June 2, 1970 | J. G. TRUMP | 3,515,939

DUST PRECIPITATOR

Filed July 13, 1967 | 2 Sheets-Sheet 1

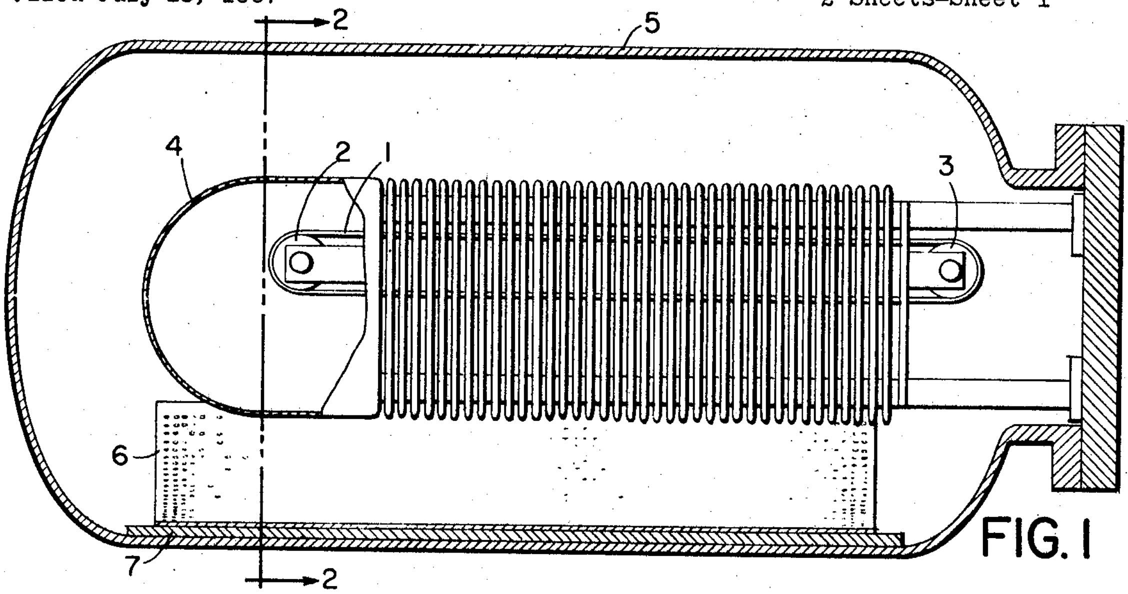


FIG. 1

FIG. 2

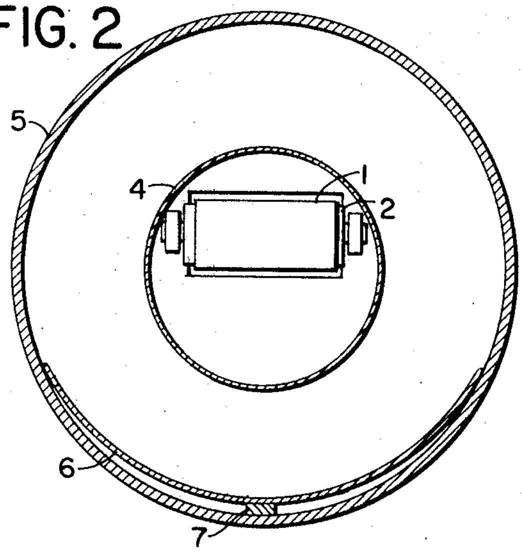


FIG. 3

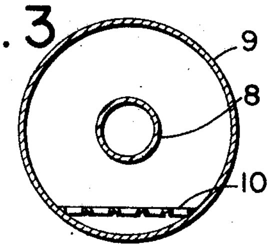
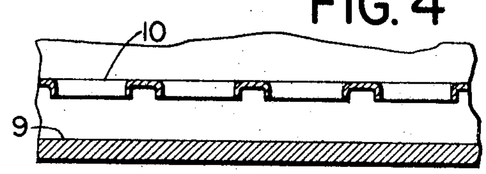


FIG. 4



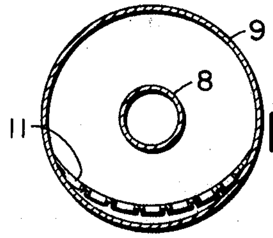
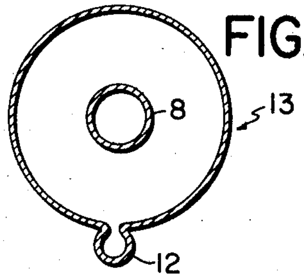


FIG. 5

FIG. 6



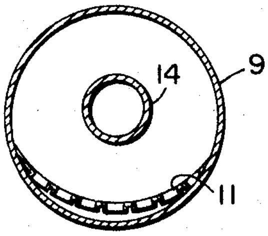


FIG. 7

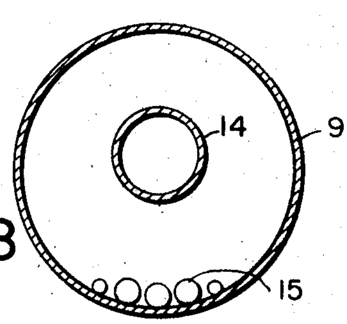


FIG. 8

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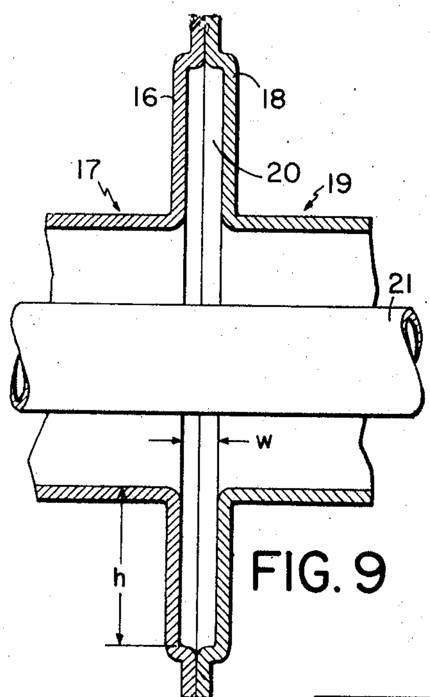

FIG. 9

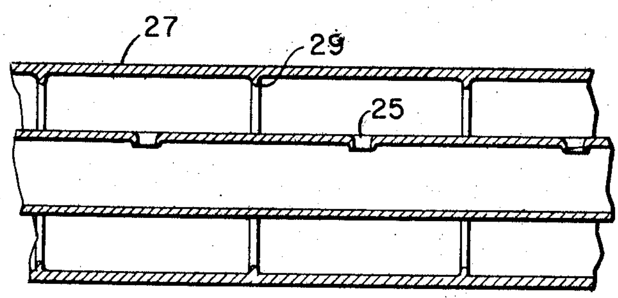

FIG. 13

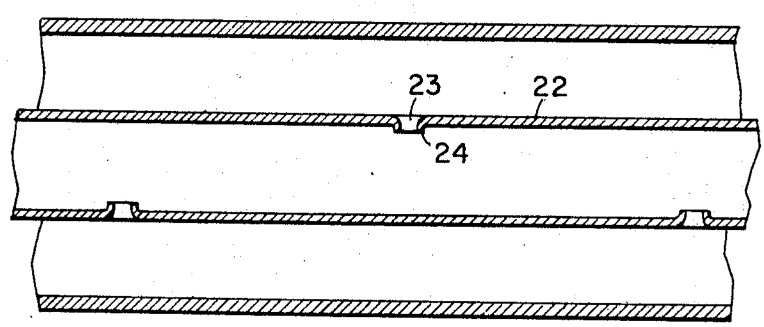

FIG. 10

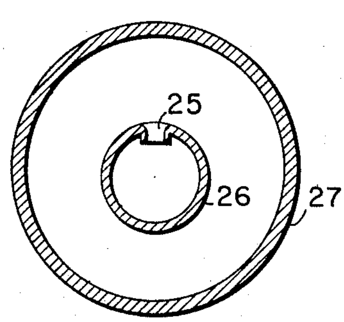

FIG. 11

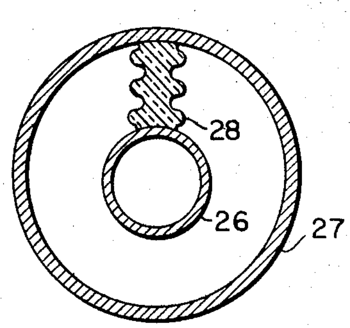

FIG. 12

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3,515,939
DUST PRECIPITATOR

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Int. Cl. H03c 3/00
U.S. Cl. 317—3 13 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to compressed-gas-insulated systems, such as belt-type electrostatic generators, and in particular to increasing the insulating capability and reliability of such systems. My invention comprehends a belt-type electrostatic generator or other high-voltage compressed-gas-insulated system wherein a region of reduced electric field is provided along the surface of at least one of the pair of electrodes between which the high voltage is applied for the entrapment of solid particulates. My invention is not limited to electrostatic generators, but includes any two or multi-electrode system insulated in compressed gases, such as compressed-gas-insulated transmission lines. For example, one such embodiment of my invention comprehends a high voltage transmission line for the transport of electric power whether A-C or D-C, of the type in which a gas or a mixture of gases (such as N_2, CO_2 or SF_6) at several to many times atmospheric pressure is used as the principal voltage-insulating medium, in which the central conductor is at high potential and supported at spaced intervals along its length by a solid insulator or by several such solid insulators, in which the outer cylindrical container is of aluminum or other metal to withstand internal gas pressure and is grounded and may serve as the grounded return line, and in which an electric field exists between the central conductor or conductors and the grounded shell; and, in accordance with the invention, means are provided for systematically reducing the electric field at regions near the surface of said shell or said conductor. For example, means may be provided for producing at frequent intervals along the bottom envelope of said shell regions a substantially lower electric field for the collection of particles of matter. For this purpose, a perforated metallic plate may be mounted in the lower portion of the shell to produce regions of low electric field between plate and shell into which solid particulates may become lodged and inactivated. In this way the electric field of the energized transmission line is employed to accelerate loose fragments of matter into regions of such low electric field intensity that they are permanently trapped (inactivated).

One of the experimental factors which has been shown to precipitate at sub-normal voltages discharges between electrodes in compressed gas is the presence of particulates such as dust, fibers or fragments of solid conductive or semi-conductive materials; and, as indicated, the invention deals with a general method of eliminating such unwanted particulates by means for entrapping foreign particles in compressed-gas-insulated systems.

Consider the situation when such a particle is of a semiconducting or conducting nature and is in contact with one of the two electrodes between which the electrical field exits. By electrostatic induction, the particle will become charged continuously or periodically by an amount q related to its physical geometry and electric field intensity E at the electrode to which it is connected. If and when the resultant electrostatic force, $f=qE$ acting on the particle, becomes sufficient to detach the particle it will

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leave this electrode and travel through the gas to the other electrode, conveying its charge to that system. Assuming the particle has not been fragmented in this operation, it will now become oppositely charged to an amount associated with its new local electric field. When the electrostatic force again becomes sufficient it will proceed to travel toward its original electrode. This process can be observed in gases at atmospheric and higher pressures and also in high vacum. In gases, charge-transfer processes can change the amount and polarity of q even when it is not in direct contact with an electrode. Particles can therefore occasionally be seen moving about the surface of a high gradient electrode in dynamic equilibrium. On the other hand, a particle may for a considerable time be attached to a high gradient electrode surface, and cause field-distorting current and space charge by its geometrical intensification of the local electric field.

One characteristic of a compressed gas transmission line of concentric cylindrical geometry is that there are no regions where weak or substantially zero electric fields exist. Thus there is no escape or "sink" for a particle which by some inadvertence has been produced or left in the inter-electrode region. The presence of a great number of conductive particles adhering to and projecting from the surface of the central conductor results in a continuous inter-electrode current which serves as a power drain on the power line. Far more important, these particulates produce local intensifications of the electric field through the corona currents and residual positive-ion space charges. These tend to precipitate instability and account for much of variability in the insulation behavior of a compressed-gas-insulated system.

One method that would greatly improve this situation lies in providing continuously along the length of a compressed gas transmission line a region of low electric field which can serve as a sink or permanent repository for the unwanted particulates. A particular method of accomplishing this which is suitable for a practical transmission line would be to provide along the lower region of the transmission line cross-section a low-field region by modifying the geometry of the outer shell in this region. This could be done, for example, by interposing a perforated metal shield as a kind of chord across the bottom portion of the interior cylindrical surface. Particulates which are traveling back and forth in the manner indicated above, due to electrical induction and electrostatic force, would find their way before long into one of the openings in this grounded shield. It can be shown that beneath the shield the electrical field intensity will be much reduced Even beneath the center of each opening in the shield, the electric field intensity will be reduced by a factor which can be made several orders of magnitude. For example, if the spacing of the shield above the inner surface of the cylinder is equal to the diameter of the shield opening, then the electric field intensity on the pipe surface under the opening will be about 5 percent. If this spacing is equal to three diameters the field reduction factor increases from about 20 to more than 500. Since the force acting on a particle is equal to the product of its induced charge and the electric field intensity, the force acting on a particle, even under the center of an opening, would be reduced by a factor equal to the square of the reduction in the electrical field intensity.

The invention may best be understood from the following detailed description thereof, having reference to the accompanying drawings, in which

FIG. 1 is a diagrammatic view of an electrostatic belt-type generator embodying the present invention;

FIG. 2 is a transverse sectional view along the line 2—2 of FIG. 1;

FIG. 3 is a transverse section of a transmission line having a perforated chord-like shield for entrapping foreign particles;

FIG. 4 is a detail of FIG. 3;

FIGS. 5–8 are views similar to that of FIG. 3, each showing a different modification of the shield;

FIG. 9 is a longitudinal central section of a coupling for transmission line adapted to entrap foreign particles;

FIG. 10 is a longitudinal central section of a transmission line of which the central conductor is adapted to entrap foreign particles;

FIG. 11 is a transverse section of a modified form of the transmission line shown in FIG. 10;

FIG. 12 is a view similar to that of FIG. 11, showing a modification thereof; and

FIG. 13 is a view similar to that of FIG. 10, showing a modification of the embodiment shown in FIG. 11.

Referring to the drawing and first at FIG. 1 thereof, the operation of the electrostatic belt type generator therein shown is in general well known and need not be described herein in any detail. Suffice it to say that electric charge is carried by an insulating belt **1** supported between two pulleys **2**, **3** from the grounded end of the apparatus to a hollow electrode **4** which constitutes a high voltage terminal. The voltage-generating apparatus is enclosed within a tank **5** containing insulating gas under pressure. Details of operation of electrostatic belt type generators may be found, for example, in U.S. Pat. No. 1,991,236 to Van de Graaff and No. 2,252,668 to Trump and at Volume XI, page 1 of "Reports on Progress in Physics" (1948).

In accordance with the invention a sheet of metal **6** having apertures is placed over the surface of the tank **5** opposite the high voltage terminal **4** and at the portion of the tank wall having the lowest gravitational potential i.e. at the side nearest ground in a gravitational as distinct from electrical sense. This sheet **6** may be for example No. 20 gauge 304 stainless steel mesh having ¼-inch diameter holes on ⅜-inch centers. Along the axis of this sheet is supported a stainless steel bar (304) ⅜-inch thick, 1½-inch wide, and protruding 3-inches beyond the ends of the sheet, which might be five feet long and five feet wide for a five-foot-diameter tank. The sheet is screwed or bolted to the surface of the tank at several points, the bar serving to increase the depth of the field-free region between the sheet and the tank. The ratio between the diameter of the holes in the sheet and the distance from the inner surface of the perforated sheet to the inner surface of the tank is an important one and should preferably be as 1 to 3 or 4.

Referring to FIGS. 3 and 4, a central conductor **8** is supported along the axis of a pressure pipe **9**, in any of the manners described in my copending patent application Ser. No. 749,135, filed July 31, 1968. In accordance with the invention, a perforated metal shield or plate **10** is interposed across the bottom portion of the interior cylindrical surface of the pressure pipe **9**, so as to form a kind of chord. The shield **10** is electrically connected to the grounded shell **9**, so that radial field lines originating at the central conductor **8** at high potential terminate on the shield **10**, and the region between the shield **10** and the shell **9** is one of low electric field from which particulates cannot readily escape.

In the modified embodiment of FIG. 5, the shield **11** is curved to approach the contour of the shell **9** so as to increase spacing between central conductor **8** and shield **11**.

In the modified embodiment of FIG. 6, the low field region is produced by extending a small portion **12** of the circumference of the shell **13** toward and preferably downward to form a channel.

In the modified embodiment of FIG. 7 the center conductor **14** is off-centered upward so as to (1) reduce the radial electric field in the lower portion of the line and (2) diminish the effective weight of the central conductor **14** by the differentially greater upward electrostatic force.

In the modified embodiment of FIG. 8, the low field region is provided by metal pipe or ducts **15** which serve not only to carry control and information cables (or even liquids) but also by their arrangement to produce low gradient regions along the bottom of the main pipe **9** in which particles of matter can become permanently entrapped. The pipes **15** should be slightly separated, as shown, to allow the particulates to get in between. For example, the narrowest portion of the gap between adjacent pipes **15** may be about one-third the radius of the pipe **15**.

The joint or coupling of the outer shell or pipe of a compressed gas transmission electric power line may itself provide an electrostatic particle catcher, as shown in FIG. 9. Referring to FIG. 9, one end **16** of a pipe **17** may be welded to one end **18** of an adjacent pipe **19**. The welded joint **16**, **18** forms a channel **20** of depth h and width w. The gap w should be less than the depth h by a factor of at least 3, and preferably about 4 for good "trapping" of particles, particularly conducting particles. The center conductor is shown at **21**.

It is not necessary that the low-field particle-trapping region be associated with the outer shell. Although the gradient at the outer surface of the inner conductor is substantially higher than the gradient at the inner surface of the outer conductor, so that the provision of a low gradient region is inherently more difficult at the central conductor, nevertheless in cases where the central conductor is hollow the region within it will be a naturally field-free region and may be used to trap particles. One such arrangement is shown in FIG. 10. Referring thereto, the central conductor **22** has perforations **23** into which particles will fly. Inside the central conductor **22** the electric field is nearly zero and therefore particles which reach the interior of the central conductor **22** are trapped. The perforations or apertures **23** are preferably rimmed as shown at **24** to prevent particles from dropping out again. For example, in making the perforations the metal may be pressed from the outside inward so as to form an inwardly projecting rim **24**. In addition to serving for particle entrapment the system of periodic holes **23** in the central conductor **22** shown in FIG. 10 will also help cool it by causing convection currents in the insulating gas.

A modification of the embodiment shown in FIG. 10 is shown in FIG. 11. Referring thereto, particle-collecting apertures **24** are provided only along the top of the central conductor **26**. The central conductor **26** is supported not at the center of the outer shell **27** but off center in a downward direction by about 10%. This lowers the gradient in the region of the apertures **25** with respect to the gradient at other portions of the circumference of the central conductor **26** so that particles rotate gradually towards the region of lowest electric field, which region exists above the central conductor **26**, from which, they will gradually be collected by the periodic holes or slots **25**. When the central conductor **26** is off-centered in this way, the added radial length may then be used to advantage by locating a post type suspension insulator in this region of added radial length, as shown at **28** in FIG. 12.

Off-centering the central conductor **26** as shown in FIG. 11 creates a low-field region above the central conductor towards which particulates gravitate. If the aperture **25** is a continuous slot, it will tend to collect all these particulates. If, however, the apertures **25** are longitudinally spaced, a longitudinal gravitation may be superimposed upon the azimuthial gravitation by mounting inward ridges **29** on the inner surface of the outer shell **27** between adjacent apertures **25** or aperture groups, as shown in FIG. 13.

Having thus described the principles of the invention, together with several illustrative embodiments thereof, it is to be understood that although specific terms are employed, they are used in a generic and descriptive sense, and not for purposes of limitation, the scope of the invention being set forth in the following claims.

I claim:

1. A high voltage gas-insulated transmission line for the transport of electric power comprising an outer conductor of low potential enclosing insulating gas, an inner conductor at high potential, means for insulatably supporting said inner conductor at spaced intervals along its length and means for systematically reducing the electric field at regions near the surface of at least one of said conductors.

2. The high voltage gas-insulated transmission line as set forth in claim **1**, wherein said field reducing means comprises an extension of said outer conductor forming a longitudinal channel along the interior of said outer conductor thereby defining a low field region within said channel for entrapping moving particles.

3. The high voltage gas-insulated transmission line as set forth in claim **1** wherein said field reducing means comprises a plurality of ducts slightly separated and resting on the interior surface of said outer conductor so as to create a low field region for entrapping moving particles.

4. The high voltage gas-insulated transmission line as set forth in claim **1**, wherein said field reducing means comprises an apertured electrode physically near and electrically connected to the interior surface of said outer conductor, said electrode and said outer conductor defining a region of low electric field for entrapping particles moving in said insulating gas.

5. The high voltage gas-insulated transmission line as set forth in claim **4**, wherein said apertures are distributed systematically over the electrode surface.

6. The high voltage gas-insulated transmission line as set forth in claim **4**, wherein said apertures are in the form of holes or slots.

7. The high voltage gas-insulated transmission line as set forth in claim **4**, wherein said inner conductor is mounted off-center and said apertured electrode faces the region of maximum gap between said outer conductor and said inner conductor, with said maximum gap developing a region of minimum electric field.

8. The high voltage gas-insulated transmission line as set forth in claim **4**, wherein said apertured electrode has apertures which are rimmed on that side of the apertured electrode facing said outer conductor and which further inhibit the passage of particles therefrom.

9. A high voltage gas-insulated transmission line for the transport of electric power comprising an outer conductor at low potential enclosing insulating gas, a hollow apertured inner conductor at high potential, means for insulably supporting said inner conductor within said outer conductor, and wherein said hollow apertured conductor encloses a region of low electric field for entrapping particles moving in said insulating gas.

10. The high voltage gas-insulated transmission line as set forth in claim **9**, wherein the apertures of said hollow apertured conductor are rimmed on the interior to retain particles driven in by the electric field.

11. The high voltage gas-insulated transmission line as set forth in claim **9**, wherein said hollow apertured conductor has a linear distribution of apertures into the hollow interior thereof.

12. In an electrostatic generator apparatus for the removal of conducting and semiconducting particles, the combination of: a sealed tank enclosing insulating gas connected to ground potential, a high voltage electrode designed to be corona-free and mounted within said tank, an apertured electrode electrically connected to and supported by the interior surface of said tank for defining a region of low electric field to entrap said particles moving in said insulating gas.

13. The electrostatic generator apparatus as set forth in claim **12** wherein the ratio of the diameter of the apertures in said apertured electrode to the distance between the electrode surface and the tank surface is approximately 1:3.

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J D MILLER, Primary Examiner

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U.S. Cl. X.R.

174—14, 28; 317—262