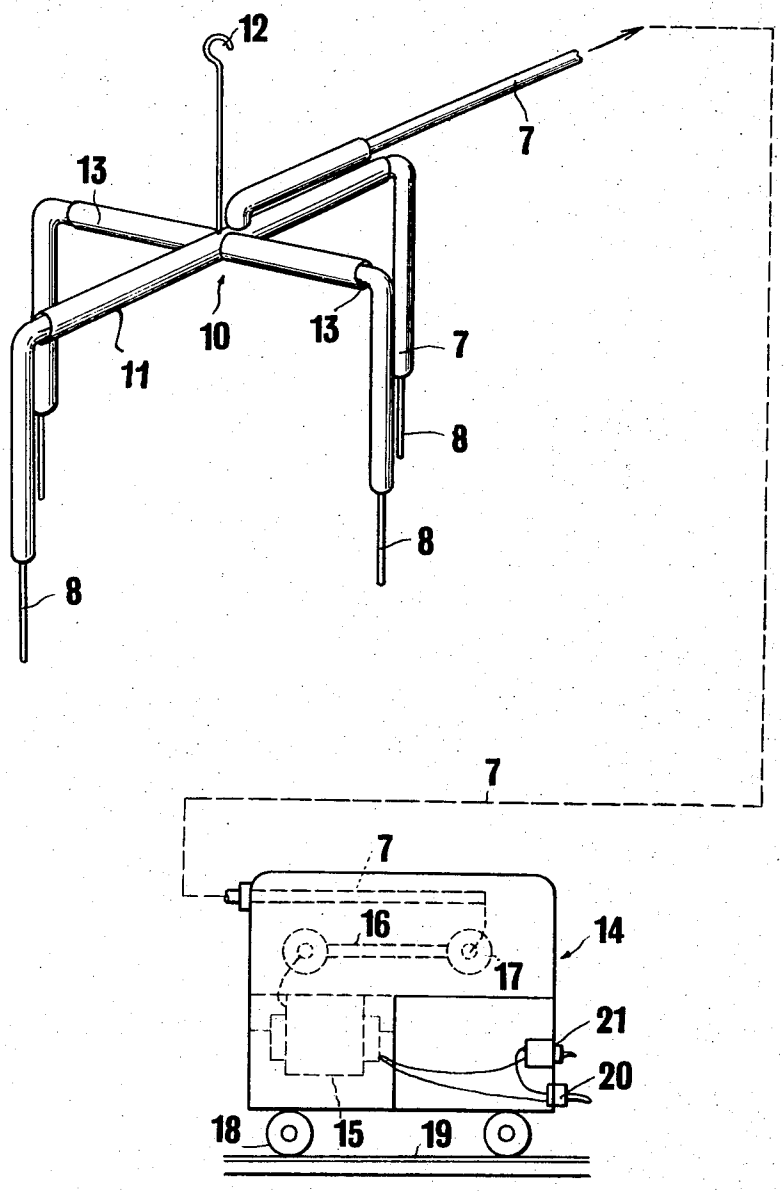
Fig. 5



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METHOD AND SYSTEM FOR REMOVING PARTICLES OF FLOATING DUSTS PRODUCED UPON AN EXCAVATION OF A TUNNEL

BACKGROUND OF THE INVENTION

This invention relates generally to a method and apparatus for removing particles of floating dust and more particularly to a method and apparatus for removing particles of floating dust produced upon excavation of a tunnel.

Heretofore, there have existed in the prior art various ways of excavating a tunnel including power excavation and blasting excavation, each of which may be utilized alone or in combination so as to efficiently produce a tunnel within a mountain or mine.

In the excavation of stones, rocks, earth, sand, and the like, there have been used other excavating devices such as a rotary excavator and a reciprocating excavator. Modern excavating equipment is constantly being improved so as to provide increased speeds of excavation removing larger amounts of material in a shorter time. One problem with such modern equipment is that there results a large amount of particles, such, for example, as dust and other particulate materials, which tend to float in the atmosphere within the tunnel. These particles are extremely detrimental to the workmen and operators within the tunnel decreasing the efficiency of their operation and, in some cases, resulting in illness, such as silicosis.

In the case of blasting excavation, there is an even greater tendency for the dust and mist to float within the air and take a much greater amount of time for the particles to settle after the blasting operation, resulting in a greater delay before the operators and workers may again enter the tunnel to remove the broken stones and rocks. This is a result of the safety precautions taken when blasting, including the provision of a shield plate to seal off the blasting zone from the remainder of the tunnel. The shield plate has the adverse effect of interrupting the flow of air between the inside of the tunnel and the outside thereof, such that the particles of stone and rock produced by the blasting tend to float in the atmosphere within the sealed portion of the tunnel. In addition, when water is utilized during the excavation of the tunnel, the water evaporates due to the heat generated during the excavation, thus producing a mist which will also tend to float within the atmosphere inside of the tunnel.

There have been various attempts in the prior art to overcome the aforesaid disadvantages including the methods of blowing fresh air into the tunnel or exhausting the particles of stone and rocks from the tunnel through a duct extending from the inside to the outside of the tunnel. None of the prior art attempts have been wholly satisfactory, since in the former method, the dust and mist are diffused throughout the tunnel, and in the latter method, the required ducting and other equipment for blowing the air or exhausting the particles require a large amount of valuable space within the tunnel. The longer or deeper the tunnel is, the larger the required capacity of the equipment is, thus resulting in great expense and lost time in installing ducting and equipment.

Even utilizing one of the above-mentioned methods for the excavation of a tunnel, it takes approximately 30 to 40 minutes to remove the floating particles

produced by the excavation of the tunnel, during which time the workers and operators must remain out of the tunnel and cannot be carrying the blasted stones and rocks therefrom. Since blasting excavation only proceeds at a rate of 30 centimeters for each blasting operation, it can be seen that a great deal of time will be wasted during the operation of clearing the dust from the tunnel. In the case of power excavation, there has been a great tendency for the workers and operators to suffer from silicosis due to the incomplete removal of the particles of dust and mist.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a method of quickly removing particles of dust and mist floating in the atmosphere within a tunnel as a result of excavation of the tunnel.

It is another object of this invention to provide a method of accelerating the removal of particles of floating dust and mist produced upon excavation of a tunnel.

It is a further object of the subject invention to provide a system for removing particles of floating dust and mist produced upon excavation of a tunnel

It is a still further object of the subject invention to provide for the shutting off of the electrical circuit of a particular electrode which is short-circuited as a result of falling onto the ground in a system including a plurality of electrodes utilized for removing particles of floating dust and mist during the excavation of a tunnel.

It is a still further object of the subject invention to provide a mobile system which is capable of being utilized for removing particles of floating dust and mist within a tunnel.

According to one aspect of the present invention, the foregoing and other objects are attained by providing a method of removing particles of floating dust and mist produced upon excavation of a tunnel by charging the particles through the use of an electric field created between the inner wall of the tunnel and a plurality of electrodes equidistantly positioned within the tunnel and having a high potential applied thereto.

Other features and advantages of the subject invention will become apparent from the following description, taken in conjunction with the accompanying Drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a tunnel inside of which posts are provided;

FIG. 2 is a side view of the tunnel, wherein the system of the subject invention is provided;

FIG. 3 is a sectional view of the tunnel taken along the line III—III of FIG. 2;

FIG. 4 is a sectional view of the tunnel taken along the line IV—IV of FIG. 2; and,

FIG. 5 is a schematic exploded perspective view of a second embodiment of the subject invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the Drawings, wherein like reference characters are used to designate the same or similar parts throughout the several views, and more

particularly to FIG. 1, wherein there is illustrated a tunnel having a gallery 1 and a plurality of arch posts 2 constructed therein for preventing earth, sand, stones and rocks from collapsing within the gallery. In the case of blasting excavation, shield plates, such as illustrated at 5 in FIGS. 2 and 3, are provided between an excavation portion 3 and the excavated gallery 4 of the tunnel so as to isolate the excavated area from the gallery and prevent damage to the gallery from scattered stones, rocks, earth and sand.

During the excavation of the tunnel, a great deal of dust is created which prevents the workmen from entering into the portion 3 to remove the stones, rocks, earth, sand, and other debris. In order to remove the undesirable dust from the atmosphere within the excavated portion of the tunnel, a plurality of electrodes 8 are suspended from the top portion 9 of the arch posts 2 which are provided between the excavating portion 3 and the shield plate 5 within the tunnel. The electrodes 8 are connected through a high potential cable 7 to a source of high potential 6, as best illustrated in FIGS. 2 and 4.

When the excavating portion 3 is blasted, the resulting earth, sand, stones, rocks, and like materials are blown up into the space between the blasting portion 3 and the shield plate 5 so as to create a cloud of particulate material therethrough. Immediately after the explosion, a high potential is applied to the electrodes 8 from the source 6 so as to form a high electric field between the electrodes 8 and the inner wall of the tunnel such that the particles of floating dust and mist within the tunnel are charged resulting in the particles being electrically deposited onto the inner wall of the tunnel which has the opposite polarity with respect to the electrodes 8.

The high potential of the electric field to be applied to the electrodes is preferably above 1 kilovolt per centimeter in mean potential gradient.

If a negative high potential with respect to the ground is applied to the electrodes, minus ions are generated, which force the particles to be deposited onto the walls of the tunnel. A negative high potential generating minus ions will not create an uncomfortable feeling for human beings.

According to another aspect of the present invention, a method is provided which accelerates the removal of the particles by applying an intermittent or pulsating high potential to the electrodes which are equidistantly positioned within the tunnel. Utilizing this method, the time for removing the floating particles from the atmosphere within the tunnel is substantially shortened. The electric field is preferably extended throughout the accessible portions of the tunnel by disposing a multiplicity of electrodes equidistantly disposed with respect to each other through as broad an area as is possible within the tunnel.

As a result of experimentation, it has been found that in a tunnel having a diameter of approximately 4 meters, it took approximately 30 to 40 minutes to remove the particles of dust and mist produced by blasting excavation by utilizing the conventional methods, while it only took approximately 1 minute to deposit the particles onto the inner walls of the tunnel according to the method of the present invention utilizing a potential of approximately 200 kilovolts applied to the electrodes 8. During the experiment, the electrodes 8 were equidistantly disposed at approximately 1 meter intervals from each other and from the wall of the tunnel.

The electrodes are preferably shaped so as to provide as sharp a point as possible so as to provide a good corona discharge. Therefore, the electrodes may consist of bared wires at the end portions thereof and having the high voltage cable provided with an insulated cover or, in the alternative, the electrodes may be an elongated member having a sharpened tip at the end portion thereof. However, the particular shape of the electrode should not be considered a limitation upon the present invention in that various types of electrodes which are capable of producing a corona discharge can be utilized.

When excavating utilizing blasting techniques, the high voltage cable and associated electrodes are preferably constructed in a flexible manner such that deflection of the electrodes due to the scatter of blasted material does not adversely affect the electrodes so as to render them defective.

Further precautions may be taken when excavating utilizing blasting techniques, including the provision of electrical insulation between the electrodes and the inner wall and bottom of the tunnel prior to the blasting operations and the mounting of the electrodes such that they do not move due to the shock of the blasting operations within the tunnel. Furthermore, in order to assure the safety of the operation in the event that an electrode is short-circuited by falling upon the ground, there may also be provided a device for shutting off the electrical circuit to the particular electrode which has become short-circuited. Thus, even though one or more of the electrodes may accidentally fall to the ground due to the shock of the blasting operation and thus become short-circuited, the rest of the electrodes can still operate so as to form an electric field which is capable of removing the particles by depositing them onto the inner wall of the tunnel. The method of the subject invention is particularly effective for depositing particles onto the inner wall of the tunnel by forming an electric field within the tunnel when the air containing the particles of floating dust and mist is relatively steady or moving slowly within the tunnel. In the event that a strong wind exists within the tunnel, the method is less effective, although it is better than conventional methods. It is preferable to apply the electric field within the tunnel after the explosive gases have exhausted so as to dilute the gas and render the method more effective.

The greater the distance between the inner wall of the tunnel and the electrodes, the higher the potential necessary to carry out the method of the instant invention. The distance utilized for spacing the electrodes will depend upon the economic considerations in choosing the particular high voltage power supply and the type and extent of the excavation.

The number of electrodes may also be dependent upon the type and extent of the excavation, but preferably, the electrodes are disposed equidistantly so as to form a uniform electric field within the tunnel so as to uniformly charge the particles of dust and mist produced upon excavation.

According to a further aspect of the present invention, as illustrated by a second embodiment thereof,

there is provided a system for removing particles of floating dust and mist produced upon excavation of a tunnel comprising a plurality of electrodes which are equidistantly positioned within the tunnel for forming an electric field between the inner wall of the tunnel and the electrodes so as to charge the particles with a high potential with respect to the inner wall and bottom of the tunnel, and includes a plurality of posts provided within the tunnel for supporting the electrodes and a source of high potential for application to the electrodes whereby the particles are electrically deposited onto the inner wall of the tunnel. The insulator for equidistantly spacing the electrodes, as shown in FIG. 5, may preferably be made of polyethylene resin, teflon resin, rubber which has not been blended with carbon black, or like high molecular compounds. In order to prevent the constant distance between the electrodes from varying, even during blasting excavation, there is also provided in the system a means for equidistantly spacing the electrodes, which may comprise, for example, a plurality of resilient and flexible tubes of high molecular compound through which the electrodes of metal wire or covered wire are disposed and which have the end portions thereof exposed. In addition, according to still another aspect of the present invention, there is also provided means for shutting off the circuit to the electrode which has become short-circuited upon falling to the ground due to the shock of a blasting operation, which may comprise, for example, a circuit breaker or fuse connected in series to the high potential supply circuit. It has been found necessary in the system of the present invention to prevent some of the electrodes from forming a high electric field with the inner wall of the tunnel, and this has been accomplished by equidistantly disposing the electrodes throughout the tunnel. In such a system, an electrode having an opposite charge with respect to the electrodes connected to a negative high potential terminal may be installed within the inner wall or earth of the tunnel by grounding a high positive potential terminal of the source of high potential or by grounding the positive terminal to a rail on which a movable source of high voltage is carried.

Within the present system, in order to reduce the depositing time of the particles to substantially one-half of that of the system utilizing a steady electric field, a pulsating voltage may be applied to the electrodes. Such a pulsating voltage may be applied to the electrodes by manually or automatically switching on and off the power switch with the cycle of pulsation preferably less than 1,000 cycles per second and normally less than 100 cycles per second.

Referring now more specifically to FIG. 5, which shows the second embodiment of the electrodes of the present invention, utilized within the system of the subject invention, a charging portion **10** of the present system is provided for removing the particles of floating dust and mist produced upon excavation of a tunnel and includes a suspension type insulating sleeve **11** of cross shape through which the high potential cable **7** is inserted and is suspended at the end portions **13** of the sleeve **11** such that wires **8** utilized as electrodes are bared at the end portions thereof, and a suspension member **12** is connected to the center of the sleeve **11** for suspending the sleeve from the top of the tunnel.

The wires **8** are connected to a source of high potential **14** for supplying a negative high potential to the electrodes **8**, which source comprises, for example, a high voltage power supply including a step-up transformer **15**, a selenium rectifier **16**, and a capacitor **17** or a rectifying circuit of the Cockcroft and Walton type of selenium rectifier and capacitor. Wheels **18** may be provided for moving the system on rails **19** within the tunnel and a power switch **20** and circuit breaker **21** may also be provided as illustrated in FIG. **5**. An electronic switching circuit (not shown) may also be provided for producing a pulsating high voltage to the system.

A "mist" as described within this application would include a fog generated as a result of supersaturation in which a vapor is converted into a dew in the case of 100 percent humidity within the atmosphere.

In the case of power excavation within the tunnel, since the excavator is covered with particles of floating dust and mist, the electrode may preferably be provided to the excavator so as to form an electric field within the tunnel in order to remove the particles of dust and mist which have covered the excavator.

It should be readily understood from the foregoing description that since the system of this invention removes quickly the particles of floating dust and mist produced upon the excavation of the tunnel, the excavation of the tunnel will be quickly and efficiently completed thereby.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed as new and desired to be secured by letters patent of the United States is:

1. A method of removing particles of floating dust produced through blast excavation of a tunnel comprising the steps of:

placing a shield between a portion of the tunnel to be blast excavated and an already excavated gallery portion;

disposing a plurality of electrodes in spaced relation along the tunnel length between said shield and said portion of said tunnel to be blast excavated; and

applying a high potential to said plurality of electrodes after blasting to form an electric field between the inner wall of said tunnel and said electrodes, whereby the particles of floating dust produced upon blasting are charged and caused to be deposited on the inner wall of said tunnel.

2. The method as set forth in claim **1**, wherein said high potential applied to the plurality of electrodes is a negative high potential with respect to the inner wall of said tunnel.

3. The method as set forth in claim **1**, further including the step of pulsating the high potential applied to said electrodes.

4. A system for removing particles of floating dust produced during excavation of a tunnel comprising:

a plurality of electrodes;

means for supporting said plurality of electrodes in substantially equidistant relation within said tunnel; and

high voltage power source means for supplying a high potential to said plurality of electrodes for forming an electric field between the inner wall of said tunnel and said electrodes, whereby said particles may be electrically deposited onto the inner wall of said tunnel.

5. The system as set forth in claim 4, wherein said means for supporting said plurality of electrodes in substantially equidistant relation comprises a plurality of posts erected within said tunnel.

6. The system as set forth in claim 4, wherein said means for supporting said plurality of electrodes in substantially equidistant relation comprises a suspension type insulating sleeve having a plurality of arms spaced at equal angular intervals in a given plane.

7. The system as set forth in claim 4, further comprising means for shutting off the circuit to an electrode which becomes short-circuited.

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