

[54] **MODULARIZED ELECTROSTATIC PRECIPITATOR**

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[52] U.S. Cl. **55/114, 55/120, 55/121, 55/138, 55/139, 55/146, 55/149, 55/152, 55/155**

[51] Int. Cl. **B03c 3/10**

[58] Field of Search.....55/114, 116, 120, 121, 138, 55/139, 146, 149, 152, 155

[56] **References Cited**

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[57] **ABSTRACT**

A self-contained electrostatic precipitator module adapted to be inserted into and removed from a housing as a unitary assembly includes a slatted, endless belt defining a composite attractor electrode-collector electrode subassembly, a forced air system for cooling and cleaning electrode holder structures, a power supply for establishing the charging and precipitating fields, a drive motor and train and mounting system for moving the endless belt, and rotary brushes at a remote location for neutralizing and cleaning the belt. The belt slats are flat, rigid members of simplified design and are individually mounted to allow selective replacement of a local belt section. Insulating gaps of optimized configurations are provided around high-potential electrode holders to prevent electrical shorting or sparking. Increased capacity is readily obtainable by employing plural units arranged in parallel within a common housing.

32 Claims, 13 Drawing Figures

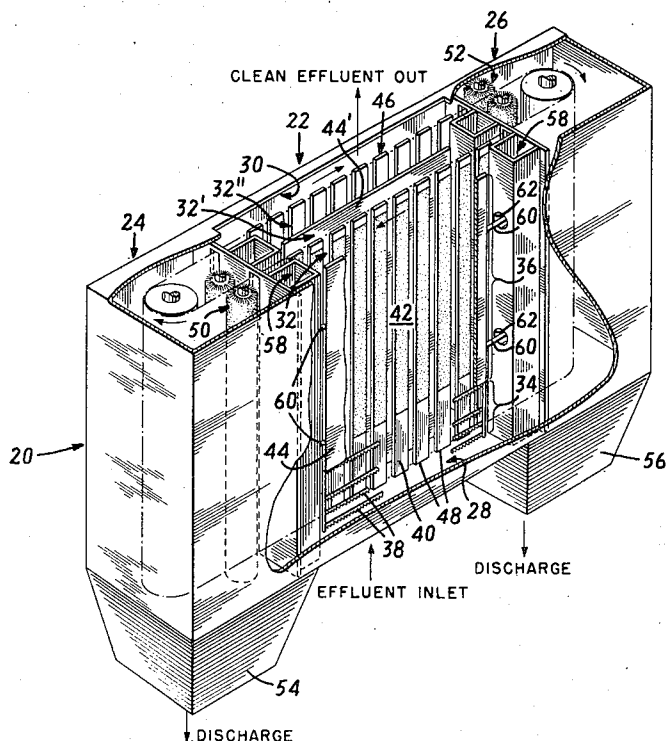


FIG. 1

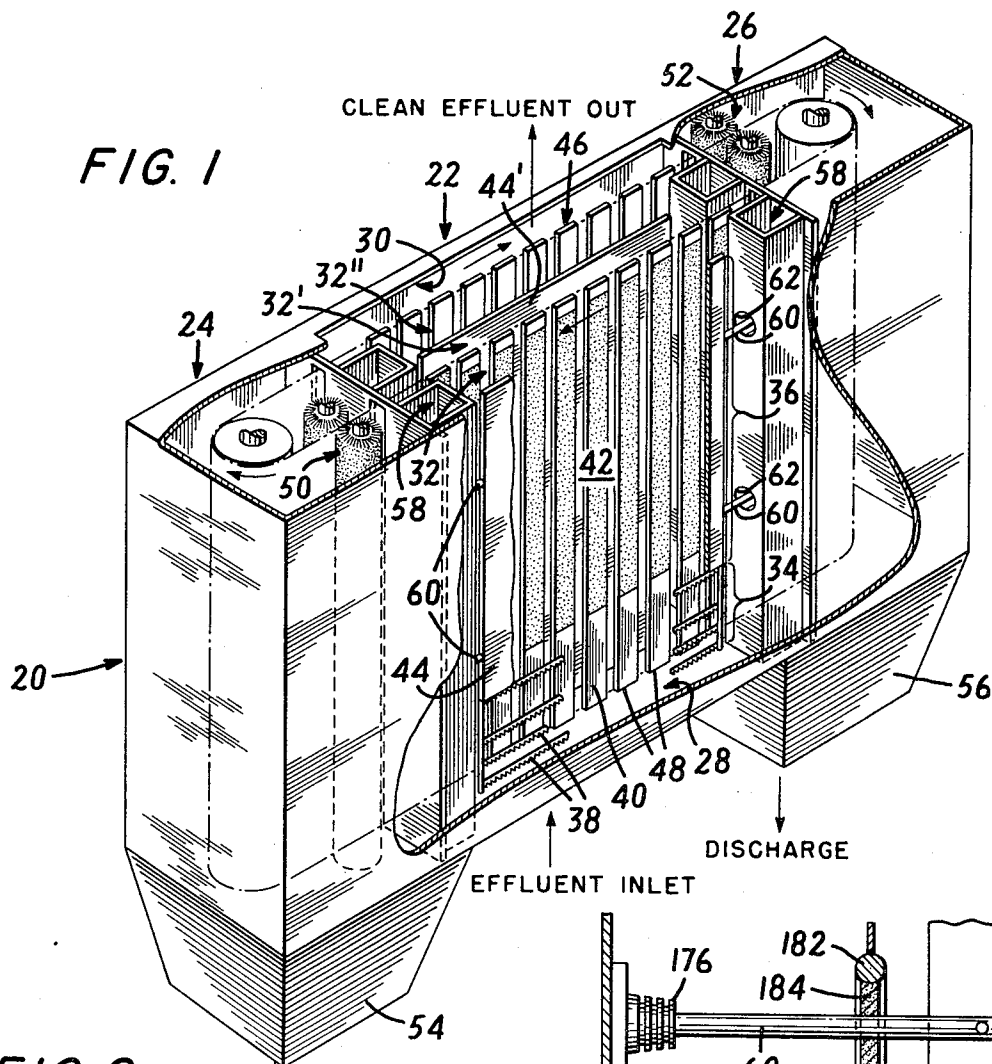


FIG. 9

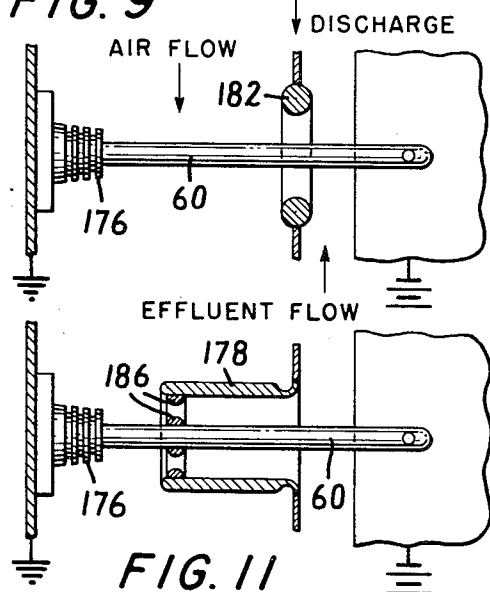


FIG. 10

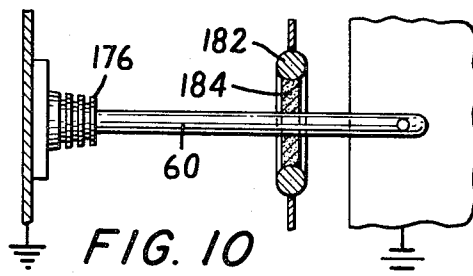
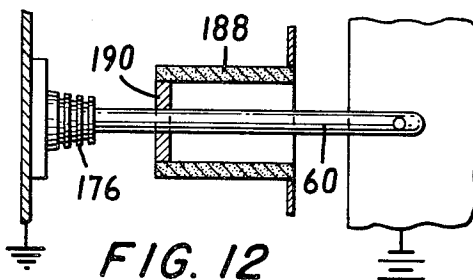


FIG. 12



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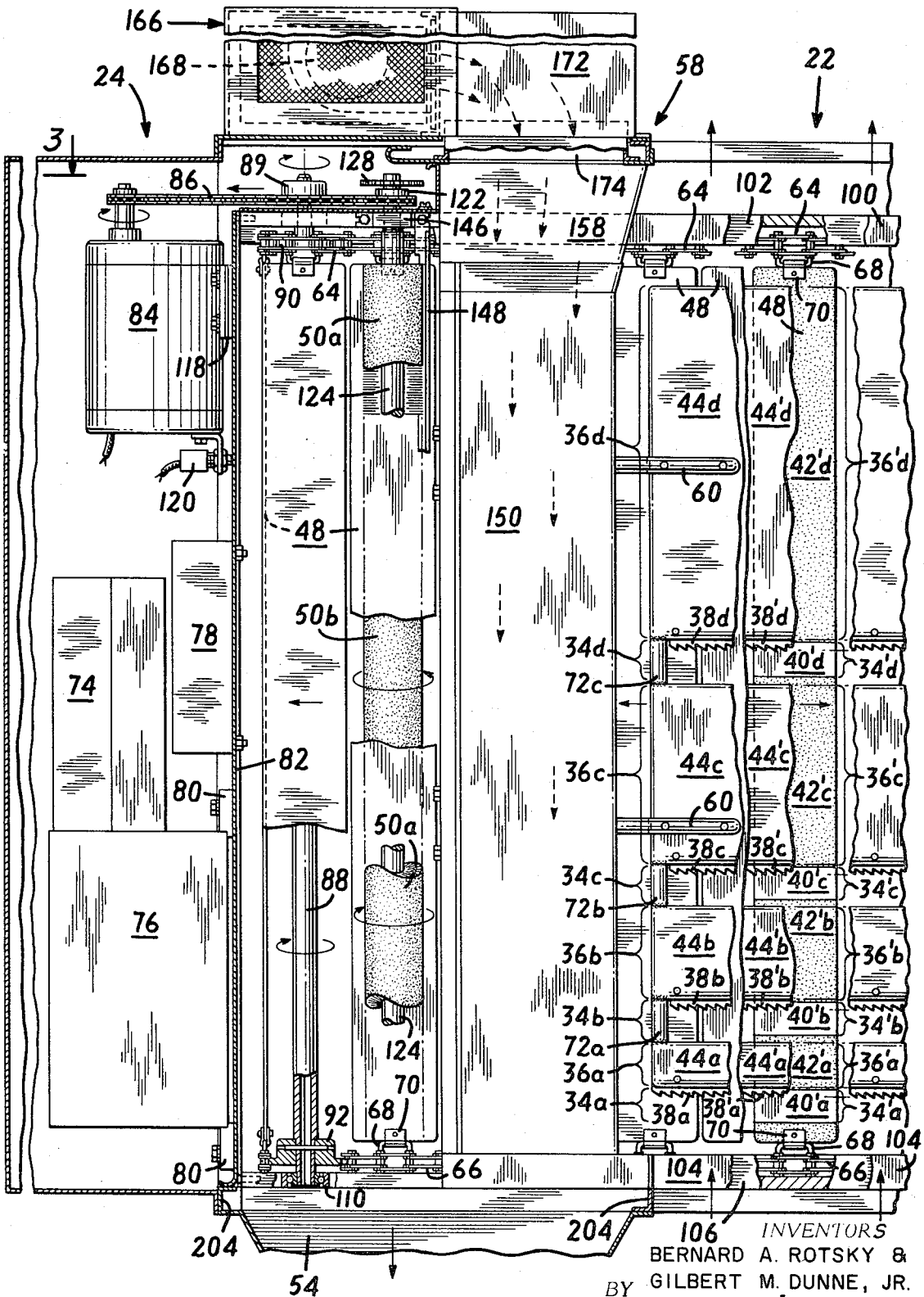


FIG. 2A

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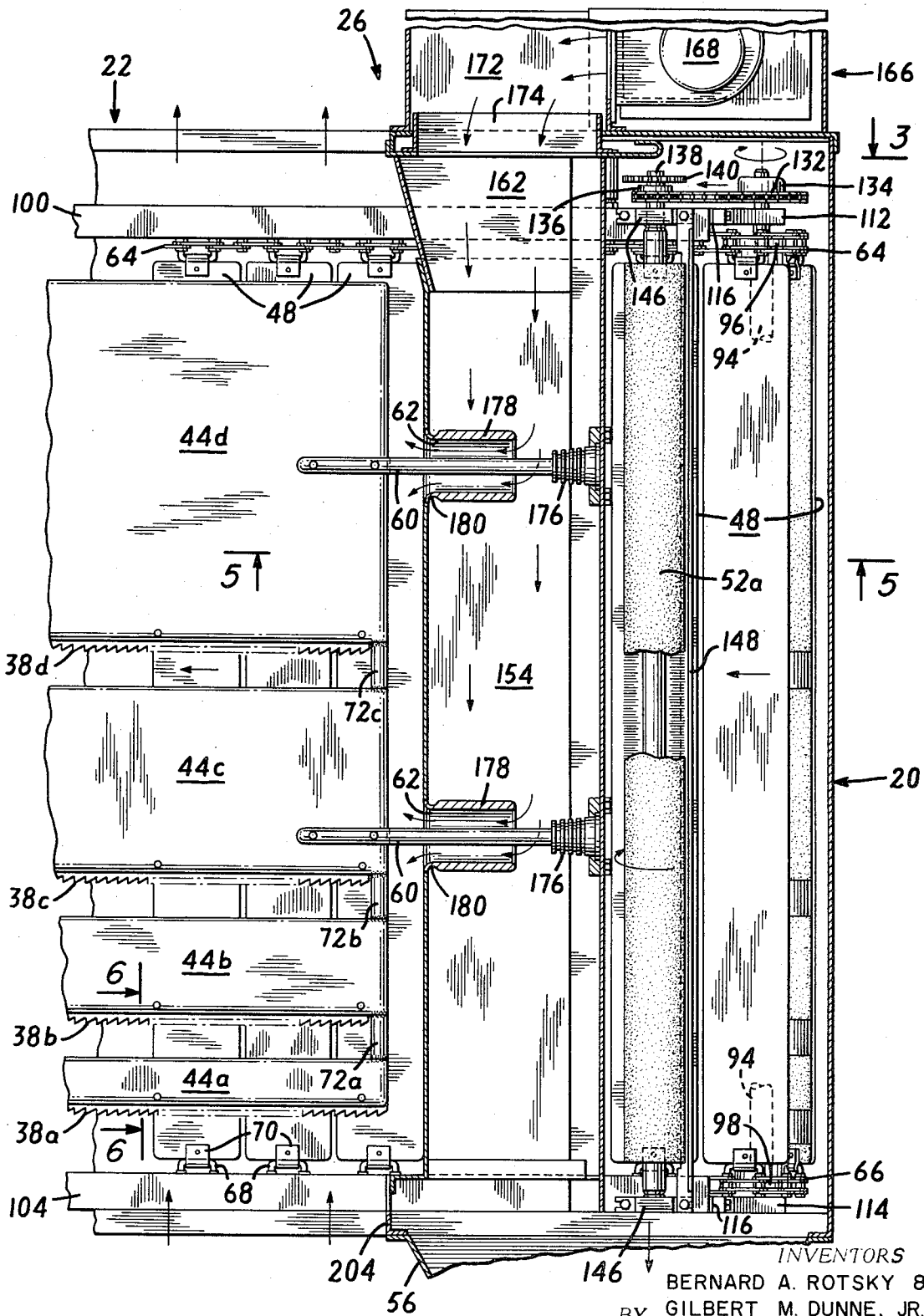


FIG. 2B

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FIG. 3

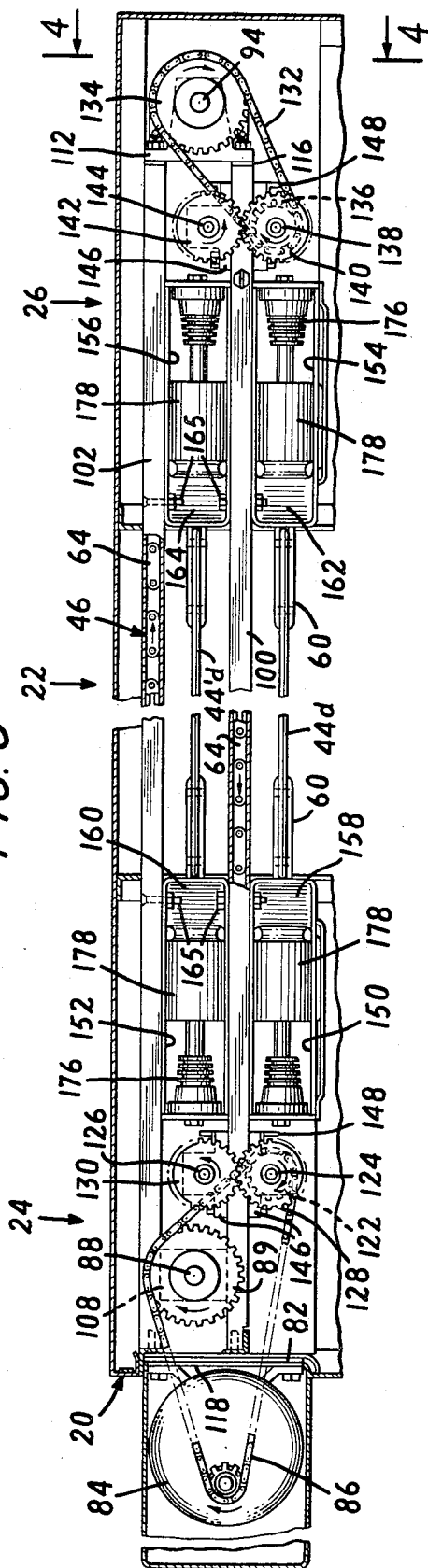
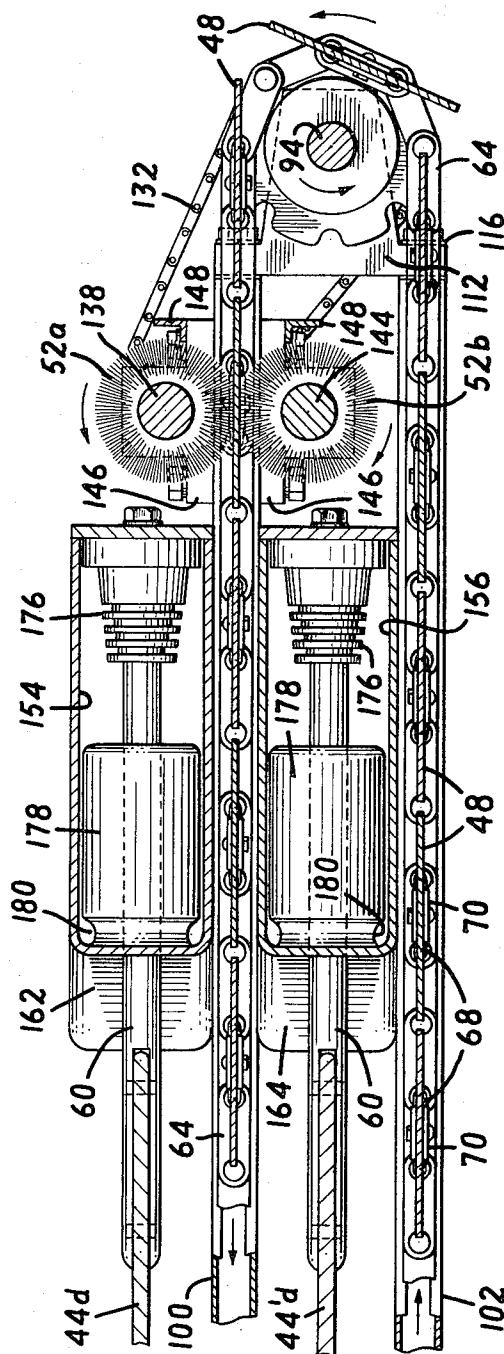


FIG. 5

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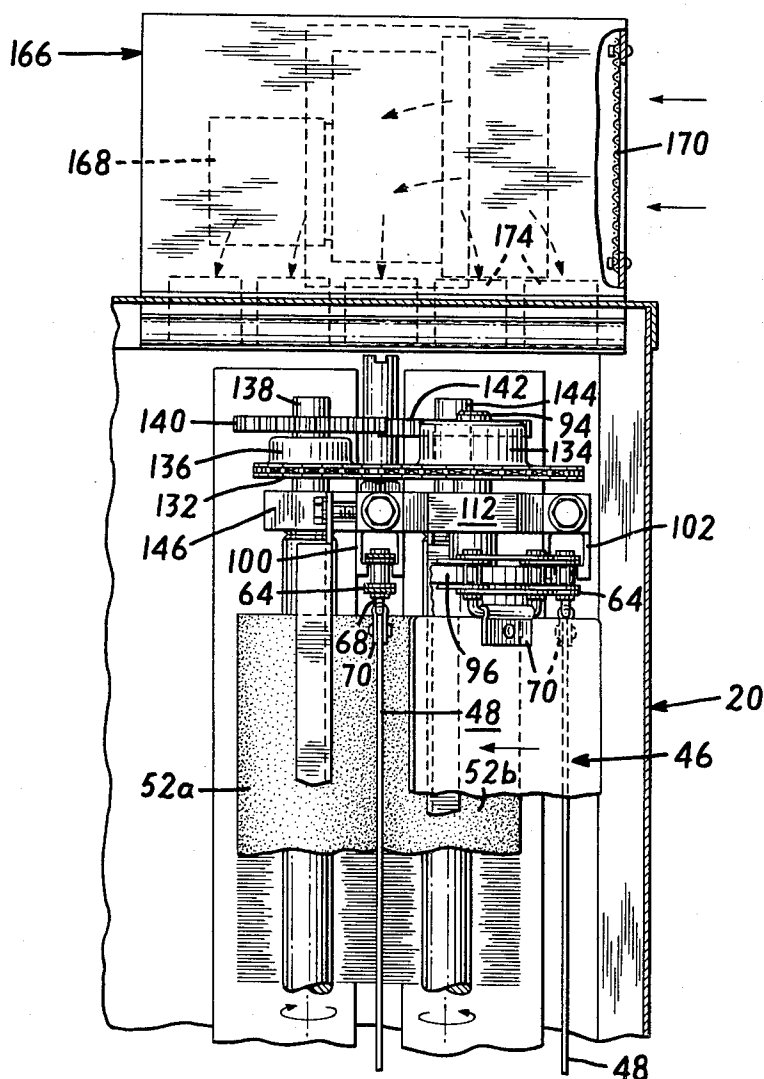


FIG. 6

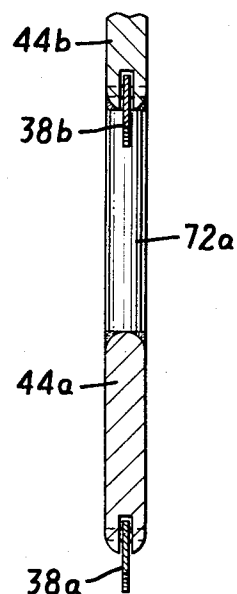
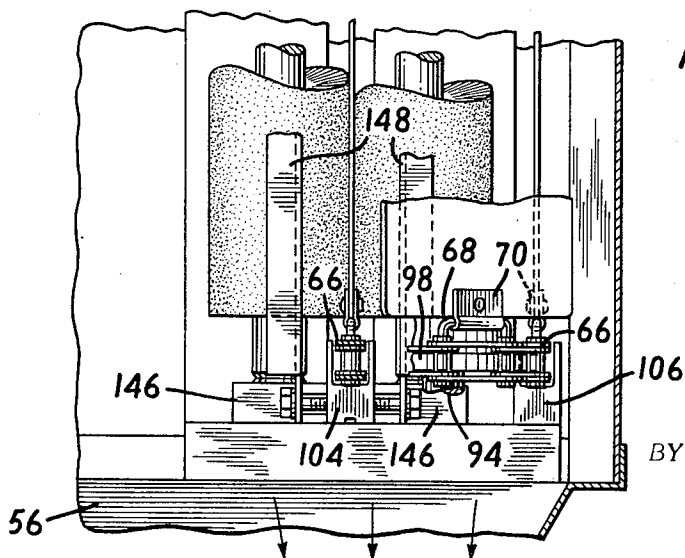


FIG. 4

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FIG. 7

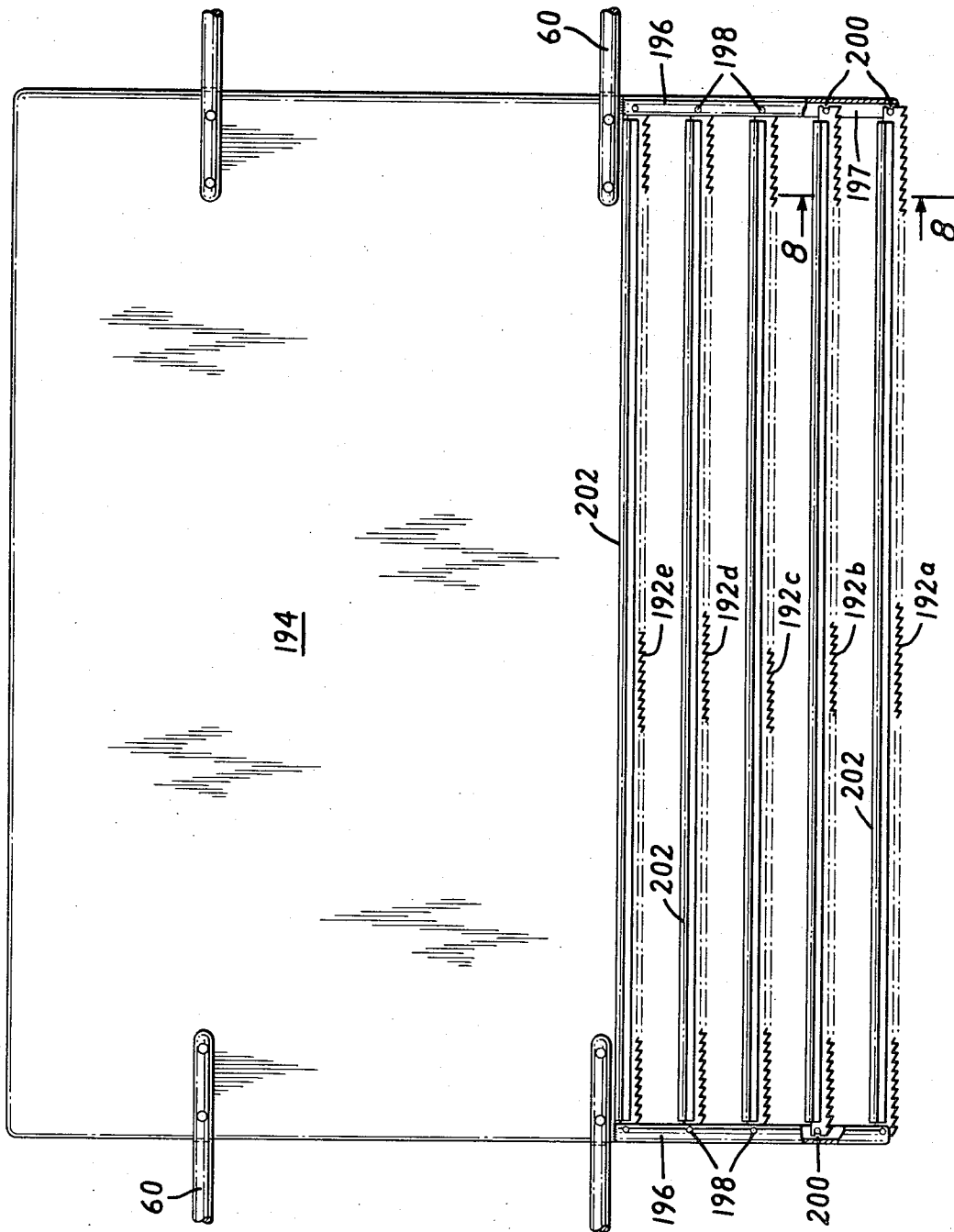
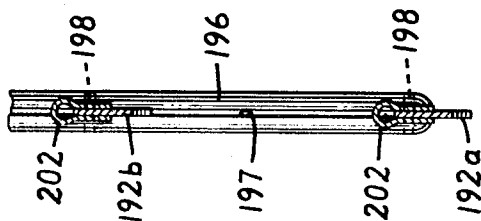


FIG. 8



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MODULARIZED ELECTROSTATIC PRECIPITATOR

BACKGROUND

This invention relates generally to electrostatic precipitators, and, in particular, to an improved construction for an electrostatic precipitator that affords a compact, high-performance unit having special utility in the treatment of relatively small stack flows, e.g., effluent flows on the order of 10,000 c.f.m. or less.

In recent years it has become increasingly important to assure that emissions into the atmosphere from industrial stacks, municipal and private incinerator stacks, and the like are as free as practicable from gas-borne impurities, such as fly ash, soot, or other particles, whose presence pollutes the atmosphere. Electrostatic precipitators of various types are, of course, widely used to clean such emissions of pollutants. Commercially available precipitators of the required efficiency, however, are in general so costly to install and operate as to render them economically unattractive for use in treating small stack flows. Consequently, emissions from such stacks are often permitted to escape untreated into the atmosphere. Because there may be hundreds or thousands of low flow stacks in even a single city, these emissions collectively constitute a major source of atmospheric pollutants in urban areas.

SUMMARY OF INVENTION

In accordance with the novel construction features of the present invention, a precipitator unit is provided which is particularly suited for applications of the aforementioned nature. Operating components of the precipitator, which in prior art devices are typically independently mounted, are integrated into a module, forming a fully self-contained unit that is insertable into and removable from the precipitator housing as a single assembly. Such modular construction simultaneously minimizes downtime and enhances operating flexibility since a malfunctioning module can simply be replaced in toto for repairs, while an additional module or modules can be added for increased capacity. Important advantages in respect of the ease and cost of fabrication, assembly and operation are also afforded. In particular, shorting out of the power supply is prevented by a clean gas purge of exposed electrode support structures, together with the provision of insulating gaps of optimized configuration against sparkover and current leakage in the region of power feed through to the high-potential electrodes. Additionally, the use of composite subassemblies throughout the unit permits standardization of components, facilitates relative location control among operating components, and allows required electrical harness and connections to be simplified and limited in number.

More specifically, a precipitator constructed in accordance with the invention includes a composite attractor electrode-collector electrode subassembly (electrically grounded) composed of a multiplicity of separate, elongate slats positioned in parallel, side-by-side relation to form an endless belt, with each slat being removably attached at either end to an endless chain of the positive drive (no-slip) variety. So mounted, the slats are individually removable for replacement or repair of a local section of the belt

without necessitating disassembly of the entire belt. The belt is driven in sequence through a particle collecting station and remote cleaning stations. A belt mounting system supports and guides the belt during this movement.

The slats, preferably oriented in the direction of effluent flow, are each formed with at least one conductive region adjacent the upstream end thereof, the regions being aligned transversely of the longitudinal axes of the slats to define at least one peripheral conductive band on the belt. A dielectric region is formed on the slats immediately downstream of each conductive region, these also being aligned to form a peripheral dielectric band. One or a series of such conductive bands and dielectric bands may be provided along the length of the slats.

One or more high-potential ionizer electrodes are provided in spaced relation to each conductive band on the belt to establish a corona discharge in the effluent flow and thus impress electrical charges on particles entrained therein. Similarly, a high-potential, passive, i.e., nondischarging, electrode is positioned in cooperating relationship with each dielectric band to maintain a precipitation field transverse to the belt. Particles entering the precipitator are thus, successively, charged in one or more corona discharges, reacted with one or more transverse precipitation fields, and collected on the dielectric surfaces of the belt.

As another feature of the invention, the ionizer electrodes and passive field electrodes are constructed as a composite subassembly, with the ionizer electrodes, preferably in the form of saw-toothed blades, supported at the upstream ends of the respective passive electrodes. Accordingly, the number of electrode holders and electrical connections required are minimized, as both the ionizer and the passive field electrodes are fed by a single power supply and are supported within the precipitator unit by common electrode holders. The subassembly construction, therefore, simplifies fabrication and servicing procedures and affords a convenient and inexpensive method of achieving relative location control between the ionizer and passive field electrodes.

Shorting out or shunting of the power supply for the high-potential electrodes is prevented, according to still another aspect of the invention, by isolating the insulator supports for the electrode holders within an enclosed duct system and purging the holders of deposited particles by flowing a clean gas through insulating gaps formed in the ducts at the point of feed through of the holders. The insulating gaps are given configurations designed to allow optimum voltage delivery to the electrodes without sparkover or corona leakage in the feed through sections. The prevention of spark or corona breakdown originating at the holders, in addition, significantly increases the service life of the holders. Also, where the effluent being cleaned is at an elevated temperature, as is often true of combustion exhausts, for example, an additional insulating benefit is derived at the insulating gaps due to the higher dielectric strength (higher density) of the purging gas as compared to the dielectric strength of the warmer effluent at the ionizer areas.

A further feature of the invention involves the use of an overall modular construction in connection with the

operating components of the precipitator to provide a self-contained unitary assembly capable of essentially independent operation. That is to say, the attractor electrode-collector electrode subassembly (slatted-belt), and the drive means and support system for the belt, the composite ionizer electrode-passive field electrode subassembly, and the high voltage power supply are all carried by an integral built-up frame structure. This module in its entirety may be readily inserted into or removed from the precipitator housing in the nature of a "sliding drawer." Rotatable brushes for cleaning and neutralizing the conductive and dielectric regions of the slatted belt are located on either side of the collecting station, and these elements too are supported on the frame structure, as is the gas duct system (save for a centralized blower and filter assembly carried by the housing) for maintaining the electrode holders in a clean condition.

By virtue of the foregoing modular construction, access to the operating components of the precipitator for servicing is greatly facilitated, while at the same time affording a totally enclosed unit during normal operation. Further, the capacity of the precipitator may be increased simply by the insertion of one or more additional "sliding drawer" modules, each of which constitutes a self-contained precipitating unit. This construction also offers the opportunity for realizing further servicing economies through replacing individual modules and conducting repair operations at a central site.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, reference may be made to the following description of an exemplary embodiment, taken in conjunction with the figures of the accompanying drawings, in which:

FIG. 1 is a pictorial view of a precipitator module, and housing therefor, constructed in accordance with the invention, with parts broken away for clarity;

FIGS. 2A and 2B are elevational views of the left hand side and the right hand side, respectively, of the precipitator of FIG. 1, with parts broken away to show the details of construction;

FIG. 3 is a horizontal sectional view taken along the line 3—3 of FIGS. 2A and 2B, looking in the direction of the arrows;

FIG. 4 is a vertical sectional view taken along the line 4—4 of FIG. 3, looking in the direction of the arrows;

FIG. 5 is an expanded detail view taken along the line 5—5 of FIG. 2B, looking in the direction of the arrows;

FIG. 6 is an expanded detail view of one embodiment of the composite ionizer electrode-passive field electrode subassembly of the invention taken along line 6—6 of FIG. 2B, looking in the direction of the arrows;

FIG. 7 is an elevational view, partly in section, of another embodiment of the composite ionizer electrode-passive field electrode subassembly;

FIG. 8 is an expanded detail view taken along the line 8—8 of FIG. 7, looking in the direction of the arrows; and

FIGS. 9 to 12 are detail views, partly in section of alternative insulating gap configurations in the power feed through section.

DESCRIPTION OF AN EXEMPLARY EMBODIMENT

The general organization of an exemplary embodiment of a precipitator constructed in accordance with the invention is illustrated in FIG. 1. A housing 20, conveniently constructed of sheet metal supported by a rigid, conductive frame, encloses a centrally located collection station 22 and two cleaning stations 24 and 26, one on each side of the collection station 22. The collecting station is provided with an inlet 28 and an outlet 30 arranged to permit the vertical passage of an effluent stream to be cleaned, such as the effluent from an incinerator stack, or the like.

A vertical flow orientation is preferred since it simplifies coupling of the housing 20 to duct work of existing installations, facilitates the use of the attractor electrode-collector electrode subassembly of the invention, described more fully hereinafter, and permits gravity collection of particles cleaned from the collector electrodes. Although not shown, a secondary blower may be connected on line with the housing outlet 30 to compensate for pressure drop through the precipitator and connecting duct work.

Upon entering the housing 20, particles entrained in the effluent stream flow along a parallel array of flow paths 32, 32' and 32'', where they are charged electrically in ionization zones, only one of which, 34, is visible in FIG. 1, and thereafter pass upward into collection zones 36 and are precipitated. A single ionization zone-collection zone flow path arrangement is illustrated in FIG. 1, but, as made clear below, a plural, or cascaded, zone arrangement may also be used.

In the embodiment of FIG. 1, each ionization zone, for example, 34, includes one or more ionizer electrodes 38 and an opposed attractor electrode region 40, while the associated collection zone 36 has a collector electrode region 42 and a spaced passive field electrode 44.

It is a feature of the invention, exemplified in FIG. 1, that the attractor electrode region 40 and the collector electrode region 42 are carried as a composite subassembly by an endless belt 46 composed of a multiplicity of elongate slats 48 arranged in parallel, side-by-side relation. The belt 46 is arranged to be moved successively through the collection station 22 and the cleaning stations 24 and 26 in a direction transverse to the effluent flow (see the arrows in FIG. 1). The cleaning stations 24 and 26 each contain a set of rotary brushes 50 and 52, respectively, for removing particles deposited on the belt. Hoppers 54 and 56 are provided at the lower ends of the respective cleaning stations to receive the particles cleaned from the belt by the brushes.

Collecting station 22 is separated from the cleaning stations 24 and 26 by an enclosed duct construction, indicated generally at 58 in FIG. 1, which forms part of a clean gas system for preventing shorting out or shunting of the electrical power supply for the ionizer electrodes 38, etc., and passive field electrodes 44 and 44', the belt 46, and hence the attractor electrode 40 and collector electrode 42, being connected to electrical ground. To that end, the electrodes 38, 44 and 44' are supported within the collecting station by holders 60 that extend into the collecting station through openings

62 in the facing surfaces of the ducts. The insulator supports (not shown in FIG. 1) for the holders 60 are located within the ducts in a manner set out hereinafter. A clean gas, conveniently air, is fed to the ducts and then through the openings 62 into the collecting station, thus purging the holders 60 of deposited particles and isolating the insulator supports from the dirty effluent stream.

Turning now to FIGS. 2A and 2B, portraying respectively the left hand side and the right hand side of the precipitator as viewed in FIG. 1, the slats 48 are seen to be mounted at either end to a pair of spaced endless chains 64 and 66 of the positive drive (no-slip) variety. Chain pitch and width are selected to accommodate thermal expansion of the slats during operation. According to the invention the individual slats 48 are separately attached to the chains 64 and 66, thereby allowing them to be separately removed for repair to or replacement of a local section of the belt 46 without necessitating removal of the entire belt. Attachment of the slats 48 to the chains is conveniently made through rigid U-shaped brackets 68 affixed to the chains and cooperating brackets 70 bolted or otherwise secured to the slats.

Owing to this simplified mounting structure, whereby the slats 48 require no special forming or attachment features other than a small hole at either end for receiving a bolt or the like, the slats are readily producible at low cost and are quickly and easily assembled to form a complete belt 46. Suitably, the slats are constructed of a conductive, noncorrosive material, such as aluminum alloy, and are coated on those portions lying within the collection zones with a temperature-resistant, dielectric material. The slats, alternatively, may be constituted by a rigid dielectric, such as a glass laminate, about a conductive coating or strip. Conductive coatings on the dielectric form the attractor regions. In either construction both sides of the slats are identical, particle collection going forward on all surfaces of the belt except that nearest the far housing wall as seen in FIG. 1.

While a single attractor electrode region 40 is depicted in FIG. 1, more than one such region may be provided on the slats. Thus, as indicated in FIGS. 2A and 2B (where parts are broken away to reveal the structure of the inner flow paths 32' and 32''), a series of spaced attractor regions 40'a through 40'd (formed on the inner surface of the belt 46) may be utilized to establish a series of corona discharges in the effluent stream. A corresponding number of ionizer electrodes 38'a through 38'd would be used with this arrangement, as would a corresponding number of passive field electrodes 44'a through 44'd. A collector electrode region 42'a through 42'd would then be formed on each slat immediately downstream of the respective attractor regions 40'a through 40'd. As mentioned, those portions of the slats constituting the collector electrode regions are coated with a high resistivity dielectric material, indicated in FIG. 2A by stippling.

It will be appreciated that ionizer electrodes 38'a through 38'd and passive field electrodes 44'a through 44'd cooperate with the opposing regions on the inner surface of the endless belt 46 to establish a series of ionization zones 34'a through 34'd and collection zones 36'a through 36'd along both flow paths 32' and

32'' (see also FIG. 1). A similar series, or cascade, of ionization zones 34a through 34d and collection zones 36a through 36d (see FIG. 2A) is formed in flow path 32 by the outer belt surface and the electrodes 38a through 38d and 44a through 44d, respectively.

The slatted belt 46 accordingly incorporates both the attractor electrodes and the collector electrodes of the precipitator into a single composite subassembly which may be readily produced and assembled at low cost. Moreover, it provides rigid, flat attractor and collector surfaces which enhance collection efficiency through establishing a definitive air gap with the ionizer and passive electrodes. The rigidity of the belt also insures good contact with the brushes 50, 52 for particle neutralization and removal.

Important and substantial improvements in respect of collection efficiency and overall precipitator size reduction are obtainable through proper positioning of the ionizer electrodes, attractor electrodes, passive field electrodes, and collector electrodes relative to each other to afford ionization zone and collection zone geometrics of optimum configurations. These features are fully set out in the copending application, Ser. No. 64,243, filed Aug. 17, 1970, and assigned to the assignee of the present application. Reference may be made to that application for a description of such features, it not being set out here in the interest of brevity.

As another feature of the invention, the ionizer electrodes and associated passive field electrodes are integrated into a composite subassembly of conductive material. In the embodiment shown in FIGS. 2A and 2B, the ionizer electrodes 38a through 38d, for example, which preferably comprise saw-toothed blades, are pinned or otherwise suitably attached to the respective upstream ends of the passive field electrodes 44a through 44d. The passive field electrodes 44a through 44d are in turn electrically and mechanically interconnected by frame elements 72a, 72b and 72c (see also FIG. 6), forming a single, composite electrode subassembly including both the ionizer and passive field electrodes. Ionizer electrodes 38'a through 38'd and passive field electrodes 44'a through 44'd are assembled in a like manner into a composite unit.

It will be appreciated that this construction significantly reduces the number of electrode holders 60 needed to support the ionizer and passive field electrodes as compared to the conventional arrangement where the electrodes are separately mounted. The number of electrical connections which must be made to the electrodes is similarly reduced. Moreover, the composite electrode subassembly of the invention allows relative location control between the ionizer electrodes and the passive field electrodes to be achieved in a convenient and inexpensive way. Together with the fewer number of electrical connections, this affords servicing and replacement advantages over conventional electrode arrangements.

The electrode subassemblies are connected through the holders 60 and a limiting resistor box 74 to a suitable source 76 of d.c. power (see FIG. 2A). The polarity of the ionizer and passive field electrodes is preferably negative, but a positive potential may be applied if desired. Good results have been obtained with a voltage of -20 kv at the ionizer electrodes. Although each electrode subassembly requires only a single d.c.

source, additional sources may be used, as, for example, where a cascaded ionization zone-collection zone flow path configuration is adopted, for increased performance.

The d.c. power source (or sources) is selected to be operable off all locally available a.c. lines, and includes a ballast and mounting tube assembly 78 on the input side to regulate a.c. current input in accordance with ionizer and passive field electrode demand. Support blocks 80 may be provided to mount the source 76 and resistor box 74 to a rigid, vertical panel 82, which also carries the ballast and mounting tube assembly 78. Alternative to the use of separate components, the resistor box 74, source 76, and ballast and mounting tube assembly 78 may be incorporated into a single package, with attendant savings in fabrication and assembly costs.

Looking now to FIGS. 2A and 3, the belt 46 is driven through a drive train including an electric motor 84, a drive chain 86, a drive shaft 88, and a drive sprocket 89. Spaced sprockets 90 and 92 fitted to the shaft 88 engage the endless chains 64 and 66, respectively, to provide a positive, no-slip movement of the belt. (See FIGS. 2A and 3). An idler shaft 94 (FIG. 2B) is located in the right hand cleaning station 26, and includes spaced sprockets 96 and 98 for receiving and returning the belt 46 (see also FIGS. 3 and 4).

The chains 64 and 66 are supported between the shafts 88 and 94 by generally C-shaped upper guide members 100 and 102 and lower guide members 104 and 106 (see FIG. 4) so as to eliminate belt sag. The guide members 100 through 106 suitably are constructed of noncorrosive material of high mechanical strength, e.g., stainless steel.

While the drive shaft 88 is journaled in bearing blocks 108 and 110 (see FIGS. 2A and 3) fixed between the upper chain guide members 100 and 102, the bearing blocks 112 and 114 for the idler shaft 94 are adjustably bolted to the right hand ends of the upper and lower guide members, respectively. An appropriate tension may therefore be applied to the chains 64 and 66 by placing shims 116 (FIGS. 2B and 3) between the blocks 112 and 114 and the ends of the upper and lower guide members.

The rate of movement of the belt through the collecting station is adjusted to limit the percentage of saturation charge build-up on the dielectric collecting surfaces of the belt, so that significant degradation of precipitation field strengths and hence of particle collection efficiency is avoided. Belt speed may be controlled by use of a motor sprocket of appropriate size, or by way of a variable speed motor. The motor used would of course vary according to the power available at any given site.

Whatever the motor used, it is shimmed, as at 118 (FIGS. 2A and 3), to vertical panel 82 to allow proper tensioning of the drive chain 86. Desirably, it also includes an overload device, such as the microswitch 120 in FIG. 2A, to prevent damage to the belt 46. The switch 120 rests against the panel 82, and is actuated to shut off the motor 84 after a predetermined amount of distortion of the motor shaft, which might result from excessive shaft torque. Alternatively, a slip-clutch (not shown) may be interposed between the motor and the drive chain to prevent the imposition of excessive torque on the motor.

In addition to the drive sprocket 89, the drive chain passes over a sprocket 122 (see FIGS. 2A and 3), affixed to the shaft 124 of the foremost brush 50a of the left hand set 50. The other brush 50b of the set, having a shaft 126, is then caused to be rotated by intermeshing gears 128 and 130 carried by the respective shafts 124 and 126. As indicated by the arrows in FIG. 3, the brushes 50a and 50b rotate in opposite directions relative to each other, as well as in opposition to the direction of movement of the belt 46.

The brushes 52a and 52b at the right hand cleaning station 26 are driven in a manner similar to the brushes 50a and 50b. There, a no-slip drive chain 132 couples a sprocket 134 on the idler shaft 94 (see FIGS. 3 and 4) with a sprocket 136 attached to the shaft 138 of the brush 52a. Intermeshing gears 140 and 142 on the brush shafts 138 and 144 then effect rotation of the brush 52b in the manner previously described. (see the arrows in FIGS. 4 and 5).

The brushes 50a, 50b, 52a and 52b are rotatably supported within the cleaning stations, by opposed pairs of bearing blocks 146 that are bolted in vertical alignment to the upper and lower chain guide members 100 and 104, in a manner to bear against the opposite surfaces of the belt 46 with sufficient pressure to dislodge the collected particles without imposing an unduly high load on the belt or belt drive train. Flexible conductive material is preferred for the brush bristles, so that charges retained by the particles and the dielectric collection surfaces will be neutralized upon contacting the brushes which are grounded. A flicker bar 148 (see FIGS. 4 and 5) extends along the full length of each brush to engage the bristles of the brush and thereby prevent the accumulation of particles on the brushes with consequent loss of cleaning efficiency.

After each pass through the collecting station, therefore, the attractor and collector surfaces of the belt 46 are thoroughly cleaned and neutralized by the brush sets 50 and 52. Build-up of charges on the dielectric collection surfaces, leading to quenching of the precipitation fields, is thus avoided.

The duct construction 56 separating collecting station 22 from cleaning stations 24 and 26 includes a pair of enclosed, elongate ducts 150 and 152 at the left hand side of the collecting station and a second pair of ducts 154 and 156 at the right hand side. (see FIGS. 2A, 2B and 3). Ducts 150 through 156 are similarly shaped and extend the entire height of the collecting station 22, connecting at the bottom with hopper 54 or 56, as the case may be, and at the top with flared-mouth channels 158, 160, 162 and 164, respectively. As indicated in FIG. 3, the channels 158 through 164 are rigidly attached, as by bolts 165, to the upper guide members 100 and 102, with the guide member 100 passing therebetween. Attachment is also made between the ducts 150 through 156 and the lower guide members 104 and 106.

The ducts and channels, therefore, define boundaries for the effluent stream between the collecting station 22 and the cleaning stations 24 and 26. The belt traverses each boundary through vertical slots formed by the upper and lower guide members between the ducts and channels of each pair, for example, ducts 150 and 152 and channels 158 and 160, and between the housing wall and the adjacent duct and channel, for example, duct 152 and channel 160.

Like assemblies 166 are mounted on housing 20, one over each of cleaning stations 24 and 26, and incorporate blower units 168 which take in air through filter units 170 and deliver it, as indicated by the arrows in FIGS. 2A, 2B and 4, through plenum chambers 172, having flow dividers 174, to the channels 158 through 164.

The air fed to the ducts 150 through 156 flows therethrough and is directed through the openings 62 in the ducts and into the effluent stream. Since this air is substantially dust free, it serves to maintain the electrode holders 60 in a clean condition by purging them of particles precipitated on them from the effluent stream. This clean air purge significantly increases the service life of the holders, particularly where conductive particles are carried by the effluent stream, by preventing the build-up of charged particles on the holder surfaces, where they might accumulate to an extent that the air gaps between the holders and the openings 62 are reduced to levels at which corona or spark breakdown would occur. An additional benefit is derived in applications where the effluent is at an elevated temperature, as is often true with incinerator stacks, or the like, due to the cooling effect of the cleaning air in the electrode holder air gap. Thus, the margin between breakdown voltage at the holders relative to the corona voltage at the ionizer electrodes, e.g., 38a through 38d, is increased due to the higher gas density and higher dielectric strength of the cooler air as compared to the density of the effluent at the ionizer areas.

The integrity of the power supply to the ionizer and passive field electrodes is further insured by the foregoing duct construction since the insulator supports 176 (see FIGS. 2B and 5) for the holders 60 are isolated from the effluent stream. Accordingly, charged particles from the stream are prevented from depositing on the insulators and hence from shorting out the power supply. The service life of the insulators 176 is also increased by this feature.

Air is preferred as the cleaning gas because it is readily available and economical to use. On the other hand, any suitable gas, including inert gases, may be used, it being necessary only that it have appropriate dielectric properties.

Supplemental to flowing clean gas over the electrode holders 60, it is another feature of the invention that the openings 62 surrounding the holders are given special configurations so as to provide an insulating gap at the power feed through region of optimum insulative characteristics against sparking or voltage leakage. One such configuration is illustrated in FIGS. 2B and 5. Cylindrical sleeves or shields 178 are attached to the facing surfaces of the ducts so as to be coaxial with the holders 60 and to extend away from the collecting station 22. Each sleeve 178 is provided with a smooth inner surface and is flared outwardly at its inner end 180 (see FIG. 2B) to merge with the duct wall along a radius of curvature sufficiently gradual to prevent charge concentration at the juncture of the wall and the sleeve. Optimum results are obtained if the sleeve 178 is sized such that its inner diameter is substantially 2.718 times as great as the outer diameter of the electrode holder.

FIGS. 9 to 12 illustrate additional insulating gap configurations. The configuration of FIG. 9 affords a simplified construction, utilizing only a generally circular metal ring 182 around the holder 60. As with the sleeve 178, the inner diameter of the ring 182 is preferably at about 2.718 times the outer diameter of the holder. The cross sectional radius of the ring 182 is sufficiently large to provide a smooth, nondischarging inner surface.

The embodiment of FIG. 10 is similar to that of FIG. 9, except that it includes a gas-porous dielectric disc 184 interposed between the holder 60 and the surrounding ring 182. In general, a low dielectric constant material, e.g., polytetrafluoroethylene, is preferred for the disc 184.

FIG. 11 depicts a configuration having a sleeve 178 as in the embodiment shown in FIG. 2B, but which includes in addition one or more annular restrictors 186 adjacent the outer end of the sleeve 178 productive of an increase in gas flow velocity therebetween. The higher flow rate of the gas between the restrictors 186 further serves to prevent leakage of the effluent to the region of the insulator supports 176 for the holders 60.

In FIG. 12, a further configuration includes a cylindrical sleeve 188, coaxially arranged relative to the holder 60 and constructed of a material porous to the gas flow. The sleeve 188 may be either metallic or dielectric. An annular, nonporous disc 190 is used with the embodiment of FIG. 12 to close off the outer end of the sleeve 188, forcing the gas to flow through the sleeve.

An alternative embodiment of a composite ionizer electrode-passive field electrode subassembly, suitable for use in a single ionization zone-collection zone unit of the type shown in FIG. 1, is disclosed in FIGS. 7 and 8. In that embodiment, a plurality of ionizer electrodes 192a through 192e are supported at the upstream end of a single passive field electrode 194 by a pair of holders 196 extending upstream from the passive electrode. Elongate grooves 197 formed in the facing surfaces of holders 196 and transverse pins 198 spaced along the length of the grooves 196 support the ionizer electrodes. For this purpose, open-ended slots 200 are provided at either end of each ionizer electrode. These slots also allow the electrodes to expand or contract during operation. A backing member 202 preferably is fitted to each ionizer electrode 196 for stiffening and to prevent corona discharge, reducing electrical stress at this area.

As a further feature of the invention the belt 46, brush sets 50 and 52, electric motor 84 and the other elements of the drive train and belt mounting structure, ducts 150 through 156, channels 158 through 164, composite ionizer electrode-passive field electrode subassembly and the holders 60 therefor, and the power supply elements 74, 76 and 78 are all insertable into and removable from the housing 20 as a unit. The foregoing components are supported in operating relation by a built-up frame assembly composed basically of the vertically extending ducts 150 through 156, the horizontally extending upper guide members 100 and 102 and lower guide members 104 and 106, and the vertical panel 82 carrying the drive motor 84 and power supply elements (secured at opposite ends to the chain guide members), thus forming an essentially self-

contained precipitator module in the nature of a "sliding drawer." Appropriate cross frame members 204 (see FIGS. 2A and 2B) are provided at the bottom of the housing 20 to support the "sliding drawer" module.

This modular construction greatly enhances serviceability access, while affording a fully enclosed precipitator system during operation. It further facilitates servicing and reduces downtime by allowing a malfunctioning unit to be replaced in its entirety. Repairs may then be carried out at a centralized location where they can be more effectively made. Fabrication and assembly costs are also reduced since components are standardized among the modules. Further, greater flexibility of operation is possible inasmuch as flow capacity can be easily varied simply by adding or removing modules. With reference to FIG. 3, for instance, one or more additional modules could be inserted in housing 20 adjacent to and parallel with the unit there portrayed. A typical application might, for example, utilize three separate modules within a common housing. All such modules would be served by the same blower assemblies 166, plenum chambers 172, and flow dividers 174.

It will be understood by those skilled in the art that the above-described embodiment is intended to be merely exemplary, in that it is susceptible of modification and variation without departing from the spirit and scope of the invention as defined in the appended claims.

We claim:

1. An electrostatic precipitator comprising:
 - a housing having an inlet and an outlet for an effluent stream entraining particles to be precipitated,
 - means defining at least two enclosed gas ducts extending between the inlet and the outlet, the ducts being spaced apart in opposed relation and defining between the facing surfaces thereof a flow path for the effluent stream,
 - an ionizer electrode extending transversely of the flow path at an upstream region thereof,
 - a passive field electrode disposed transversely of the flow path downstream of the ionizer electrode,
 - a pair of parallel, endless chains arranged transverse to the flow path and spaced therealong in the direction of effluent flow,
 - a multiplicity of elongate slats extending lengthwise between the chains and arranged in parallel, side-by-side relation to form an endless belt, each slat having an electrically conductive region formed thereon adjacent the upstream end thereof and a dielectric region formed thereon downstream of the conductive region, the conductive and dielectric regions of each slat being aligned with the corresponding regions of the other slats so as to define a conductive band and a dielectric band around the periphery of the belt,
 - means for mounting the ionizer electrode and the passive field electrode between the ducts in parallel, spaced relation to the slats such that the ionizer electrode is positioned opposite the conductive band and the passive field electrode opposite the dielectric band, said means including conductive holder members extending through the facing surfaces of the ducts,

means defining an insulating gap between each holder member and the facing surface of each duct at the point of feed through of the holder member, means associated with the ducts for flowing clean gas through the insulating gaps into the flow path, power supply means for establishing a potential gradient between the ionizer electrode and the opposed conductive band productive of a corona discharge to charge particles entrained in the effluent stream and between the passive field electrode and the opposed dielectric band productive of a nondischarging precipitation field, and means for successively moving the endless belt transversely of the flow path and through a location remote from the flow path.

2. An electrostatic precipitator according to claim 1 further comprising means for removably attaching each slat to the chains separately of the other slats, whereby the slats are individually removable from the belt.

3. An electrostatic precipitator according to claim 2 in which the slats are constructed of rigid, conductive material, and in which the dielectric region of each slat is constituted by a dielectric coating on the slat.

4. An electrostatic precipitator according to claim 2 in which the slats are constructed of rigid dielectric material overlying a conductive material, and in which the conductive region of each slat is constituted by a conductive coating on the slat.

5. An electrostatic precipitator according to claim 1 further comprising cleaning means at the remote location for removing particles from the slats.

6. An electrostatic precipitator according to claim 5 further comprising frame means for supporting the gas duct defining means, ionizer electrode and passive field electrode, endless belt and moving means therefor, and potential establishing means in mutual operating relationship and for permitting the insertion thereof into the housing and the removal thereof from the housing as a unit.

7. An electrostatic precipitator according to claim 6 in which the frame means includes rigid guide means extending transversely of the flow path between the spaced ducts for supporting and guiding the endless belt during the movement thereof.

8. An electrostatic precipitator according to claim 7 in which the cleaning means comprises rotatable brush means for cleaning and neutralizing the slats.

9. An electrostatic precipitator according to claim 1 in which the insulating gap defining means includes means defining an opening of generally circular cross section in the duct facing surface in surrounding relation to each holder member, the inner wall of the opening having a rounded, electrically nondischarging configuration.

10. An electrostatic precipitator according to claim 9 in which each holder member is generally circular in cross section, and in which the inner diameter of the surrounding opening is substantially 2.718 times as great as the outer diameter of the holder member.

11. An electrostatic precipitator according to claim 9 in which the inner wall of the opening constitutes a generally cylindrical sleeve, substantially coaxial with the holder member and extending away from the flow path.

12. A self-contained electrostatic precipitator module adapted to be inserted as a unitary assembly into a housing having an inlet and an outlet for an effluent stream to be cleaned comprising:

- particle charging means,
- particle collecting means spaced from the particle charging means in the direction of effluent flow and including a movable collecting surface,
- means for moving the collecting surface through the effluent stream and through a location remote from the stream,
- means at the remote location for cleaning the collecting surface,
- electrical power supply means for the particle charging means and the particle collecting means, and
- frame means independent of the housing for supporting the particle charging means, particle collecting means, collecting surface moving means, cleaning means, and power supply means in mutual operating relationship thereby to provide a self-contained, modular precipitator unit.

13. An electrostatic precipitator module according to claim 12 in which:

- the movable collecting surface comprises an endless belt, and
- the surface moving means includes a pair of spaced rotatable shafts, the longitudinal axes of which are parallel and extend in the direction of effluent flow, and drive means connected to at least one of the shafts for rotating the belt.

14. An electrostatic precipitator module according to claim 13 in which the endless belt comprises:

- a pair of chains spaced in the direction of effluent flow, one supported at either end of the shafts,
- a multiplicity of separate, elongate slats extending lengthwise between the chains in parallel, side-by-side relation, and

means for attaching each slat to the chains separately of the other slats, whereby the slats are individually removable from the belt.

15. An electrostatic precipitator module according to claim 14 in which the slats are constructed of rigid, conductive material, and in which each slat has an electrically conductive region formed thereon adjacent the upstream end thereof and a dielectric region formed thereon downstream of the conductive region, the conductive and dielectric regions of each slat being aligned with the corresponding regions of the other slats so as to define a conductive band and a dielectric band around the periphery of the belt.

16. An electrostatic precipitator module according to claim 15 in which the particle charging means includes an ionizer electrode positioned in opposed, parallel relation to the conductive band on the belt, and the particle collecting means includes a nondischarging, passive field electrode positioned in opposed, parallel relation to the dielectric band on the belt.

17. An electrostatic precipitator module according to claim 16 in which the ionizer electrode is supported by, and electrically connected to, the upstream end of the downstream passive field electrode to form an integral electrode assembly.

18. An electrostatic precipitator module according to claim 14 in which the slats are constructed of rigid, dielectric material overlying a conductive material, and

in which each slat has an electrically conductive region formed thereon adjacent the upstream end thereof and a dielectric region formed thereon downstream of the conductive region, the conductive and dielectric regions of each slat being aligned with the corresponding regions of the other slats so as to define a conductive band and a dielectric band around the periphery of the belt.

19. An electrostatic precipitator according to claim 14 in which the frame means includes at least two enclosed gas ducts extending in the direction of effluent flow, the ducts being spaced apart in opposed relation and defining between the facing surfaces thereof a flow path for the effluent stream, the particle charging means includes an ionizer electrode supported between the facing surfaces of the ducts at an upstream region of the flow path, and the particle collecting means includes a passive electrode supported between the facing surfaces of the ducts downstream of the ionizer electrode.

20. An electrostatic precipitator according to claim 19 further comprising conductive electrode holder members extending through the facing surfaces of the ducts for supporting the ionizer electrode and the passive field electrode, and means defining an insulating gap between each holder member and the facing surface of each duct at the point of feed through of the holder member.

21. An electrostatic precipitator according to claim 20 in which the ionizer electrode is supported by, and electrically connected to, the upstream end of the downstream passive field electrode to form an integral electrode assembly, whereby the ionizer and passive field electrodes are supported between the ducts by common holder members.

22. An electrostatic precipitator according to claim 19 in which the frame means further includes rigid, guide means extending transversely of the flow path between the spaced ducts for supporting and guiding the endless belt during the movement thereof.

23. An electrostatic precipitator comprising:
a housing having an inlet and an outlet for an effluent stream entraining particles to be precipitated,
means defining at least one pair of enclosed gas ducts extending between the inlet and the outlet, the ducts being spaced apart in opposed relation and defining between the facing surfaces thereof a flow path for the effluent stream, particle charging means located at an upstream region of the flow path and including a high-potential ionizer electrode extending transversely of the stream,

particle collecting means located downstream of the charging means and including a high-potential passive field electrode extending transversely of the stream,

means for supporting the ionizer electrode and the passive field electrode between the ducts, said means including conductive holder members extending through the facing surfaces of the ducts, means defining an insulating gap between each holder member and the facing surface of each duct at the point of feed through of the holder member, and

means associated with the ducts for flowing clean gas through the insulating gaps into the flow path,

thereby to purge particles from the region of the insulating gaps and to prevent outflow of the effluent stream from the flow path.

24. A precipitator according to claim 23 in which the insulating gap defining means includes means defining an opening of generally circular cross section in the duct facing surface in surrounding relation to each holder member, the inner wall of the opening having a rounded, electrically nondischarging configuration.

25. A precipitator according to claim 24 in which each holder member is generally circular in cross section, and in which the inner diameter of the surrounding opening is substantially 2.718 times as great as the outer diameter of the holder member.

26. A precipitator according to claim 24 in which the insulating gap defining means further includes a dielectric member, porous to the clean gas flow, interposed between each holder member and the inner wall of the surrounding opening.

27. A precipitator according to claim 24 in which the inner wall of the opening constitutes a generally cylindrical sleeve, substantially coaxial with the holder member and extending away from the flow path.

28. A precipitator according to claim 27 in which the

cylindrical inner wall is constructed of material porous to the clean gas flow, the end thereof remote from the flow path being closed to gas flow.

29. A precipitator according to claim 27 in which the insulating gap defining means further includes flow restricting means located within the sleeve.

30. A precipitator according to claim 23 in which the temperature of the clean gas is substantially lower than that of the effluent stream, thereby to enhance the insulative value of the clean gas flow within the insulating gaps relative to that of the effluent stream at the particle charging means.

31. A precipitator according to claim 23 in which the means for flowing clean gas through the insulating gaps includes blower means coupled to the ducts.

32. A precipitator according to claim 23 in which the ionizer electrode is supported by, and electrically connected to, the upstream end of the downstream passive field electrode to form an integral electrode assembly, whereby the ionizer and passive field electrodes are supported between the ducts by common holder members.

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