

- [54] **CENTRIFUGAL AIR CLEANER WITH
STATIC CHARGE DISSIPATING
STRUCTURE**
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55/457, 161/170, 260/41 B, 260/DIG. 15,
264/140, 317/2 J**
- [51] Int. Cl.**B01d 45/14**
- [58] Field of Search.....55/360, 396, 435, 457;
161/170; 260/41 B, DIG. 15; 264/140; 317/2
J

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[57] **ABSTRACT**

A tubular member is provided with means, such as vanes, to swirl air passing therethrough to centrifugally separate particles from the air. The tubular member and means are injection molded from plastic, preferably polypropylene, having aluminum or equivalent fibers well dispersed therein to dissipate through the walls of the tubular member the static charge being formed by the impact of randomly charged airborne particles on the inner wall surface thereof.

10 Claims, 2 Drawing Figures

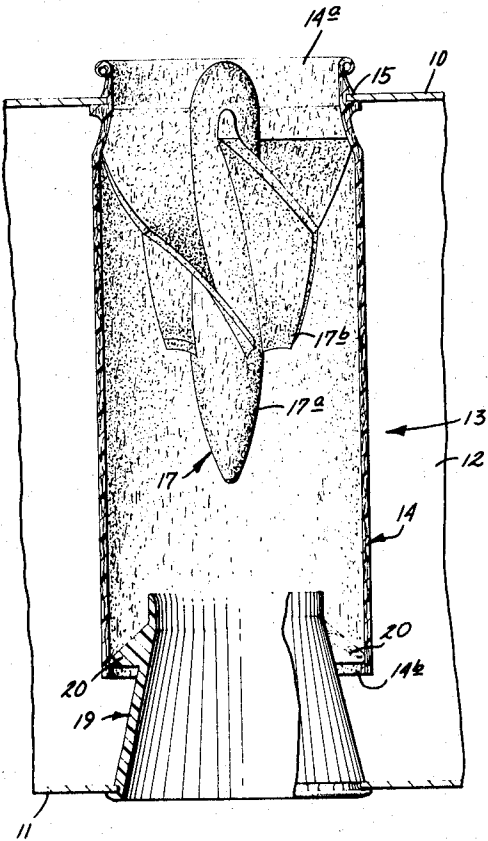


FIG. 1

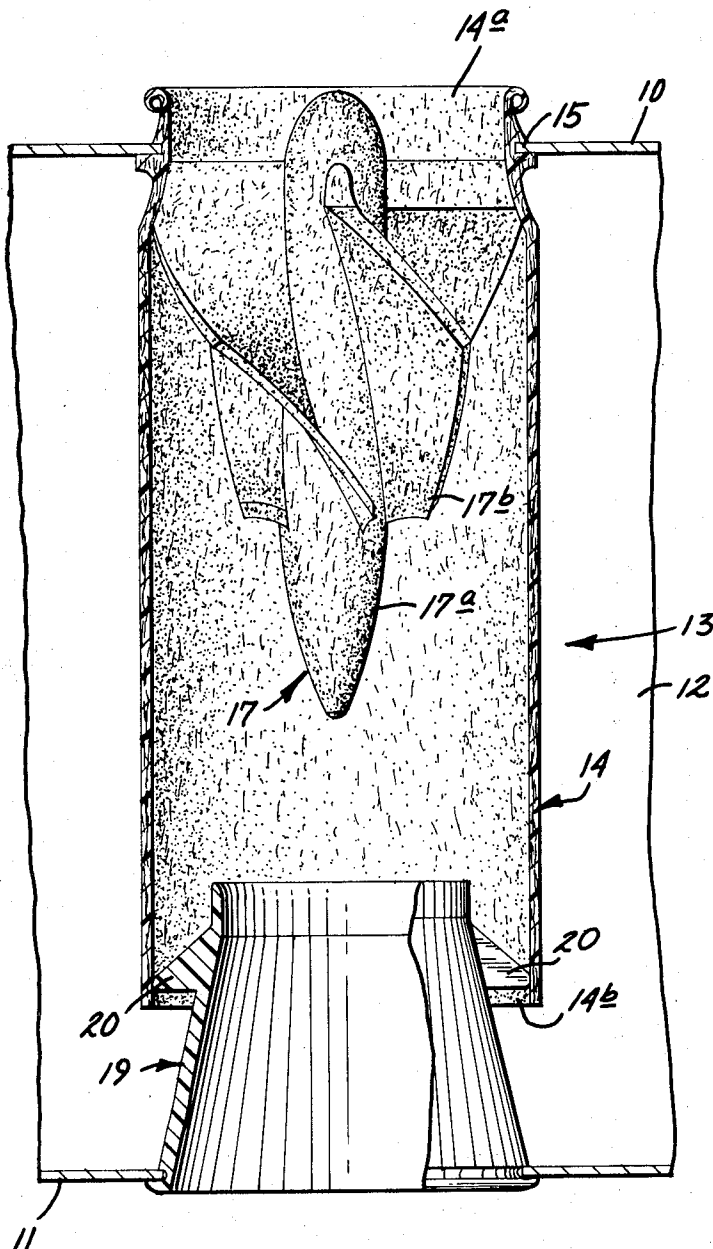
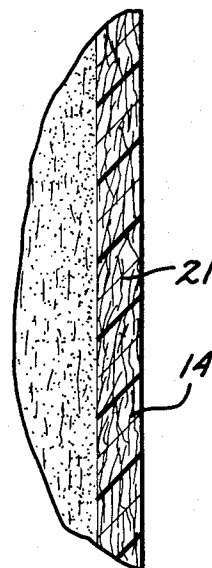


FIG. 2



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CENTRIFUGAL AIR CLEANER WITH STATIC CHARGE DISSIPATING STRUCTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to the construction of centrifugal separators and more particularly relates to an injection molded plastic separator having conductive material mixed therein to dissipate the static charge that is normally developed on a plastic part by the impact of charged airborne dust particles.

2. Description of the Prior Art

Centrifugal separators have long been used to separate unwanted materials from fluids. In particular, centrifugal-type air cleaners are commonly used with engines to eliminate the heavier dirt particles from air being used by the engine. The L. J. Olson et al. U.S. Pat. No. 3,383,841 that issued May 21, 1968 discloses a plurality of centrifugal filter elements mounted upstream from a dry-type filter to remove the larger dirt particles from the air stream. The D. R. Monson et al. U.S. Pat. No. 3,517,821 that issued June 30, 1970 discloses an improved vane construction for use in centrifugal separators of this kind. In the Shohet et al. U.S. Pat. No. 3,449,891 that issued June 17, 1969, centrifugal separators of this kind are used to clean the air entering the engine of an aircraft.

In the prior art, these separators have been constructed from a metal such as aluminum. If the tubular member and vanes of the separator are constructed from aluminum, which is an efficient electrical conductor, there is virtually no build-up of a static electrical charge on the separator because the aluminum conducts the static charge out of the tube interior as fast as it is generated. A static charge on the interior wall surface of the tube is undesirable because it tends to repel the larger dirt particles, preventing many of them from reaching the wall surface from which they are later scavenged. It has been recognized that a separator designed to rapidly dissipate static charges is much more efficient than a separator in which static electrical charges are allowed to develop.

In aircraft applications, however, it has been unfeasible to use aluminum tubes because of excessive weight, high costs and some tube retention problems. The weight, cost and retention problems were solved by constructing the tubes and vanes from polypropylene. However, it took several years to recognize why separators constructed from plastic were not efficient as metal tubes. It was eventually discovered that it was because of the development of a static electrical charge. Therefore, our problem was to design a separator that would retain the desirable features of the plastic separator, such as light weight, low cost (because of low cost material and high production rate), flexibility over a wide temperature range and good abrasion resistance, while at the same time providing means to conduct static charges away at a rapid rate to maintain the necessary high efficiency. We were aware that conductive floor tiles had been used in hospitals and in plants which manufacture explosives to prevent static discharges. In the Slosberg et al. U.S. Pat. No. 3,386,001 that issued May 28, 1968, carbon black is used as a conductive medium in a floor coating of plastic chips. In the Abegg et al. U.S. Pat. No. 3,121,825 that issued Feb. 18, 1964, the floor

covering employs aluminum metal powder. Carbon black and aluminum powders have also been used in Teflon fuel tubing as shown in the Rowand et al. U.S. Pat. No. 3,166,688 that issued Jan. 19, 1965. We were also aware that compression molded floor tiles containing long strands of aluminum yarn had been used to prevent static charges from building up. We soon became aware, however, that prior art anti-static plastics were not effective in inertial separators where static charges are continuously present. In particular, we found that the prior art techniques and compositions used in manufacturing compression molded floor tiles were wholly inadequate to produce an injection molded anti-static plastic separator retaining the above desirable features. We found that none of the commercially available anti-static agents or chemical additives, such as graphite, provide surface or volume resistivity properties approaching that of a desirable metal such as aluminum. An inertial separator injection molded from a plastic material containing such additives was incapable of dissipating the static charge quickly enough to provide a separating efficiency comparable to that of an aluminum separator. It was not possible to even test the concept of using aluminum yarn because the long aluminum fibers became entangled in the feeders and nozzles of the injection molding equipment. It quickly became apparent that the prior art teachings were wholly inadequate to solve the problem with which we were faced. We then considered such alternatives as plating the polypropylene parts. However, this possibility was ruled out because of the limited erosion life of a plated part, because of part distortion occurring during the plating process and because of excessive plate build-up that would occur on sharp edges. We then decided that it would be necessary to depart from the teachings of the prior art and devise a new anti-static plastic combination that would retain the necessary mechanical and electrical properties and that could be manufactured in production quantities by injection molding equipment.

SUMMARY OF THE INVENTION

To our knowledge, there is no teaching in the air cleaner art of any satisfactory solution to the problem of static charge build-up in inertial separators, and the teachings of the non-analogous prior art previously described herein provided no solution to the problem we faced. We discovered that short, extremely fine aluminum filaments or fibers could be successfully mixed with polypropylene and thereafter injection molded into the necessary form while retaining the necessary electrical and mechanical qualities. We also found that in order to obtain maximum conductivity, it is necessary to sand blast or otherwise abrade the plastic part after the injection molding operation so that the fibers are exposed. The exposed fibers apparently alter the surface resistivity of the plastic part to a level close to that of the metal part, since the resulting efficiency is nearly that for an all-aluminum tube. For best results, the inlet tube and vane (if any) of the separator should be constructed in accordance with the invention. The outlet tube can continue to be made from any desirable material.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an enlarged fragmentary section of an air cleaner employing an inertial separator constructed according to the present invention; and

FIG. 2 is a further enlarged sectional view of a portion of the cylindrical wall of the separator shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

There is disclosed in FIG. 1 an air cleaner subassembly including spaced, generally parallel wall portions 10 and 11 defining a scavenging chamber 12 between them. A centrifugal separator 13 is mounted between wall portions 10 and 11. Separator 13 includes a first tubular member 14 having a generally cylindrical wall with inner and outer wall surfaces, and having an air inlet end 14a and an air outlet end 14b. The outer surface of the air inlet end 14a is provided with a peripheral groove 15 that engages the edge of a circular opening in wall portion 10, as shown. Because tubular member 14 is constructed from a plastic material, its upper end can be snapped into the opening in wall portion 10 to lock the separator in place by means of groove 15.

A deflecting element 17 is mounted within tubular member 14 adjacent air inlet end 14a. Deflecting element 17 is provided with a coaxially located hub member 17a and a plurality of curved vanes 17b that extend between hub portion 17a and the inner wall surface of tubular member 14. As the air passes downwardly through tubular member 14, deflecting element 17 produces a swirling motion causing the air or fluid stream to rotate in a spiral fashion as it continues in its passage through the tubular member 14.

As the fluid passing through the centrifugal separator swirls, the larger dirt particles or other heavy materials are thrown outwardly against the inner wall surface of tubular member 14.

A second tubular member 19 has a substantially smaller diameter than first tubular member 14 and is mounted coaxially in the outlet end 14b of tubular member 14. Second tubular member 19 is provided with a peripheral groove 20 adjacent its lower end that snaps into a circular opening in wall portion 11. The upper end of second tubular member 19 is provided with a plurality of spacer members 21 that extend between its outer wall and the inner wall surface of tubular member 14 to hold member 19 in a coaxial relationship with member 14.

Again, the swirling motion provided by deflecting element 17 causes the heavier particles to be thrown outwardly to pass out of the tubular member 14 at the outlet end 14b thereof between the tubular member 19 and the tubular member 14, to be discharged into scavenging chamber 12. The cleaner fluid at the center of tubular member 14 passes downwardly and out through the center of second tubular member 19. In actual practice, a plurality of these centrifugal separators are normally mounted between the wall portions 10 and 11 and large quantities of air are drawn through them to provide intake air for an engine. A continuous separating action is provided. In many applications, a scavenging pump is provided to draw the dirty air out of the scavenging chamber 12.

The separator shown in the drawing can be described as an axial flow, straight through inertial separator. It is typical of the many different tubular type inertial separators. Separators of this type may employ vanes or other deflecting means or may employ a tangential inlet to swirl the air. The air flow may be axial and straight through as shown, or it may enter tangentially, reverse direction and then leave axially. Reverse flow type centrifugal separators with deflecting means are shown in the Baden et al. U.S. Pat. No. 2,907,406, and the Copp et al. U.S. Pat. No. 2,889,008. The present invention is applicable to all known types of tubular type inertial separators.

If the tubular member 14 and the deflecting element 17 are constructed from aluminum, no static electricity build-up occurs because of the high conductivity of the metal. If the elements of the separator are constructed from plastic, however, the airborne dust continuously passing through the separator causes a static charge to build up on the inner wall surface of tubular member 14 and on the various surfaces of deflecting element 17. This static charge repels the larger dirt particles and causes more of them to pass through tubular member 19 rather than between it and member 14.

To overcome this problem, we have injection molded the tubular member 14 and the deflecting element 17 from an anti-static plastic material comprising short aluminum fibers in polypropylene so that the static electrical charge is rapidly and continuously dissipated. We have found that with this construction, most of the static charge is conducted out of the tube interior as fast as it is generated. There is no need to provide a ground for the exterior of the separator as the static charge is conducted away from the interior wall to a point where it no longer affects efficiency.

We have found that the best plastic material is polypropylene although other injection moldable thermoplastic materials could be used as well. The best electrical properties have been achieved with a 20 percent by weight mixture of $0.005 \times 0.005 \times 0.125$ inch aluminum filaments. Although the volume resistivity of this heterogeneous mixture is high, the fibers apparently alter the surface resistivity to a level close to that of the metal itself, because the efficiency of this mixture is nearly that for an all-aluminum tube.

The preferred method of constructing the separator is to first thoroughly mix the proper proportions of the dry plastic powder and the aluminum fibers. The mixture is then forced through a screw-type extruder and chopped into small pellets. These pellets are then used to feed a screw-type plastic injection molding machine to actually form the tubular member 14 and the deflecting element or vane means 17. Before assembly, the resulting part or parts are sand blasted or tumbled to remove an outer plastic skin that forms during the injection molding operation. This abrading step removes the outer skin and exposes the fibers. It is necessary to expose the fibers on the inner surface of the tube but it is not necessary to expose them on the outer surface. After the abrading step is completed, the separator is assembled as shown in FIG. 1. Preferably, both the tubular member 14 and the deflecting element 17 are constructed from the anti-static plastic material, but the outlet tube 19 can be made from any desirable material.

As shown in FIG. 2, the filaments, designated by the numeral 22, tend to align themselves with the flow of the material during the injection molding process. The drawing of FIG. 2 is not according to scale.

It is difficult to establish exact workable size ranges for the aluminum fibers. The length of the aluminum fibers is limited by the fact that the longer fibers tend to become jammed in the injection molding equipment. The preferred length of the fibers is between one-eighth inch and one-fourth inch. If the fibers are shorter than one-eighth inch long, they tend to be less effective in dissipating the electrical charge. If they are longer than one-fourth inch, they tend to clog the presently existing injection molding equipment.

As previously mentioned, the best results have been achieved by using $0.005 \times 0.005 \times \frac{1}{8}$ inch aluminum fibers. The cross-sectional area of these fibers is thus 25×10^{-6} square inches. We have found that the best results are achieved by the smallest cross-sectional area, but if the fibers are too small in cross section they tend to get broken in the blending and molding processes. This shortens the average fiber length thus requiring that more fibers be added to insure adequate electrical properties. On the other hand, too large a fiber also requires that a larger weight of fiber be added to obtain the desired electrical properties. This destroys the physical properties of the material, making it too brittle or crumbly to be used in the manufactured product. It also undesirably increases the weight of the part, increases its cost and makes it more difficult to mold. We have found that the minimum usable cross-sectional area of the fibers is approximately 9×10^{-6} square inches. Further, the cross-sectional area of the fibers should not exceed 36×10^{-6} square inches, otherwise too much weight will be added. For example, with the optimum $0.005 \times 0.005 \times \frac{1}{8}$ inch fibers, 20 percent by weight of aluminum fibers is the minimum fibers that should be added to obtain the best efficiency. Adding additional fiber does not appreciably increase the efficiency but it does add undesirable weight to the part.

Although aluminum fibers are presently preferred, other fibers can be used if their effective resistivity is less than or similar to that of aluminum. For example, graphite fibers plated with aluminum can be used. Graphite fibers are lighter, smaller in diameter and stronger than metal fibers (thus less weight of a lower density additive is needed) and they can be plated with aluminum while bundled as a yarn, then mixed with plastic by the same techniques by which glass fiber reinforced plastic pellets are made. This is made possible by the new Dow Electroless Aluminization Process (U.S. Pat. No. 3,462,288). Silver coated fibers could also be used.

Our invention provides a material that has an effective volume or surface resistivity that is several orders of magnitude lower than any of the mixtures described in the prior art patents we have seen. In addition, the desirable physical properties of the original plastic part are adequately retained. Our anti-static plastic blend can continuously dissipate a static charge from the separator interior at a rate sufficient to give separation efficiencies approaching that of an aluminum tube. The old conducting plastic mixtures that made use of graphite, carbon black, organic semi-conducting powders

or liquids, and powdered metals such as aluminum, are completely inadequate to solve the static charge problem we faced. To our knowledge, none of the prior art anti-static plastic compositions can meet the needs of this application. Without the present invention, it would be necessary to construct the tubes from aluminum, making the resulting air cleaner much too heavy for many applications.

What is claimed is:

1. In a centrifugal separator including a tubular member and means to swirl fluid passing therethrough to centrifugally force solid materials carried by said fluid against the inner wall surface of said tubular member to aid in separating said materials from said fluid, the improvement comprising said tubular member being an injection molding of a moldable plastic having particles of conductive material well dispersed therein to immediately and continuously dissipate through the walls of said tubular member the static charge being formed on the inner wall surface by the impact of said solid materials thereon.
2. The apparatus of claim 1 wherein said means to swirl fluid is a deflecting element, said element being an injection molding of the same plastic-conductive material mixture from which said tubular member is molded.
3. The apparatus of claim 1 wherein said conductive material comprises conductive fibers, the effective resistivity of which is less than or equal to that of aluminum fibers.
4. The apparatus of claim 3 wherein said fibers have a large length/diameter ratio but are short enough to be injection moldable without clogging the injection molding equipment.
5. The apparatus of claim 3 wherein the fibers are exposed on the inner wall surface of said injection molded tubular member.
6. The apparatus of claim 3 wherein the fibers are aluminum fibers and wherein the proportion of fibers to plastic is at least 20% by weight.
7. The apparatus of claim 6 wherein said fibers have a cross-sectional area between approximately 9×10^{-6} square inches and 36×10^{-6} square inches and wherein the fiber length is between approximately one-eighth and one-fourth inches.
8. The apparatus of claim 7 wherein said fibers are approximately $0.005 \times 0.005 \times \frac{1}{8}$ inch in size.
9. The apparatus of claim 3 wherein said plastic is polypropylene and said fibers are aluminum fibers.
10. A centrifugal separator designed to remove dirt particles from the air, comprising:
 - a. a tubular member having a generally cylindrical wall with inner and outer wall surfaces, an air inlet and an air outlet;
 - b. means mounted in said tubular member adjacent said air inlet to impart a spiral motion to air passing through said tubular member to centrifugally force said dirt particles against said inner wall surface;
 - c. means on said air outlet to separately channel away said peripherally located dirt particles and the centrally located stream of cleaner air; and
 - d. said tubular member being an injection molded thermo-plastic part having homogeneously mixed therein a predetermined proportion of conductive

fibers, some of said fibers being exposed on the inner wall surface to immediately and continuously dissipate through the wall the static charge being developed on said inner wall surface by the impact of randomly charged airborne dirt particles thereon.

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