United States Patent [19]

Anderson

[11] **3,823,602**

[45] **July 16, 1974**

[54] **SAMPLING DEVICE**

[75] Inventor: **Paul L. Anderson,** Pleasanton, Calif.

[73] Assignee: **Kaiser Aluminum & Chemical Corporation,** Oakland, Calif.

[22] Filed: **Nov. 20, 1972**

[21] Appl. No.: **307,772**

[52] **U.S. Cl.** ..... **73/28,** 73/432 PS, 55/270

[51] **Int. Cl.** **G01n 15/00**

[58] **Field of Search** ... 73/28, 421.5 R, 424, 432 PS; 55/270; 209/135

[56] **References Cited**

UNITED STATES PATENTS

2,926,783	3/1960	McGinn	209/135
2,932,394	4/1960	McGinn	73/432 PS X
2,956,434	10/1960	Donoghue	73/432 PS
3,074,627	1/1963	Goetz	73/432 PS
3,237,455	3/1966	Slater	73/432 PS

FOREIGN PATENTS OR APPLICATIONS

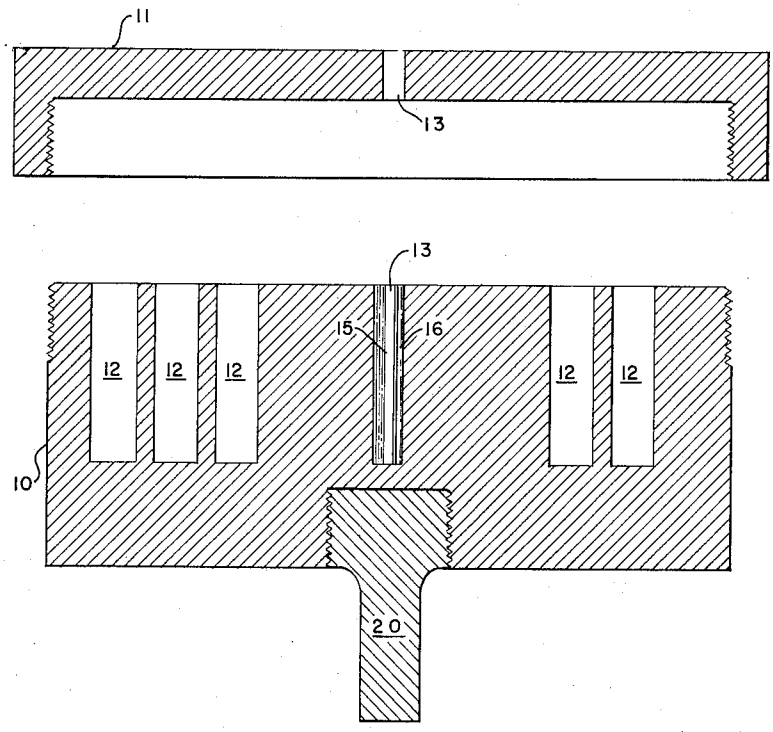
740,128	11/1955	Great Britain	209/135

Primary Examiner—Richard C. Queisser
Assistant Examiner—Stephen A. Kreitman
Attorney, Agent, or Firm—Paul E. Calrow; Edward J. Lynch

[57] **ABSTRACT**

An improved centrifuge sampling device for the capture and size segregation of particles less than 2 microns in diameter from a fluid containing same. The device comprises a rotating body and cap which define a spirally shaped conduit having from 1.5 to about 2.5 convolutions. The particulate-laden fluid as sampled is split by the sampler into a large stream and a small stream. The large stream is directed to the beginning of the spiral conduit where entrained particles are removed by centrifugal forces. The smaller stream is introduced into the larger stream contained in the spiral conduit when substantially all particulate matter has been removed from the larger stream and the flow has been rendered laminar.

9 Claims, 2 Drawing Figures



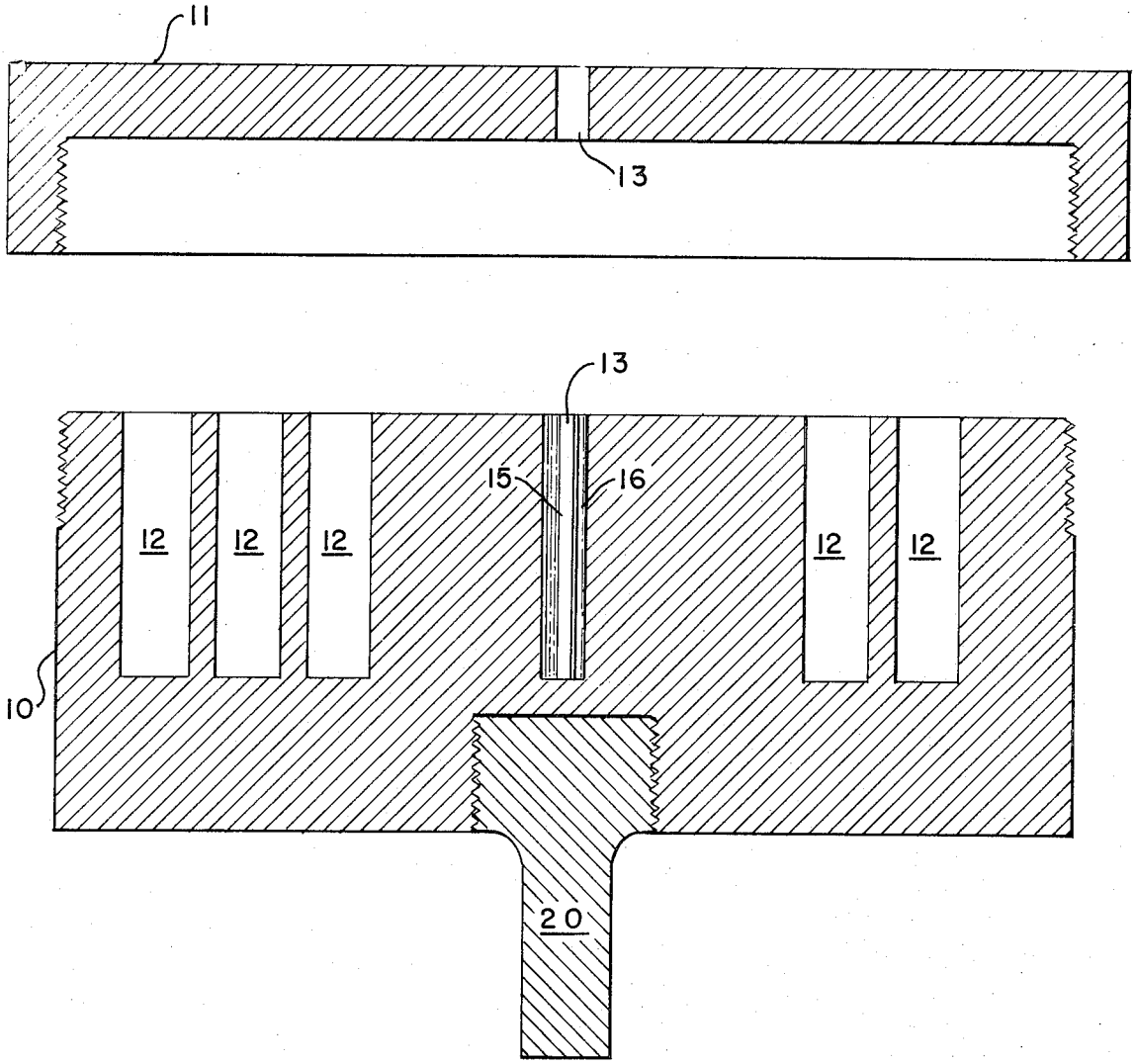


FIG. 1

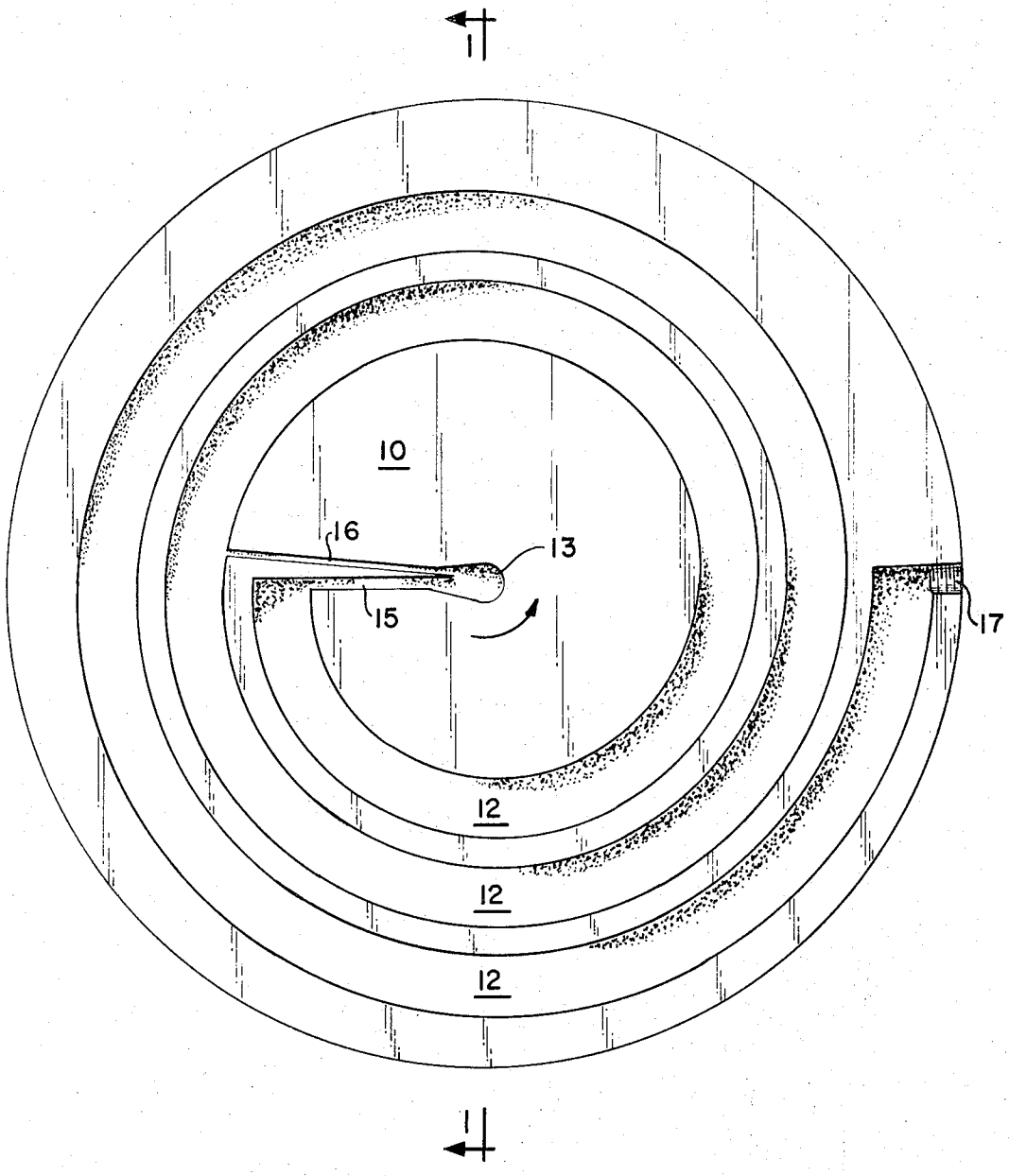


FIG. 2

SAMPLING DEVICE

BACKGROUND OF THE INVENTION

This invention relates to a device for sampling the particulate matter in a fluid stream ranging from about 0.05 to 2.0 microns in size.

Of late, there has been considerable interest in the sampling and analysis of air-borne particles below 2 microns in size. Medical evidence has tended to show that the particles below 2 microns tend to be the most damaging to human health. Moreover, it is well known that particles below 2 microns often account for the dirty look to the air over a large city. Generally, particles greater than 2 microns in size settle readily and therefore the sampling and size segregation of the particles can be accomplished by conventional means. However, the capture and particularly the size segregation of particles below 2 microns in size is very difficult.

Cascade inertial impactors are frequently used to capture and segregate according to size particles less than 2 microns in diameter. However, the efficacy of these devices is extremely low below a particle size of 0.8 micron. This loss in efficiency is due primarily to the re-entrainment of the small particles from stage to stage. Also, with these devices, the small particles tend to agglomerate on impact, preventing any optical post mortem evaluation of the particle size and shape.

Particles from about 5 to 0.5 microns in diameter have been analyzed with a centrifuge spectrometer, such as that described by Stober (see Environ. Sci. Technol. 3, 1,280–1,296 (1969). Similar centrifuge spectrometers by Moss et al. and Cotrapa et al. are described in an article in IEEE Transactions on Nuclear Science, Vol. NS19, No. 1, February, 1972, by Otto G. Raabe entitled, "Instruments and Methods for Characterizing Radioactive Aerosols." These devices generally comprise a centrifuge rotor which has a spiral duct in the upper surface thereof. The aerosol sample is drawn by negative pressure into the duct through an inlet slit at the axis of rotation of the rotor and near the inner wall of the duct where it meets a laminar stream of clean air. The rotor is spun rapidly by suitable means and the aerosol particles move across the clean air stream and collect on the outer wall of the channel in accordance with their aerodynamic diameters. These centrifuges are not useable as portable field devices because of their large size, and because they require a separate clean air source. Moreover, due to the coriolis forces characteristic of these centrifuges, segregation of particles below about 0.6 micron is poor.

Hockrainer in Interface Science, Vol. 36, No. 2, June, 1971, page 191, described an improved centrifuge spectrometer. With this device, the aerosol sample is aspirated into the spectrometer through an aperture located in the cap at the axis of rotation of the rotor. The aerosol stream is split into large and small streams. The larger stream is directed through a conduit in the rotor to a circular conduit on the outer portion of the rotor. As the large aerosol stream passes through the first half of the circular conduit, it is cleansed of the particulate matter and the gas flow is rendered laminar. The smaller aerosol stream is introduced into the second half of the conduit where the gas is clean and the flow is laminar. The particulate matter in the small stream is forced to the outer walls of the conduit in accordance with its aerodynamic diameter and is deposited thereon. While this is an efficient device for sampling aerosol-containing gases, the particle size range for this instrument is very small unless the radius of the rotor is increased considerably. A radius of up to about 6 inches is suitable for a field device, but the maximum particle size range for such a unit generally is about 0.3 to about 1 micron which is inadequate for a full analysis of the particulate size range below 2 microns.

Against this background, the present invention was developed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of the sampler of the present invention.

FIG. 2 is a top view of the rotor body of the present invention with the rotor cap removed.

DESCRIPTION OF THE INVENTION

The present invention provides for an improved centrifuge sampler which can be used as a portable device in the field and moreover can capture and efficiently segregate a broad spectrum of particle sizes ranging from about 0.05 to 2 microns in aerodynamic diameter.

The centrifuge spectrometer of the present invention comprises a rotating, spirally shaped groove or conduit having from about 1.5 to about 2.5 convolutions. The first section of the spiral conduit is essentially a cleaning and laminating section so as to provide a clean, laminar gas flow to the second or sample-capturing section. The rotation of the unit causes the aerosol to be sampled to be aspirated into the centrifuge unit. The aerosol is then split into large and small fractions. The larger aerosol stream is directed to the first section of the spiral channel or conduit where the particulate matter contained therein is removed and the flow is rendered laminar. The smaller aerosol stream is then introduced into the clean, laminar gas flow in the second section where the particulate matter in the smaller stream is caused to flow by centrifugal force across the clean laminar gas flow and deposit on the outer surfaces of the conduit in accordance with its equivalent aerodynamic diameter. By placing a collector strip on the outer surfaces of the second section of the conduit, the collected particles can then be removed and the particles' morphology and chemistry can be studied by suitable means, such as scanning electron microscopy and X-ray methods without particle removal and the resuspension or particle agglomeration characteristic of the prior art devices. The coriolis forces in the present invention are minimal and therefore the size segregation is effective to below 0.1 micron.

As used herein, the expression "equivalent aerodynamic diameter" or terms of similar import refer to the diameter of a sphere of unit density which has the same terminal velocity as the particle in question in the identical accelerating field and carrying gas. All reference herein to particle diameter or size refers to the equivalent aerodynamic diameter.

With reference to FIGS. 1 and 2 which illustrate an embodiment of the present invention, the centrifuge spectrometer comprises a rotor body **10** and a rotor cap **11** affixed thereto. The rotor body and cap define a spirally shaped channel or conduit **12** which has from at least 1.5 to about 2.5 convolutions with a gradually increasing radius. As indicated in the drawing, the start of the spirally shaped conduit is disposed away from the

axis of rotation of the rotor. A co-extensive aperture **13** is provided in the rotor body **10** and cap **11** for the aspiration of the aerosol to be sampled. Means such as conduits **15** and **16** are provided to split the aerosol stream into a large and a small stream, respectively. The larger stream is directed to the start of the spiral groove through conduit **15.** Conduit **16** directs the smaller aerosol stream into the second half of the first complete convolution of the spiral channel **12.** For highly effective cleaning and laminating, the smaller aerosol stream should be introduced toward the end of the first complete convolution as shown in the drawing. Preferably, the angle θ between conduits **15** and **16** is from about 3° to about 30°. Aperture **17** is provided at the end of the spiral conduit **12** to allow for the exiting of the combined gas stream from the sampling unit. The rotor cap **11** can be suitably affixed to the rotor body **10** such as by the threaded connection. Drive shaft **20** is provided on the lower surfaces of the rotor body to facilitate rotation of the unit during operation. Although the groove **12** is shown in the drawings as being disposed in the rotor body **10,** the groove can readily be disposed in the rotor cap **11.** As indicated in the drawing the rotation of the unit is in the direction of the spiral groove.

In operating this spectrometer, the body is rotated by suitable means at a rate of about 2,000 to 20,000 revolutions per minute. The rotation of the unit draws the aerosol to be sampled through aperture **13** and into the body of the rotor wherein it is split into a large and a small stream. The larger gas stream is directed to the beginning of the spirally shaped channel or groove and while this aerosol travels through the first convolution, the particulate matter therein is forced against the outer walls of the channel or groove and a clean laminar gas flow is generated. The smaller aerosol stream is introduced into the second half of the first convolution of the spirally shaped conduit or channel. The particulate matter in the aerosol is caused to pass through the laminar clean air flow in accordance with its equivalent aerodynamic diameter and deposit on the outer walls of the remaining portion of the convoluted channel or groove. Preferably a sampler strip, such as aluminum foil, Mylar strip or the like, is positioned on the outer surfaces of the channel so as to capture the particles and render them amenable to analysis, such as by scanning electron microscopy and X-ray chemical analysis. The length of the channel for the sampling sections ranges from at least ½ to about 1½ convolutions depending upon the particulate size range desired.

The volume ratio of the large aerosol stream to the small aerosol stream ranges from about 20:1 to about 5:1. It is preferred to introduce the smaller aerosol toward the end of the first convolution to allow for the substantially complete removal of particulate matter from the larger gas stream to thereby avoid any contamination with the particulate matter in the smaller aerosol stream which is captured in the sampling section of the spiral channel or conduit.

Depending upon the rotational speed of the rotor body of the spectrometer unit and the orifice size in the entry and exit apertures, the gaseous flow rates from about 2–100 milliliters per second can be obtained. In accordance with the present invention, the spiral channel width ranges from about 0.2 to 1.5 centimeters and the depth ranges from about 0.5 to 3.0 centimeters. If desried, the width of the channel can be gradually increased from the beginning to the end of the conduit. The diameter of the spectrometer ranges from about 2 to about 6 inches. Above 6 inches, the unit is too large to be of any value as a portable field unit and below about 2 inches, no useful range of particulate sizes can be captured. For efficient size separation, the rotational speed of the rotor must be controlled within ±5 percent, preferably within ±1 percent.

To avoid blockage of the entry aperture and unnecessarily large entry losses, it is advisable to pretreat the aerosol to remove particles above 2 microns in diameter. A suitable pretreating device is a cascade inertial impactor.

In the table below, examples are given which illustrate embodiments of the present invention. The data illustrate the effect of variations of process parameters and conduit dimensions on the effective range of particulate capture. In all of the examples, the spiral conduit had two complete convolutions. A greater effective range could be obtained by extending the length of the spiral conduit. The inside radius is the radius of the inner wall of the spiral conduit at the start and finish of the sampling section of the conduit.

Example No.	Ht. of Conduit cm	Width of Conduit cm	Inside Radius of Conduit cm	Flow Rate ml/sec	Vol. Ratio of Large to Small Stream	Rotor Speed rpm	Effective Range microns
1	2.0	0.5	3.60 to 4.75	25	10/1	10,000	0.10–1.2
2	2.0	0.5	3.60 to 4.75	20	10/1	10,000	0.08–1.0
3	2.0	0.5	3.60 to 4.75	15	10/1	10,000	0.07–0.9
4	2.0	0.5	3.60 to 4.75	10	10/1	10,000	0.04–0.7
5	2.0	0.5	3.60 to 4.75	25	10/1	7,500	0.15–1.6
6	2.0	0.5	3.60 to 4.75	25	10/1	10,000	0.10–1.2
7	2.0	0.5	3.60 to 4.75	25	10/1	12,500	0.06–0.9
8	2.0	0.5	3.60 to 4.75	25	10/1	15,000	0.05–0.7
9	2.0	0.5	1.50 to 2.00	25	10/1	10,000	0.30–1.9
10	2.0	0.5	2.30 to 3.00	25	10/1	10,000	0.15–1.5
11	2.0	0.5	3.00 to 4.00	25	10/1	10,000	0.12–1.3
12	2.0	0.5	3.80 to 5.00	25	10/1	10,000	0.10–1.1
13	1.0	0.5	3.60 to 4.75	25	10/1	10,000	0.16–1.5
14	2.0	0.5	3.60 to 4.75	25	10/1	10,000	0.10–1.2
15	3.0	0.5	3.60 to 4.75	25	10/1	10,000	0.08–1.0
16	2.0	0.5	2.20 to 2.90	16	10/1	10,000	0.15–1.5

Although the invention is described in terms of removing particulate matter from a gaseous stream, the invention can be efficiently employed in removing particulate matter below 2 microns in diameter from a liquid medium, such as in a hydrosol.

It is obvious that various modifications and improvements can be made to the present invention without departing from the spirit thereof and the scope of the appended claims.

What is claimed is:

1. A sampling device for capturing and segregating particulate matter having an equivalent aerodynamic diameter from about 0.05 to about 2.0 microns from a fluid containing same comprising:

A. a generally cylindrically shaped member having a rotor body and a rotor cap, said body and cap defining a generally spirally shaped conduit having from about 1.5 to about 2.5 convolutions, the radius of said conduit gradually increasing and the beginning of said conduit being disposed a distance away from the axis of rotation of said rotor body and cap;

B. means to introduce said fluid stream into said cylindrically shaped member;

C. means to split said fluid into small and large streams;

D. means to introduce said large fraction into the beginning of the first convolution of said spirally disposed conduit;

E. means to introduce said smaller fraction into the second half of the first convolution of said spirally shaped conduit;

F. means to exhaust said combined large and small fractions from said conduit; and

G. means to rotate said cylindrically shaped member.

2. The device of claim **1** wherein said rotor body is from about 2 to about 6 inches in diameter.

3. The device of claim **1** wherein the spirally disposed conduit has a generally rectangular shaped cross section with a width from about 0.2 to about 1.5 centimeters and a depth of about 0.5 to 30 centimeters.

4. The device of claim **3** wherein a thin collector strip is positioned on the outer surface of said spirally disposed conduit.

5. The device of claim **1** wherein means to split said fluid into large and small streams provide a volume ratio of large to small streams from about 5:1 to about 20:1.

6. The device of claim **1** wherein the width of said spirally disposed conduit is gradually increasing.

7. A method of capturing and segregating particulate matter having an equivalent aerodynamic diameter from about 0.05 to about 2.0 microns from a fluid containing same comprising:

A. splitting said fluid into a small and large fraction, the volume ratio of large to small stream ranging from about 5:1 to 20:1;

B. passing said larger fraction through at least one-half convolution of a rapidly rotating, spirally shaped conduit to generate a laminar gaseous flow therein and to remove substantially all particulate matter from said larger fraction;

C. introducing said smaller fraction into said larger fraction after the flow of said larger fraction has become essentially laminar and substantially all particulate matter has been removed therefrom;

D. passing said combined streams through at least one complete convolution of said rapidly rotating, spirally shaped conduit to remove and segregate according to size said particulate matter having an equivalent aerodynamic diameter of about 0.05 to about 2.0 microns; and

E. discharging said combined streams.

8. The method of claim **7** wherein said conduit is rotating from about 2,000 to 20,000 revolutions per second.

9. The method of claim **7** wherein the total flow of fluid into said spirally shaped conduit ranges from about 2 to 100 milliliters per second.

* * * * *