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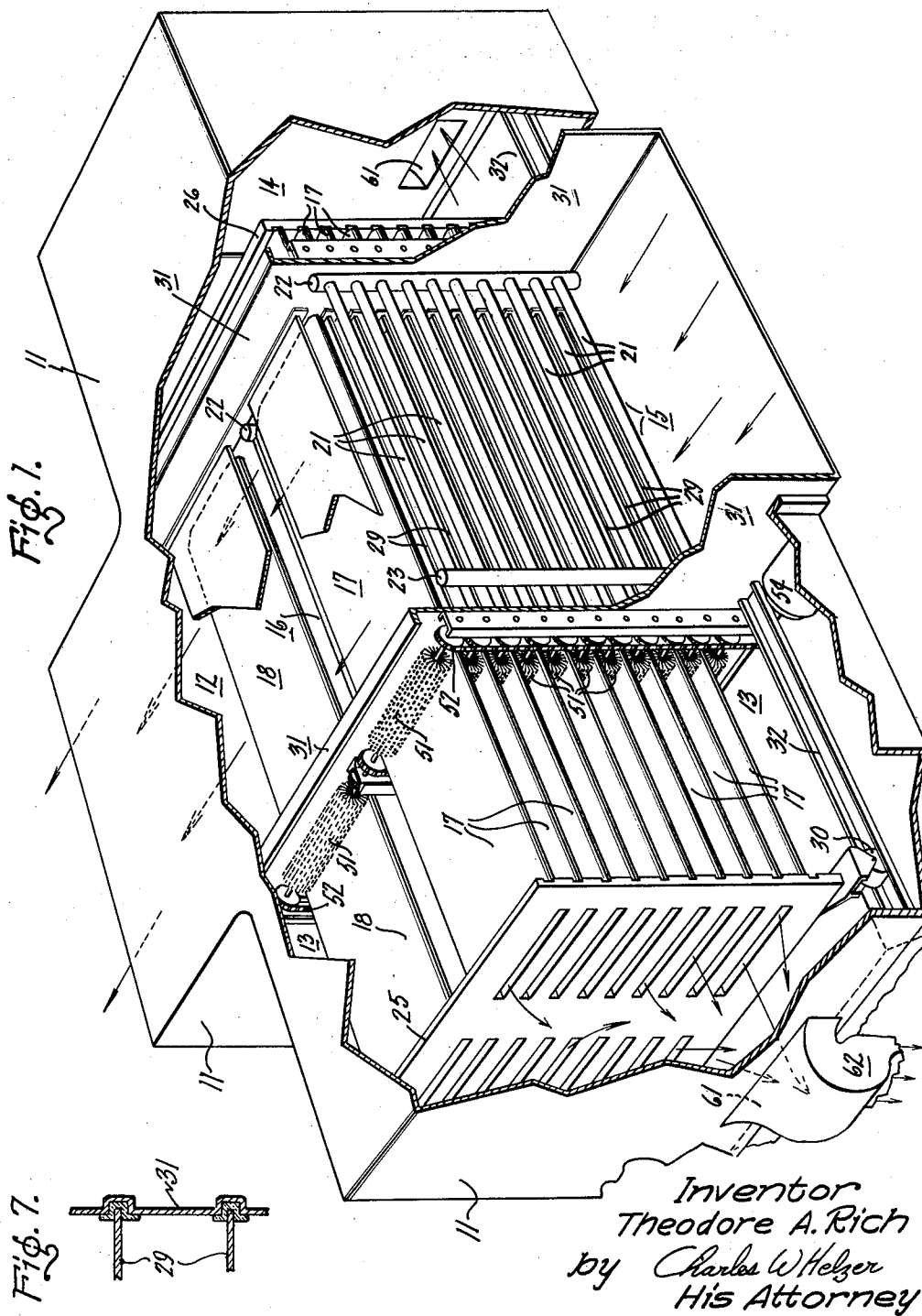
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3,149,936

ELECTROSTATIC PRECIPITATOR

Filed May 26, 1961

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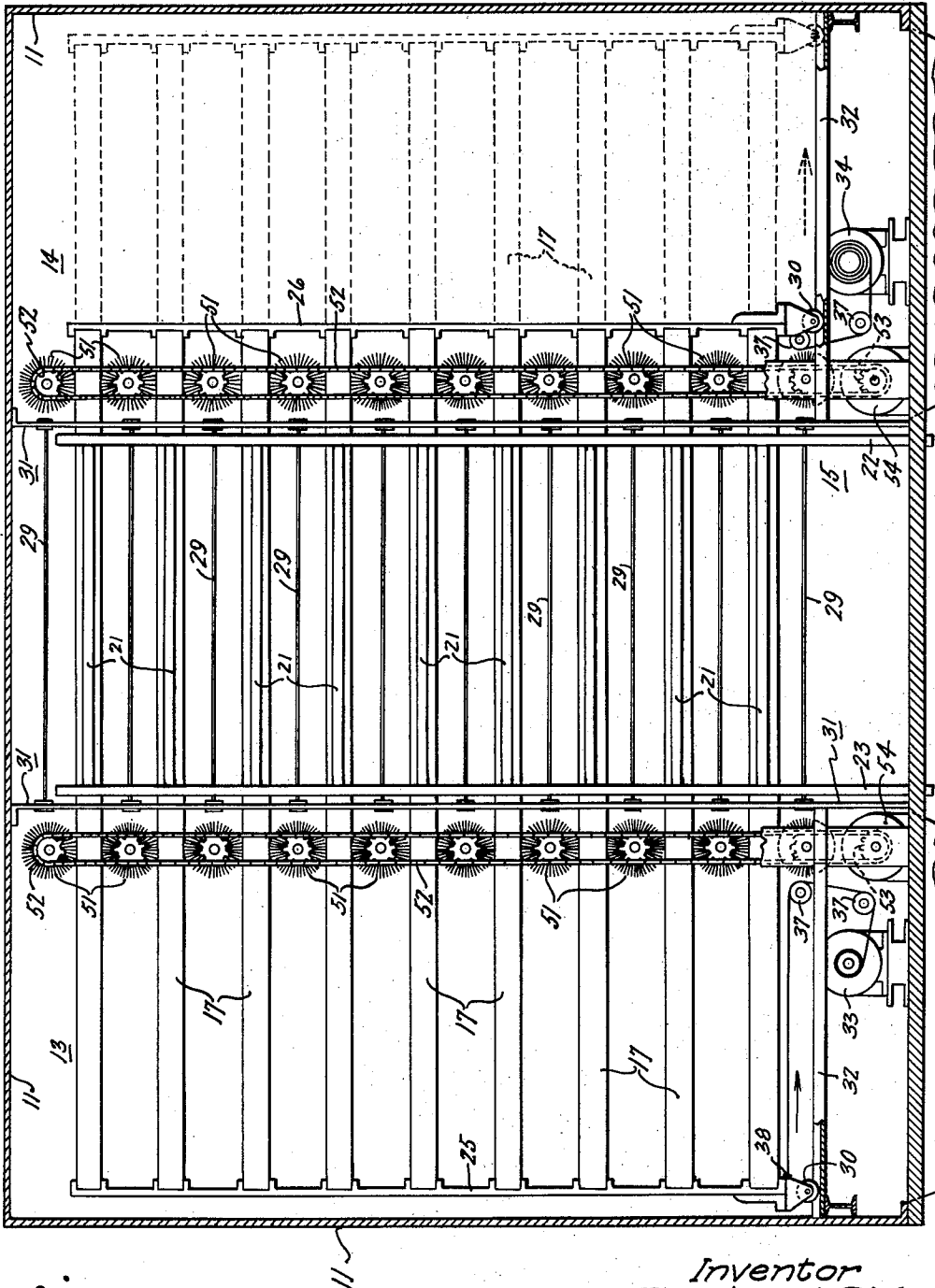


Fig. 2.

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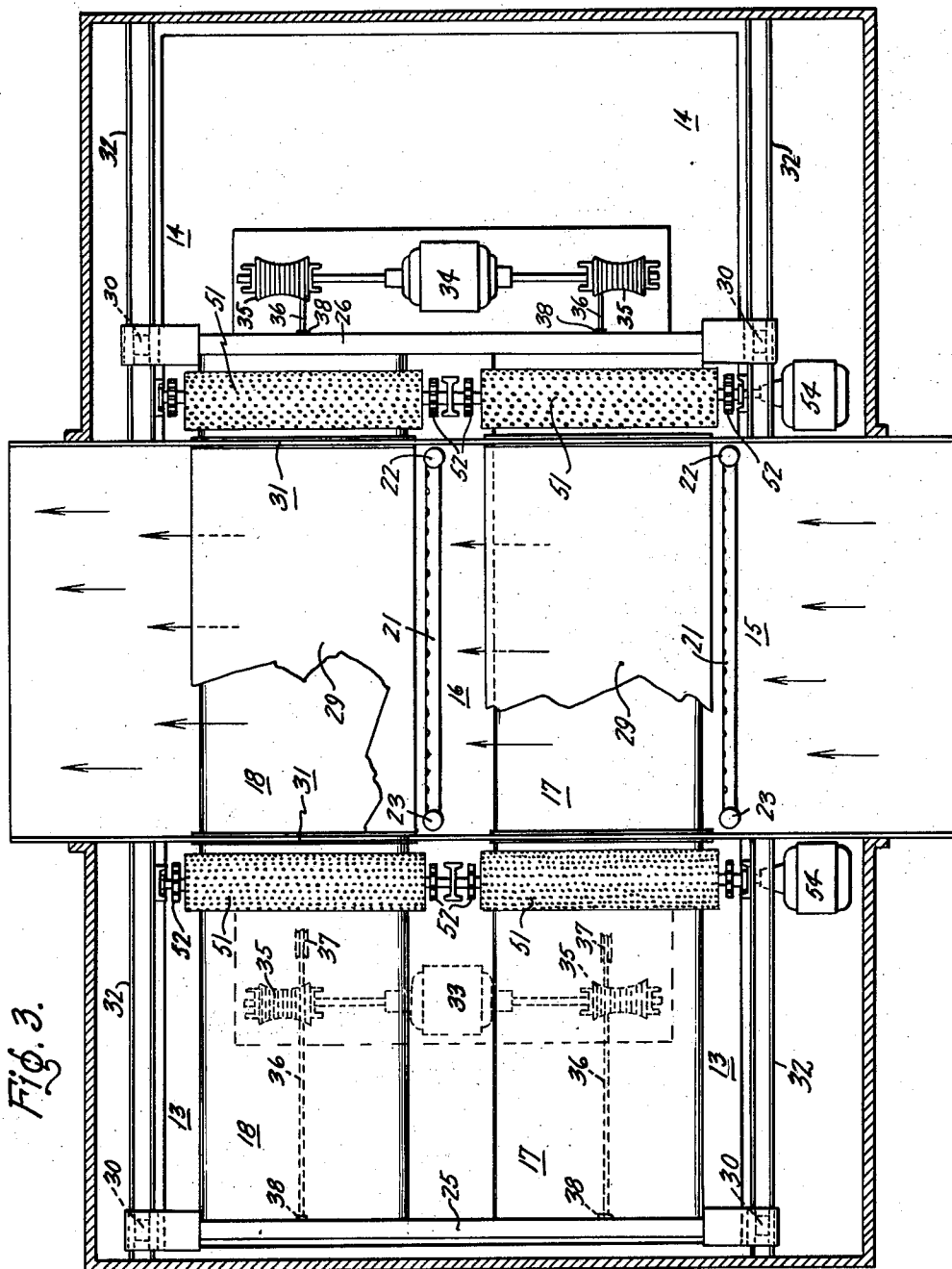
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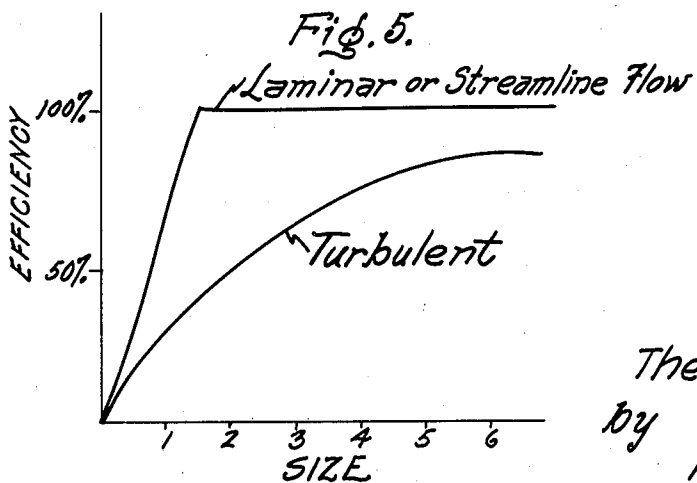
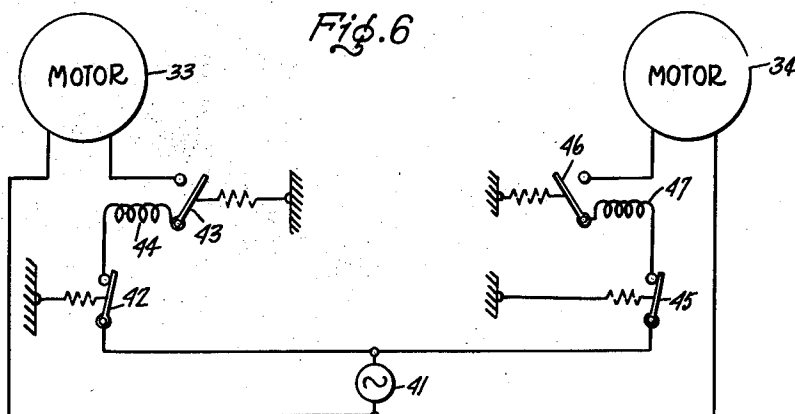
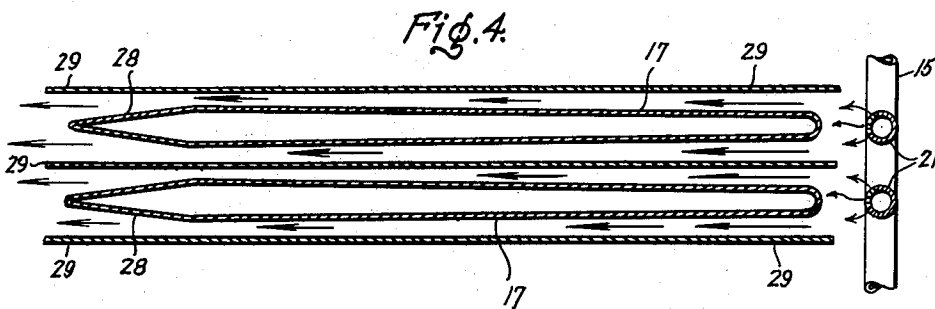
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ELECTROSTATIC PRECIPITATOR

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3,149,936

## ELECTROSTATIC PRECIPITATOR

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Filed May 26, 1961, Ser. No. 112,824  
7 Claims. (Cl. 55—114)

This invention relates to a new and improved precipitator for electrostatically removing minute particles suspended in a fluid stream.

The problem of increasing air pollution of urban communities by industrial manufacturing facilities, utilities and the like, has emphasized the need for greatly improved devices for removing undesired airborne aerosol particles such as smoke, soot, and other debris before it becomes dispersed in the air. There are a number of known electrostatic precipitators which are available to industry today for use in removing such airborne debris; however, they have certain disadvantages inherent in their design. For the most part, known electrostatic precipitators utilize a corona discharge to facilitate removal of particles or debris entrained in an airstream passing through them. This, in turn, requires the use of high electrical voltages and relatively large electrical apparatus which is subject to breakdown, arcing, and the like, in addition to being objectionable for its large size. In order to overcome the problems resulting from present electrostatic precipitator designs, the present invention was devised.

It is therefore a primary object of the present invention to provide a new and improved electrostatic precipitator which is compact in design, and requires relatively low electric voltages during operation.

In practicing the invention, an aerosol particle precipitator is provided which comprises a source of ions adapted to be positioned in a fluid stream containing undesired airborne particles. Under the action of diffusion and electric fields, the ions from the source will be picked up by the aerosol particles entrained in an air stream passing over the source. A collector-electrode structure is positioned downstream from the source of ions, and comprises a plurality of shaped collector-electrode members which are maintained at a predetermined electric potential. The collector-electrode members are shaped to provide for laminar or streamline flow of the particle bearing fluid medium through the members in the structure. The provision of streamline flow through the collecting members makes possible a much greater collection efficiency for a given size unit. In a preferred embodiment of the invention, the source of electrically charged particles comprises a flame charging source of the type described in U.S. application Serial No. 112,825, filed May 26, 1961, now abandoned, T. A. Rich, inventor, Flame Charging Method and Apparatus, and assigned to the same assignee as the present invention.

Other objects, features and many of the attendant advantages of this invention will be appreciated more readily as the same becomes better understood by reference to the following detailed description, when considered in connection with the accompanying drawings, wherein like parts in each of the several figures are identified by the same reference character, and wherein:

FIGURE 1 is a perspective view of a new and improved precipitator constructed in accordance with the invention, and illustrates the precipitator with a portion of its outer casing broken away to show the elements of its construction;

FIGURE 2 is a cross-sectional front view of the precipitator shown in FIGURE 1;

FIGURE 3 is a plan view of the precipitator shown in FIGURE 1 with the top portion of the outer casing of the

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precipitator removed to show the construction of the various elements of the precipitator;

FIGURE 4 is a partial sectional view showing the construction of the collector-electrode members of the precipitator of FIGURES 1-3;

FIGURE 5 is a curve showing a plot of the efficiency characteristics for precipitators operating under conditions which provide for either turbulent flow or laminar flow of a particle bearing fluid through the collector-electrode assemblies thereof, and illustrates the comparative efficiencies of the two modes of operation;

FIGURE 6 is a schematic circuit diagram of an electrical control circuit used for controlling the motors operating the precipitator shown in FIGURES 1-3; and

FIGURE 7 is a partially cutaway view of the interior construction of a portion of the precipitator.

A new and improved precipitator constructed in accordance with the invention is shown in FIGURE 1 of the drawings, and is comprised by an outer housing 11 which defines a collecting chamber 12. Two cleaning chambers 13 and 14 are physically located on opposite sides of the collecting chamber 12 with each cleaning chamber having a hopper (not shown) attached to the underside thereof for receiving dirt particles and the like removed from the precipitator during the cleaning operation. It is the function of the collecting chamber 12 to operate on the flue gas or other fluid stream flowing in the direction of the arrows through the collecting chamber to collect out smoke, soot, and other airborne particles, and debris, and to deposit these particles on a number of collector-electrode members to be described more fully hereinafter. It is the function of the two cleaning chambers 13 and 14 to allow for cleaning of the surfaces of the collector assembly after a predetermined period of operation so as to not impair the operating efficiency of the precipitator. While the collector assembly illustrated is a two-stage arrangement, it is to be understood that the invention is in no way limited to two or more stages, for a single long stage may be even more efficient for certain applications. Each stage of the collector assembly is formed by a flame charging member indicated at 15 or 16 followed by an associated collector-electrode structure made up of a plurality of shaped collector-electrode members indicated at 17 or 18 located downstream from the respective associated flame charging members 15 or 16.

The details of the construction of the flame charging apparatus 15 or 16 is best shown in FIGURE 2 of the drawings wherein it can be seen that the flame charging apparatus is made up of a plurality of perforated, electrically conductive pipes 21 which extend between a pair of upright or vertical supporting supply pipes 22 and 23 that are connected to a source of suitable gaseous fuel. The perforations are formed in the pipes 21 in a line along the downstream side of the pipes and extend along the entire length of the pipes. Hence, each pipe provides a flame almost entirely along its length. Additionally, an electric potential is supplied to the pipes 21 as described in the above identified copending Rich application Serial No. 112,825. Due to the combustion process, a number of small ions will be produced naturally and occur in considerable quantities. Because the flame charging apparatus is located in the presence of an electric field, due in part to the potential applied to the pipes 21, which will operate on a particular polarity ion such as the negative ions, these ions will be repelled away from the flame source. In doing this, the negative ions will collide with and adhere to any naturally occurring airborne particles such as soot particles, smoke particles, and the like, which are entrained in the fluid medium as it passes through the collecting chamber 12 in the di-

rection indicated by the arrows in FIGURE 1 of the drawings. In this manner the aerosol particles, a fraction of which normally have only a small charge, will all be given a strong electric charge, and by providing an adequate size flame charging source for the volume of air flowing through the collecting chamber 12, it is possible to charge substantially all of the airborne particles occurring in the volume of air.

In order to collect the undesired airborne particles which are charged in the manner described about out of the fluid medium as it passes through the collecting chamber 12, the two-stage collector-electrode structures comprised by the members 17 and 18 are provided. As best seen in FIGURES 1 and 3 of the drawings, the two-stage collector-electrode structures comprise two sets or stacks of some 10 or 12 shaped collector-electrode members 17 and 18. The number of stages and members depend, of course, upon the size of the unit required to handle a given volume of flue gas or air being treated, and as mentioned previously it is not essential to employ multiple stages at all for in many applications a single long stage will be the most efficient arrangement. The stacks of individually shaped collector-electrode members are held together in assembled relation one over the other by means of a pair of movable end plates 25 and 26 secured to opposite ends of the shaped collector-electrode members 17 and 18 in a manner such as to provide openings between the plates to allow for removal of dirt particles from the plates. The cross-section of the individual collector-electrode members 17 or 18 is gradually tapered outward as it proceeds downstream, and is tapered only along its width and not its length. They are sufficiently long to extend across the width of the collector chamber 12 and the width of one of the cleaning areas 13 or 14. Hence, while one-half of the collector-electrode assembly is disposed in working position in the collecting chamber 12, the other half will be positioned in either one or the other of the cleaning chambers 13 or 14.

The cross-sectional configuration of the individual collector-electrode members 17 is best seen in FIGURE 4 of the drawings. Each of the shaped collector-electrode members 17 is fabricated from an electrically conductive material, and assuming the front or upstream end of the collector assembly to be adjacent the perforated pipes 21, then the individual collector-electrode member 17 is shaped so that it tapers outwardly gradually extending from the front or upstream end to the rear or downstream end. This outwardly tapering configuration of the individual collector-electrode members causes the space between the several members to gradually decrease in cross-section so as to effectively increase the velocity of the fluid medium flowing past these members and thereby force the fluid medium to maintain its non-turbulent or streamline flow condition. The reasons for thus shaping the individual collector-electrode member 17 in this manner may best be appreciated from the following discussion.

In most industrial precipitators, due to conditions inherent in their design, the construction is such that turbulent flow conditions prevail for the fluid medium as it travels through the precipitator. Turbulent flow conditions impart a random particle trajectory in the collecting region of the precipitator which leads to a theoretical expression for the collecting efficiency of the precipitator as set forth by the following equation:

$$\text{Eff.} = 1 - e^{-\frac{A}{q} ME} \quad (1)$$

where

$A$ =collecting electrode member area in ft.<sup>2</sup>  
 $q$ =volume flow rate in cubic ft./min.  
 $M$ =particle mobility ft./sec.·volt/ft.  
 $E$ =electric field gradient volts/ft.  
 $e$ =base of the natural logarithm.

If a plot of efficiency versus precipitator size were made for a precipitator employing turbulent flow conditions as defined by Equation 1, the plot would be exponential in character as shown in FIGURE 5 requiring almost an infinite size precipitator to approach 100% efficiency. On the other hand, for laminar or streamline flow conditions, a precipitator can be designed which will collect all particles of a given size with an efficiency of 100%. The efficiency of such a laminar or streamlined flow precipitator is expressed by the following equation:

$$\text{Eff.} = \frac{MEL}{vh} = \frac{MELW}{q} = \frac{A}{q} ME \quad (2)$$

where

$v$ =fluid flow velocity in ft./sec.

$L$ =length of collecting electrode members in ft.

$W$ =width of collecting electrode members in ft.

$h$ =plate separation in ft.

The plot of the efficiency versus size of a precipitator unit designed to collect a given size aerosol particle for both streamline and turbulent flow conditions is shown in FIGURE 5 of the drawings. From an examination of Equations 1 and 2, it can be determined that the efficiency of a precipitator unit operating under streamline flow conditions is numerically equal to the exponent of the efficiency expression for the same unit operating under turbulent flow conditions. From this fact, and from an examination of the plot shown in FIGURE 5, it can be appreciated that a precipitator designed to operate at 100% efficiency under streamline flow conditions would immediately drop to 63% efficiency at the onset of turbulent flow conditions. Theoretically, 100% efficiency could never be achieved under turbulent flow conditions. Further, it can be seen that the turbulent flow precipitator must be doubled in size to increase efficiency from 63% to 87%, and to achieve 99.9% efficiency it requires a nine-fold increase in the size of the plate area and precipitator. Hence, the size of a precipitator employing turbulent flow conditions must be increased by large factors to achieve even incremental increases in efficiency. Most present day industrial electrostatic precipitators are required to produce the high efficiencies in the range of 99-99.9%, and to achieve these efficiencies they range in size sometimes as large as 50' x 50' x 180'. Accordingly, it can be appreciated that considerable gain in efficiency can be achieved from the elimination of turbulent flow conditions through the precipitator. This is achieved in the precipitator provided by the present invention by proper shaping of the cross-sectional configuration of the shaped collector-electrode members 17 and 18. This accomplishes streamline flow conditions by forcing the flow of the fluid to become streamline at a high fluid velocity by decreasing the spacing between the collector-electrode members as the fluid proceeds downstream through the collector members. Hence, the flow cross-section is decreased with a proportional increase in the flow velocity to thereby achieve laminar or streamline flow conditions. It is, of course, necessary that the entrance sections to each of the collector-electrode members be designed to provide optimum reduction of turbulence to help achieve streamline flow between the members. In this manner, it is possible to build a precipitator in accordance with the linear efficiency conditions specified by Equation 2 which has an efficiency in the region of 99% or better, and at the same time reduces the size of the precipitator by a substantial factor. Additionally, it should be noted that in order to assure proper flow of the fluid medium being cleaned through the precipitator, the trailing or downstream end sections of each of the collector-electrode members, indicated at 28 in FIGURE 4, are converged inwardly so as to produce an increase in the cross-section of the flow medium at this point to thereby recover some of the pressure drop occurring in the fluid medium as it passes through the collecting area of the collector electrode members. Further, in order to help maintain streamline flow

conditions, if desired, a number of small openings may be made along the leading edges of the electrode members, and in other critical spots on the surface of the collector-electrodes for air removal purposes. As will be explained more fully hereinafter, the inside of the collector-electrode members is pumped out at a very slow rate so that small amounts of air are removed from the exterior surfaces of the collector electrode members at selected points. The removal of this air then contributes to maintaining streamline flow conditions in the fluid medium as it flows past the electrode members.

In addition to the above features, the collector-electrode structure further includes a plurality of planar electrode members 29 which, as is best shown in FIGURE 4 of the drawings, are positioned intermediate each of the shaped collector-electrode members 17. The planar electrode members 29 are fabricated from an electrically conductive material and are maintained at approximately equal to or at a higher electric potential having the same polarity as the potential applied to the flame charging source 15. The shaped collector-electrode members 17 are maintained at ground potential preferably or at a potential of opposite polarity to that applied so as to enhance or increase the field gradient across the cross-section of the channel through which the fluid medium must travel. As can be readily determined from an examination of Equation 2, the precipitator collection efficiency is also a function of the field gradient as well as the length and width of the collecting plate so that by increasing the field gradient in this manner, collection efficiency is further enhanced. The electric circuitry for applying the electric potential to the planar electrode members 29 and flame charging sources 15 and 16 is not shown since it is conventional in nature.

The planar electrode members 29 are mechanically held in position within the collector-electrode structure by a pair of side supports 31 which are secured between the top and bottom of the outer casing 11. The planar electrode members 29 are secured within suitable bushings fastened to indentations in the supports 31 as shown in the partial cutaway view in FIGURE 7. The supports 31 have openings formed therein which are shaped to provide for movement of the shaped collector-electrode members 17 as a stack through the supports into the cleaning areas 13 or 14. It should be noted that while the electrode members 29 are described as planar, it is possible for these surfaces also to be given a tapering configuration so as to contribute to maintaining streamline flow conditions. For that matter, it is possible that the collector members 17, 18 and the planar members 29 be shaped so long as the cross-section of the fluid flow path is gradually decreased in the collecting region to enhance streamline flow of the fluid through the region.

In order to move the portion of the collector-electrode structure comprised by the collector-electrode members 17 and the end plates 25 and 26 through the supporting members from the collecting chamber 12 to either one or the other of the cleaning chambers 13 or 14, the end plates 25 and 26 are each provided with a set of rollers 30 which ride on a set of rails 32 secured within both cleaning chambers 13 and 14. To cause this portion of the collector-electrode structure to be moved into the cleaning chamber 13, for example from the collecting chamber 12, a pair of electric drive motors 33 and 34 are provided. As is best shown in FIGURE 3, each of the motors is connected to a shaft having a pair of spools 35 secured to each end around which a cable 36 is wound. The cable 36 is pulled off through a pair of pulleys 37 and secured to a respective side of the collector-electrode structure at 38. By reason of this arrangement, no unbalance or twisting of the structure will occur as the collector-electrode members are moved into or out of the cleaning chambers. In operation, the motors 33 or 34 will be alternately started and stopped and run at a very slow speed so that the collector-electrode

trode members 17, 18 are continuously moving from the collecting chamber 12 into or out of one of the cleaning chambers 13 or 14. Since the collector-electrode members are approximately twice the width of the cleaning chambers, it is assured that there will be an area of the collector-electrode members which recently has been cleaned located in working relationship in the collecting chamber 12.

A suitable control switching arrangement for actuating the motors 33 and 34 is shown in FIGURE 6 of the drawings. This arrangement includes a source of electric power 41 which is connected to either one of the motor 33 and 34 through an associated switching system. The switching system for motor 33 includes a spring biased normally closed switch 42, and a spring biased normally open switch 43, which is held in a closed position by a solenoid winding 44 upon energization. Power is similarly supplied to the motor 34 through a spring biased normally closed switch 45, and a spring biased normally open switch 46 acted upon by a solenoid winding 47 upon energization to maintain switch 46 in the closed position. By this arrangement, upon the collector-electrode members 17 reaching the end of their travel into the collecting chamber 13, as shown in FIGURE 2 of the drawings for example, the normally open switch 43 will be closed temporarily and normally closed switch 45 will be temporarily opened. Opening of the switch 45 de-energizes holding coil 47 so as to release the normally open switch 43 and allows the spring to bias switch 43 open thereby de-energizing the motor 34. Concurrently, closure of the normally open switch 43 energizes holding coil 44 so that power is supplied through switch 43 to motor 33. Upon this occurrence, motor 33 will take up wire 36 onto the spool 35 so as to pull the collector-electrode members back from the position as shown in FIGURE 2 causing that portion which was in the cleaning chamber to enter into the collector chamber 12, and that portion of the collector structure which had been in the collector chamber 12 to be moved into the opposite cleaning chamber 14. Upon reaching the end of its travel into the cleaning chamber 14, the reverse procedure occurs with respect to the control circuit of FIGURE 6, in that the normally open switch 43 will be closed temporarily thereby energizing the holding coil 47 to turn on motor 34. Motor 34 then draws in the cable 36 onto spool 35 and causes it to pull the electrode members back in the reverse direction into cleaning chamber 13. Concurrently, the normally closed switch 42 is opened thereby de-energizing the holding coil 44, and allowing the spring to bias switch 43 open, cutting off power to the motor 33. The control circuit operates in this fashion to cause the two halves of the collector-electrode members 17 or 18 to be continuously oscillated between one of the cleaning chambers 13 or 14 and collecting chamber 12 at a very slow rate.

Concurrently, with the action of drawing the collector-electrode members 17 or 18 into the collecting chambers 13 or 14, a plurality of rotary brushes shown at 51 operate on the external surfaces of the shaped collector-electrode members to brush these surfaces clean of any deposited matter adhering them. The rotary brushes 51 are rotatably mounted on each side of the collecting chamber 12, and are positioned in a manner such that in withdrawing the collector members into either of the cleaning chambers 13 or 14, the individual shaped collector-electrode members 17 will pass between two sets of rotary brushes 51 thereby assuring that the external surfaces of all of the collector-electrode members 17 will be cleaned during each cleaning cycle. Each of the rotary brushes 51 is shafted to a respective sprocket wheel which is driven from a common chain 52 that is mechanically linked over a drive sprocket wheel 53 shafted to a drive motor 54. It is anticipated that while the precipitator is in operation, the motor 54 will be running continuously thereby driving the rotary cleaning brushes 51 continuously throughout the operating period of the precipitator.

Solid matter brushed from the surfaces of the electrode members will drop down into the hoppers (not shown) attached to the bottom of the cleaning chambers 13 and 14. In addition, openings 61 are provided near the bottom of each of the cleaning chambers 13 and 14 and suction motors 62 are attached to these openings for removing the air from the cleaning chambers. These suction motors will also have the effect mentioned on page 10, line 5, of removing small amounts of air from the exterior surface of the collector electrode members. Because this air will have considerable amounts of dust, soot, dirt, etc., entrained in it, the discharge ends of the suction pumps may be connected back to the input side of the precipitator unit upstream from the flame charging source 15.

When placing the precipitator in operation, the electric drive motors 33 and 34 are energized through the switching control system shown in FIGURE 6 to cause the collecting electrode members 17 and 18 to be continuously moved back and forth between the cleaning chambers 13 and 14, and the collecting chamber 12. The motors 54 driving the rotary brushes 51 are also energized so that the exterior surface of the shaped collector-electrode members 17 or 18 are continuously cleaned as the portions of the members pass into and out of the cleaning chambers 13 and 14. A gaseous fuel is then supplied through the supply pipes 22 and 23 to the perforated flame sustaining pipes 21, and the fuel emitting from the perforations in the pipes is ignited by a suitable pilot light source not shown. Simultaneously, electric potentials are applied to the flame charging source comprised by the perforated pipes 21, and to the planar electrode members 29, it being assumed that the shaped collector-electrode members 17 or 18 are adequately grounded to the outer casing 11. The flue gas or other fluid stream being treated is then introduced into the precipitator, and flows first past the flame charging source 15 or 16 and hence through the cross-section of the collecting area defined by the shaped collector-electrode members 17 or 18 and the planar electrode members 29. The upstream or leading edge of the collector-electrode members and the planar electrode members 29 are curved so as to reduce turbulent flow of the fluid stream, and the gradually reducing cross-sectional area through which the fluid passes causes its velocity to increase to a point which turbulence does not develop, hence the fluid is allowed to flow through the collecting region under streamline flow conditions. In passing through the flame charging source 15 the smoke, soot, and other undesired airborne aerosol particles contained in the fluid stream will be charged by collision with the small ions being propelled from the flame charging source so that essentially all of the aerosol particles will receive an electric charge having the polarity of the potential applied to the flame charging source. Upon passing into the collecting region where streamline flow conditions are maintained, these charged airborne aerosol particles will be acted upon by the electric field gradient existing between the shaped collecting electrode members 17 and the planar electrode members 29. The field gradient will cause the charged airborne aerosol particles to be attracted to the shaped collector-electrode members where they will adhere to the surface of the members until such time that the member is moved into a cleaning area where they will be mechanically brushed away by the rotary brushes 51. Because the shaped collector-electrode members 17 or 18 are being continuously cleaned by the rotary brushes 51, the build up of aerosol particles on the surfaces of the collector members 17 or 18 is never sufficiently great to allow an arc over to occur between the planar electrode members 29 and the shaped collector-electrode members. Further, because of forcing the fluid stream in the collecting electrode area to maintain laminar or streamline flow conditions, it is possible to precipitate out essentially all of the undesired aerosol airborne particles of

a given size with an efficiency approaching 100%. This is made possible even though only relatively small collector-electrode members and a small electric field gradient are required when compared to existing electrostatic precipitator elements.

From the foregoing description it can be appreciated that the invention provides a new and improved electrostatic precipitator which is extremely compact in design for a given efficiency rating and further requires relatively low electric potentials in operation in contrast to existing precipitator designs of equivalent efficiencies. It is, therefore, to be understood that other modifications and variations of the invention are possible in light of the above teachings. Hence, changes may be made in the particular embodiment of the invention described which are within the full intended scope of the invention as defined by the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An airborne aerosol particle precipitator comprising a collector-electrode structure adapted to be disposed in a fluid stream and comprised by a stack of shaped collector-electrode members fabricated from an electrically conductive material and having the outer surfaces gradually tapering outwardly from the upstream edge to the downstream edge whereby the spaces between the several shaped collector members gradually decrease in cross-section from the upstream edge to the downstream edge thereby maintaining non-turbulent flow of a fluid medium through the stack of collector members, a plurality of planar electrode members each one being disposed intermediate the shaped collector-electrode members, a flame charging source positioned upstream from said collector-electrode structure and comprising a plurality of perforated pipes supported from gaseous fuel supply mains in a manner such that there is at least one pipe disposed in each of the spaces between the shaped collector-electrode members, and means for maintaining the flame charging source and said planar electrode members at a potential different from the potential of the shaped collector-electrode members.

2. The combination set forth in claim 1 further characterized by means for temporarily moving at least a portion of said stack of shaped collector-electrode members out of the fluid stream and into a cleaning area, and a plurality of rotatable brushes positioned in said cleaning area for brushing clean the outer surfaces of shaped collector-electrode members as the same are moved into and out of said cleaning area.

3. The combination set forth in claim 1 wherein said shaped collector-electrode structures at the downstream end are sharply converged inwardly to recover the pressure drop occurring in the fluid medium being cleaned while passing through the collector-electrode structure.

4. A particle precipitator comprising a source of electrically charged particles adapted to be positioned in a fluid stream, and a collector-electrode structure positioned downstream from said source for collecting the particles charged by said source of charged particles, said collector-electrode structure comprising a plurality of collector-electrode members shaped to provide a flow path through the collector-electrode members which has a gradually decreasing cross section to thereby continuously enforce the particle bearing fluid medium into a non-turbulent flow condition through substantially the full length of the collector-electrode structure, certain ones of said collector-electrode members being maintained at a predetermined electric potential different from the potential of the source of electrically charged particles, and the remaining collector-electrode members being maintained at a predetermined electric potential different from the potential of said certain ones of said collector-electrode members.

5. The combination set forth in claim 4 further characterized by means for moving certain ones of said collector-electrode members temporarily out of the fluid stream and into a cleaning area, and means operative upon



the collector-electrode members reaching the cleaning area to clean the outer surfaces of the collector-electrode members.

6. An aerosol particle precipitator including in combination a flame source of charged particles adapted to be located in a particle bearing fluid stream, and a collector-electrode structure positioned downstream from said flame charging source for collecting the particles charged by said flame source comprising a plurality of spaced-apart collector-electrode members shaped to provide a flow path through the collector-electrode members which has a gradually decreasing cross-section to thereby continuously enforce the particle bearing fluid medium into a non-turbulent flow condition through substantially the full length of the collector-electrode structure, and means for maintaining the electric potential of said flame charging source at a different value from the electric potential of at least certain ones of said collector-electrode members.

7. The combination set forth in claim 6 further characterized by means for moving at least a portion of the collector-electrode members having a polarity different

from the flame source temporarily out of the fluid stream and into a cleaning area, and cleaning means operative upon said collector-electrode members reaching the cleaning area to clean the outer surfaces of said members.

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