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Remick

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[54] **ELECTROSTATIC PRECIPITATOR**

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Related U.S. Application Data

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[52] **U.S. Cl.** ..... **55/143,** 29/624, 55/126, 55/138, 55/145, 55/151, 55/154, 317/261, 339/17 R

[51] **Int. Cl.** **B03c 3/47,** B03c 3/12

[58] **Field of Search** ..... 55/143, 145, 154, 146, 55/136, 137, 138, 139, 142, 141, 140, 156, 155, 157, 126, 151; 317/101 R, 101 B, 101 C, 101 CC, 101 CM, 101 D, 242, 256, 257, 258, 261; 339/17 R, 17 LM, 17 M, 267 R, 277 R, 278 R; 29/155.5 X, 624; 174/68.5

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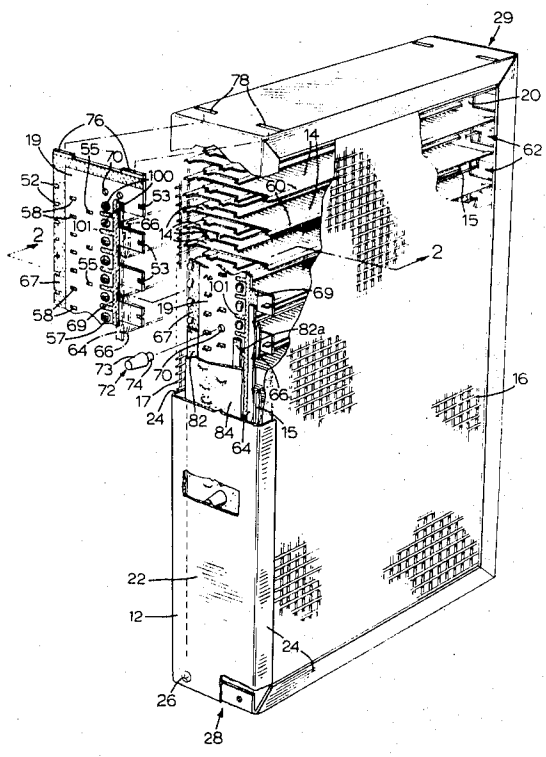
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[57] **ABSTRACT**

An electrostatic precipitator is modified so that the amount of energy that is dissipated when an arc-over occurs between any two adjacent collector plates thereof is reduced. The positive collector plates of the electrostatic precipitator are connected to a positive bus bar by means of resistors. These resistors preferably are in the form of a resistive cement. When an arc-over occurs between two adjacent collector plates, the resistors prevent the charges on the other capacitors constituted by other adjacent collector plate pairs from being dissipated via the arc-over.

8 Claims, 3 Drawing Figures



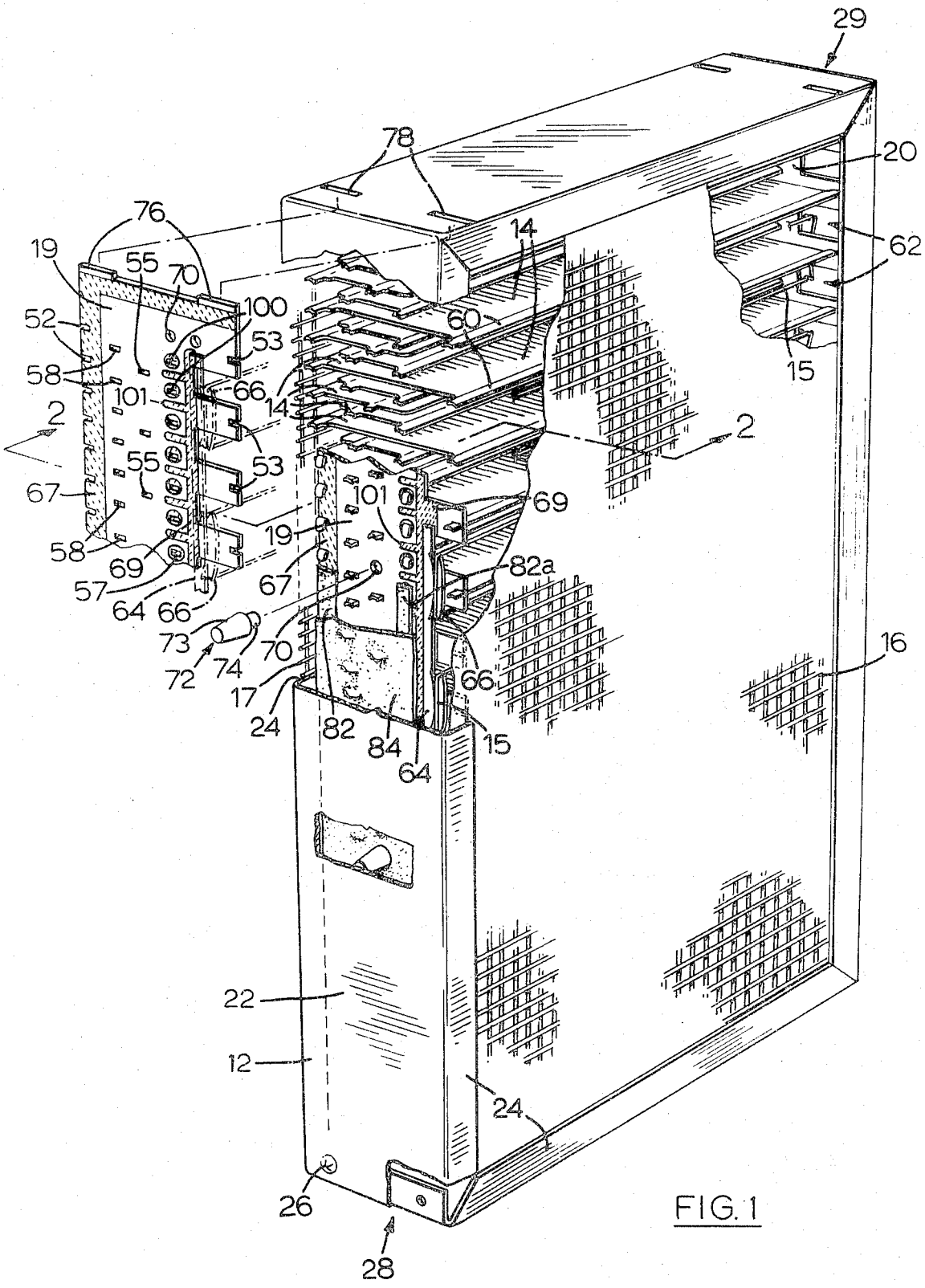

29
78
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76
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62
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55
53
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82a
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FIG. 1

FIG. 3

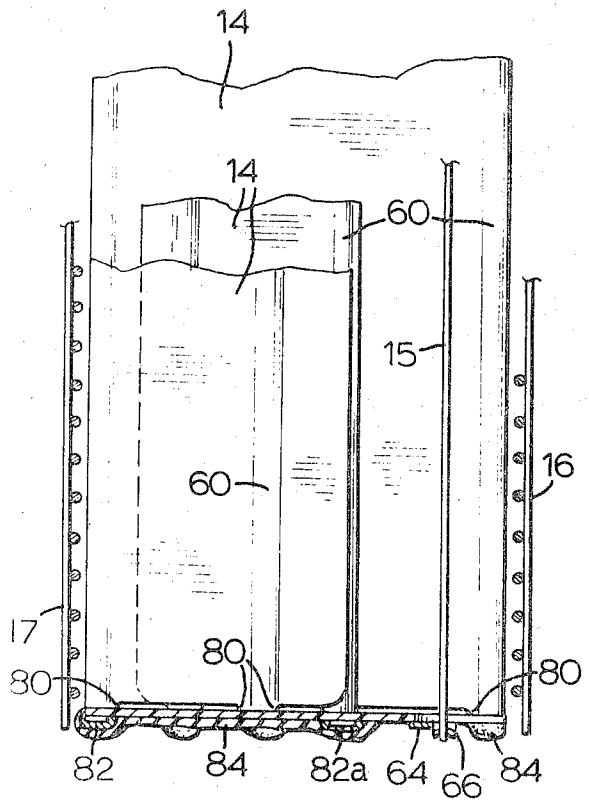
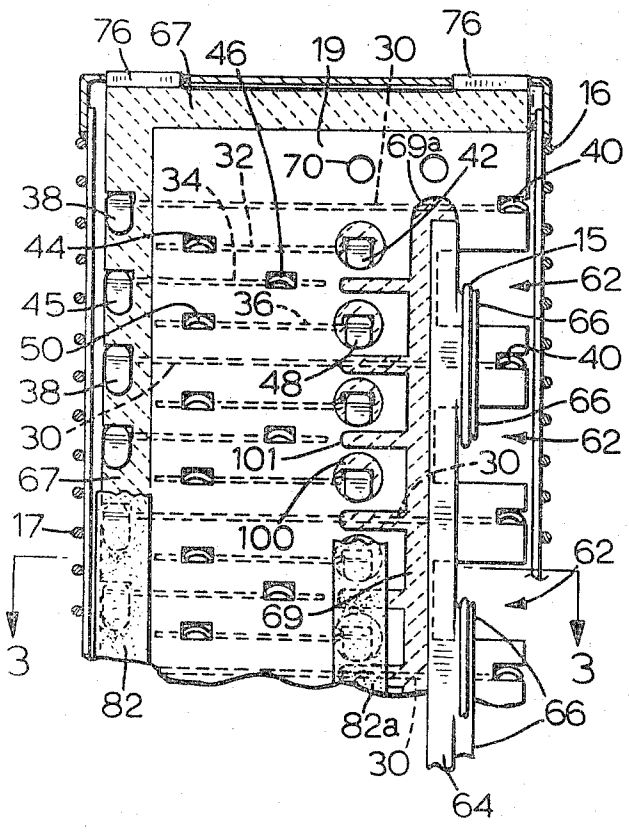

14
14
60
15
16
60
17
80
80
80
82
84
82a
64
66
84

FIG. 2


76
67
46
19
30
76
16
40
32
70
69a
42
34
38
44
15
62
45
36
66
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40
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38
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30
62
101
30
67
17
100
62
69
3
3
82
66
82a
30
64

ELECTROSTATIC PRECIPITATOR

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of copending application Ser. No. 190,211, filed Oct. 18, 1971, now U.S. Pat. No. 3,727,380.

BACKGROUND OF THE INVENTION

This invention relates generally to electrostatic precipitators of the kind adapted to remove particles such as dust, smoke and pollen from the air or other gas being passed through the precipitator. More specifically, this invention relates to that portion of an electrostatic precipitator construction which involves the mounting of the collector plates thereof and electrical connections thereto.

In the operation of an electrostatic precipitator, air or other gas containing particles such as dust, pollen, etc., is caused to pass through two zones, an ionizing zone and a collection zone. Ordinarily the ionizing zone is characterized by a plurality of positively charged parallel wires, while the collection zone contains a series of alternately arranged positive and negative plates between which the air must pass. Normally, particles that have become positively charged in the ionizing zone are collected on the negative plates in the collection zone. However, some of the positively charged particles may pick up more electrons then they require to become neutral, in which case they become negatively charged and then are attracted to the positive plates.

In the copending patent application referred to hereinbefore there is disclosed an electrostatic precipitator construction in which the several components thereof are so designed that their assembly is simple and does not require elaborate or expensive equipment. More specifically, the electrostatic precipitator includes two, spaced-apart, parallel printed circuit boards. Between the printed circuit boards extend a plurality of parallel, alternately arranged positive and negative collector plates, these plates being provided with tabs that conductively engage bus bars on the printed circuit boards that are connected to the positive and negative terminals respectively of a suitable power supply. A third bus bar also is provided on each printed circuit board and also is connected to the positive terminal of the power supply. This third bus bar conductively engages an electrically conductive, tension-providing ionizing wire support on which the ionizing wire of the electrostatic precipitator is mounted. With such an electrostatic precipitator the third bus bar is directly connected to the positive terminal of the power supply, which may be at +6,000 volts DC, for example. The other positive bus bar also is connected to the positive terminal of the power supply, as aforementioned, but via a large resistor having a magnitude of about, say, 30 meg. ohms. This resistor serves to isolate the power supply from the positive collector plates so as to protect the power supply in the event of arc-overs occurring. Such arc-overs may occur between adjacent positive and negative collector plates. As aforementioned, the electrostatic precipitator includes a large number of adjacent positive and negative collector plates, so each pair of adjacent plates constitutes a charged capacitor, and these capacitors are connected in parallel with each other. When an arc-over occurs between any two adjacent collector plates of the electrostatic precipitator, all of these capacitors discharge via the arc-over, and this considerably amplifies the arc-over effect. This is disturbing to any person who may be close to the electrostatic precipitator as the amplified arc-over is accompanied by an audible crackling sound similar to that which is head when a spark is caused to jump a gap between two conductive terminals. Also arc-overs of this type may result in damage being done to the collector plates.

SUMMARY OF THE INVENTION

In accordance with the instant invention an electrostatic precipitator of the general type disclosed in the aforesaid copending application is modified in such a way that the amount of energy that is dissipated when an arc-over occurs between two adjacent collector plates is reduced. This is achieved by connecting the positive collector plates to the positive bus bar by means of resistors. These resistors preferably are in the form of a resistive cement that is adhered to the printed circuit boards and which extends between the positive collector plate bus bar and the positive collector plates themselves, the length of the paths between the positive collector plate bus bar and the positive collector plates determining the magnitude of the resistors. With such a construction the separate bus bar for the ionizing wire support can be eliminated and the ionizing wire support connected directly to the positive collector plate bus bar. Also the previously used resistor between the positive collector plate bus bar and the positive terminal of the power supply is eliminated. When an arc-over occurs between two adjacent collector plates, the aforesaid resistors greatly reduce the extent to which the charges on the other capacitors are dissipated via the arc-over. In other words, the capacitors formed by the pairs of adjacent oppositely charged collector plates are resistively isolated from each other.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention will become more apparent from the following detailed description, taken in conjunction with the appended drawings, in which:

FIG. 1 is a partly broken-away, partly exploded, perspective view of an electrostatic precipitator construction embodying this invention;

FIG. 2 is a partial elevation view taken at the line 2—2 in FIG. 1; and

FIG. 3 is a sectional view taken at the line 3—3 in FIG. 2.

Attention is now directed to FIG. 1, in which an electrostatic precipitator 10 is seen to include an external rectangular frame 12, a plurality of collector plates 14, an ionizing wire 15, and two protective screens 16 and 17. Two printed circuit boards 19 and 20 are also provided, one at either end of the collector plates 14, and both arranged perpendicularly thereto.

As can be seen, the rectangular frame 12 is U-shaped in cross-section having a main wall 22 and two perpendicular flanges 24. In the embodimemt shown, the frame 12 is in two L-shaped parts manufactured of sheet metal, the flanges 24 being appropriately notched at locations corresponding to the corners of the electrostatic precipitator. Metal screws 26 or other suitable attachment means are employed to secure the loose ends of the frame 12 together at the corners 28 and 29, as shown.

All of the collector plates **14** have the same length (the dimension perpendicular to the plane of the printed circuit boards **19** and **20**), but they are not all of the same width. The plates **14** are preferably of aluminum or aluminum alloy. The plates **14** should have substantially smooth and non-porous (i.e., relatively "closed") surfaces so that collected dirt will be washed out easily and will not have a tendency to adhere to the surfaces.

As seen in FIG. **2**, the collector plates are arranged in repeating sets of four. The uppermost set of four collector plates includes a negative plate **30** of a width corresponding to the width of the printed circuit board **19**. Spaced apart from but immediately beneath negative plate **30** and in parallel relation thereto is a positive plate **32**. The width of plate **32** is just over half that of negative plate **30**. Positive plate **32** is set slightly inwardly from the left-hand edge of negative plate **30** and the printed circuit board **19**. Next beneath the positive plate **32**, and spaced-apart from but in parallel relation thereto, is a negative plate **34**, the left-hand edge of which is aligned with that of the first negative plate **30**. The right-hand edge of negative plate **34** is positioned leftwardly of the right-hand edge of positive plate **32**. In fact, plates **32** and **34** are identical, but are reversed end-to-end. Thus they are both of the same width. Next beneath the negative plate **34** is another positive plate **36** identical to the first positive plate **32** and aligned therewith. Thus, the right-hand edges of the plates **32** and **36** are aligned, while the left-hand edges of the plates **30** and **34** are aligned.

The same set of four plates is then repeated in the same sequence beneath the first set described above. Thus, there is a plurality of wide plates **30**, and a plurality of narrow plates **32**, **34** and **36**.

As illustrated, each plate has two projecting tabs at each end integral with the plate. In the embodiment shown in the drawings, each plate has an integral contact tab and an integral support tab at either end. Specifically, the upper negative plate **30** has a contact tab **38** and a support tab **40**, while positive plate **32** has a contact tab **42** and a support tab **44**. Negative plate **34** has a contact tab **45** and a support tab **46**, while positive plate **36** has a contact tab **48** and a support tab **50**. The repeating sets of these four plates have identical tabs to those described immediately above. For every plate, the contact tabs are longer than the support tabs.

As seen in FIG. **1**, printed circuit board **19** has a plurality of spaced slots **52** along its left-hand edge for receiving the contact tabs **38** and **45** of the negative plates **30** and **34**, and has a plurality of spaced slots **53** along its right-hand edge for receiving the support tabs **40** of the wide negative plates **30**. The support tabs **46** of the narrow negative plates **34** are received in a series of slots **55** shown in FIG. **1**. A further series of slots **57** are adapted to receive the contact tabs **42** and **48** of the positive plates **32** and **36**, while a series of slots **58** are adapted to receive the support tabs **44** and **50** of the positive plates **32** and **36**. Preferably, printed circuit board **19** is symmetrical about a transverse mid-line, so that boards **19** and **20** can be identical, but reversed end-to-end so that the bus bars to be described below always are located on the outer face.

Each plate has integral, arcuate, raised ribs **60** aligned with the pairs of tabs at its ends. Both ends of each plate are identical, which means that the tabs occur in the same positions at either end, and thus each raised rib **60** has a tab at either end. Because each tab is, in effect, an extension of the raised rib, each tab is also arcuate in crosssection. The arcuate nature of the tabs is clearly seen in FIGS. **1** and **2**. The purpose of the raised ribs **60** is to add strength and rigidity to the collector plates.

Along its right-hand edge, printed circuit board **19** has a plurality of cut-away indentations **62**, one between each adjacent pair of support tabs **40** of the wide negative plates **30**. The indentations **62** are all substantially rectangular. Secured to the printed circuit board **19** along the inner extremities of the cut-away indentations **62** is an electrically conductive bar **64** which has a plurality of resilient, wire-supporting fingers **66** which extend alternately up and down so that each finger has its end generally situated mid-way of one of the cut-away indentations **62**. The end of each finger, whether an upwardly extending or downwardly extending finger, has a V-notch which is adapted to receive ionizing wire **15**. Each finger is arcuately curved away from the printed circuit board **19**, so that when the wire **15** is tightly wound, it is maintained under tension by the resilience of fingers **66**. The bar **64** is soldered or otherwise firmly conductively adhered to a printed bus bar **69** on board **19**.

Printed circuit board **19** also has another bus bar **67**. In addition, printed circuit board **19** has terminals **100** of conductive material around each slot **57**, the terminals being in the form of discrete circles in the embodiment shown. As can be seen, bus bar **69** is arranged vertically and has conductive fingers **101** that extend between adjacent terminals **100**. Bus bar **69** has a soldering extension **69***a* at the top for soldering purposes. Bus bar **67** extends down the left-hand edge of board **19** and links all of the spaced slots **52** which are adapted to receive the contact tabs **38** and **45** of the negative collector plates **30** and **34**. Bus bar **67** also extends across the upper extremity of board **19**.

As seen in FIG. **1**, board **19** also has a number of spaced circular apertures **70** in which spacing members **72** are adapted to be received. Each spacing member **72** has a conically flared portion **73** and a reduced stem **74** adapted to be received snugly in circular aperture **70**. The purpose of the spacing members **72** is to maintain a desired spacing between the frame **12** and the printed circuit board **19**. The spacing members also give support in case the unit is dropped on its side. Printed circuit board **19** has, at either end, two extensions **76** which are adapted to be received in slots **78** provided therefor in frame **12**. The registry of the extension **76** in the slots **78** accurately locates the boards **19** and all of the collector plates with respect to the frame **12**.

It will be understood, of course, that board **20** is the same in all respects as board **19** and has the same components mounted thereon.

As seen in FIG. **3**, each of the tabs, whether contact tabs or support tabs, have a small shoulder **80**, the purpose of which is to space the main bodies of the collector plates from the printed circuit boards **19** and **20**.

The assembly of the electrostatic precipitator of this invention will now be described.

Firstly, the different collector plates and two printed circuit boards are assembled so that the different tabs register with the appropriate slots, as shown in the figures. The two printed circuit boards would be identical,

but reversed. In other words, one is the mirror image of the other. That is, the far printed circuit board **20** in FIG. **1** would have the indentations **62** at its right-hand edge as seen in FIG. **1,** but would have the bar **64,** with its arcuate resilient fingers **66,** located on the far side of the board as viewed in FIG. **1.** Bar **64** and fingers **66** also would be reversed, in the sense that fingers **66** would be arcuately curved away from the collector plates on the far side of the electrostatic precipitator as viewed in FIG. **1.** It is not necessary that both printed circuit boards **19** and **20** have bus bars **69** and **67,** although this is desirable because of the resulting advantage of uniformity.

It will be appreciated from what follows that it would be possible also to have one of the bus bars on one of the printed circuit boards and the other on the other printed circuit board. For example, the bus bar **67** could be located on printed circuit board **19,** while bus bar **69** could be located on printed circuit board **20.** In the embodiment shown, however, it will be assumed that bus bars **67** and **69** are located on both printed circuit boards **19** and **20.**

When the collector plates and the printed circuit boards have been assembled in the required arrangement, the contact tabs **38, 42, 45** and **48** of all of the collector plates are crimped over as seen in FIGS. **1** and **2.** This crimping can be done manually or by machine. The support tabs **40, 44, 46** and **50,** are left uncrimped.

It will be appreciated that for two reasons it is highly desirable to have the two vertical rows of crimped contact tabs separated from each other by the greatest possible distance. The first reason is, of course, to reduce the risk of electric arc-over between the bus bars, these being at a high potential difference when the precipitator is in use. The second reason is that the spread-apart crimping locations hold the two printed circuit boards **19** and **20** tightly against the collector plates while subsequent operations, now to be described, are performed. If both lines of crimped contact tabs were close together along one edge of the printed circuit boards **19** and **20,** it would be possible to pull the "free" edge of each board away from the collector plates, which is very undesirable. To achieve separation of the two rows of crimped contact tabs, the support tabs for the negative plates are all to the right of the negative contact tabs, while the support tabs for the positive plates are all to the left of the positive contact tabs.

After tabs **38** and **45** have been crimped over as shown in FIG. **2,** both the tabs and associated bus bar **67** are masked by the application of a coating of an electrically conductive, resilient cement. This coating prevents arcs between bus bar **67** and the crimped contact tabs **38** and **45** to minimize radio interference arising from arcing. Because of its resilient nature, cement **82** also serves to minimize rattling.

In accordance with the instant invention, bus bar **69** is isolated from each positive collector plate **32, 36** by means of a resistor. In the embodiment of the invention shown this is achieved by applying a coating of conductive but electrically resistive, resilient cement **82***a* over each of fingers **101** and terminals **100.** Cement **82***a* not only serves the same function as cement **82** but provides a highly resistive path between each finger **101** and each adjacent terminal **100.** The magnitude of the resistive path may vary widely but preferably is in the range of 1 to 30 meg. ohms. In any event, the value of the resistors so formed should be such that when an arc-over occurs between an adjacent positive and negative collector plate, the charge that is stored in the capacitors that are constituted by the other positive and negative collector plates is prevented from contributing to the arc-over. Thus, by way of example, the application of cement **82***a* creates a 30 meg. ohm resistor between bus bar **69** and each positive collector plate, so that from an equivalent circuit point of view the collector plates of the precipitator can be represented by a plurality of series circuits each including a capacitor and a resistor with the series circuits being connected in parallel with each other, whereas in the electrostatic precipitator disclosed in the aforementioned copending application the equivalent circuit is that of a plurality of capacitors connected in parallel.

As the aforesaid resistors now are effectively connected between bus bar **69** and each positive collector plate, there is no longer any necessity to provide a 30 meg. ohm isolating resistor between terminals **69***a* of bus bar **69** and the positive terminal of the power supply (not shown). The required isolation of the power supply and the collector plates is achieved by the resistors connected between fingers **101** and terminals **100.** This being the case, terminal **69***a* can be and in practice is directly connected to the positive terminal of the power supply which may be at, say, +6,000 volts DC. The fact that no 30 meg. ohm resistor is connected between the positive terminal of the power supply and terminal **69***a* also means that bar **64** can be and is electrically connected to bus bar **69** eliminating the previously required separate external connection between bar **64** and the positive terminal of the power supply. It will be understood, of course, that bus bar **67** is directly connected to the negative or grounded terminal of the power supply.

Preferably cement **82** and **82***a* is a carbon-filled silicon rubber cement which not only exhibits satisfactory resistive properties, but will withstand the vibration of the collector plates caused by air flow for an extended period of time. One material which has been found satisfactory as cement **82** and **82***a* in the electrostatic precipitator according to this invention is known as "Dow-Corning Silastic 735 RTV" (trade mark).

Following the application of cement **82, 82***a*, a further coating **84** of non-conductive (insulative) resilient material may be applied over the entire board **19** and **20** except for the bars **64.** This coating **84** entirely covers the projecting support tabs of the collector plates, as well as the earlier coatings of cement **82, 82***a*. It also covers the spacing members **72** and anchors them in place. The non-conductive, resilient coating **84** prevents arc-overs across the surface of the board, and prevents rattling at the support tabs. One material which has been found satisfactory for coating **84** is "Dow-Corning **145**" (trade mark) protective coating. This material does not dry rigid and therefore can withstand vibrations. FIG. **2** shows only cement **82, 82***a*. The non-conductive coating is seen in section in FIGS. **1** and **3.**

After the plates and printed circuit boards have been assembled as above described, ionizing wire **15** can be wrapped sinusoidally about the fingers **66.** The wrapping of the ionizing wire can take place prior to the application of the two coatings, if desired. It should be understood, however, that the arrangement of ionizing

wire **15** and its supports are not relevant to the instant invention, which is directed to the collector plate mounting and electrical connection arrangements. The ionizing wire and its supports might even be in a separate part of the precipitator.

It also should be noted that even though cements **82**, **82***a* may be the same material, there is nothing inconsistent in referring to cement **82** as conductive and cement **82***a* as resistive, since resistive material is conductive to some degree. Cement **82** is not required to exhibit any degree of resistivity and could be a "perfect conductor" if such were possible. In practise the amount of it that might find its way between bus bar **67** and tabs **38** and **45** is such that a very low resistance path is provided. On the other hand, the length of the path between each finger **101** and each terminal **100** is considerably greater providing a path having high resistance.

In the appended claims, the expression "printed circuit board" is intended to cover any plate-like element of stiff, non-conductive or insulative material which is capable of receiving a printed circuit or bus bar on one surface. "Board" is here used in its broadest sense, and is not limited to wood, wood products or cellulosic materials.

What I claim is:

1. In an electrostatic precipitator an improved arrangement for supporting and electrically connecting the collector plates thereof comprising two spaced apart printed circuit boards, a plurality of collector plates stacked in spaced apart relationship one above the other and extending between said printed circuit boards and supported thereby, said printed circuit boards having a plurality of slots extending therethrough, said collector plates having tabs extending therefrom, said tabs extending into said slots, at least two bus bars adapted for connection to two terminals of a DC power supply at different DC potentials, one of said bus bars being on one of said printed circuit boards and the other of said bus bars also being on one of said printed circuit boards, every other one of said collector plates being electrically connected via at least certain of said tabs thereof to said one bus bar, a plurality of isolating resistors, said isolating resistors being electrically connected between said other bus bar and the remaining ones of said collector plates and being of sufficient magnitude, upon occurrence of an arc-over between two adjacent ones of said collector plates, to inhibit discharge of the capacitors constituted by other adjacent pairs of collector plates via said arc-over, said isolating resistors being constituted by electrically resistive, resilient cement adhered to said printed circuit board carrying said other bus bar and electrically connecting said remaining ones of said collector plates via at least certain of said tabs thereof to said other bus bar, said certain tabs of said remaining collector plates extending through certain of said slots that are physically spaced apart from said other bus bar, whereby said electrically resistive, resilient cement bridges the spaces between said certain tabs of said remaining collector plates and said other bus bar, said electrically resistive, resilient cement also being adhered to said certain of said tabs of said remaining ones of said collector plates and extending over the slots through which the last-mentioned tabs extend and thereby inhibiting rattling of said last-mentioned tabs.

2. An electrostatic precipitator as claimed in claim **1** wherein the ones of said collector plates electrically connected to said one bus bar are electrically connected thereto via electrically conductive resilient cement adhered to said printed circuit board carrying said one bus bar and also adhered to said certain of said tabs of the last-mentioned collector plates and extending over the slots through which said certain of said tabs of the last-mentioned collector plates extend and thereby inhibiting rattling of these tabs.

3. An electrostatic precipitator as claimed in claim **2** wherein the slots through which said certain of said tabs of the last-mentioned collector plates extend also pass through said one bus bar.

4. An electrostatic precipitator as claimed in claim **2** wherein said collector plates have additional tabs other than said certain tabs, said additional tabs being electrically disconnected from said bus bars, and electrically insulating resilient cement adhered to said additional tabs, extending over the slots through which said additional tabs extend and also adhered to the portions of said printed circuit boards surrounding the slots through which said additional tabs extend to inhibit rattling of said additional tabs.

5. An electrostatic precipitator as claimed in claim **4** wherein said bus bars are both on the same printed circuit board, said additional tabs and the slots through which said additional tabs extend are located between said bus bars and said electrically insulating resilient cement is adhered to the portion of said same printed circuit board that is located between said bus bars.

6. An electrostatic precipitator according to claim **5** wherein said electrically insulating resilient cement also is coated over and adhered to said electrically conductive resilient and said electrically resistive resilient cements.

7. An electrostatic precipitator as claimed in claim **4** wherein there are two of said one bus bars and two of said other bus bars, one of each being located on each of said printed circuit boards, said additional tabs and the slots through which said additional tabs extend being located between the bus bars on the respective printed circuit boards and said electrically insulating resilient cement being adhered to the portions of said printed circuit boards located between said bus bars thereon.

8. An electrostatic precipitator as claimed in claim **7** wherein said electrically insulating resilient cement also is coated over and adhered to said electrically conductive resilient and said electrically resistive resilient cements.

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