Oct. 18, 1949. I. LANGMUIR 2,485,390

CENTRIFUGAL FLUID PURIFIER

Filed Sept. 25, 1945

Fig. 1.

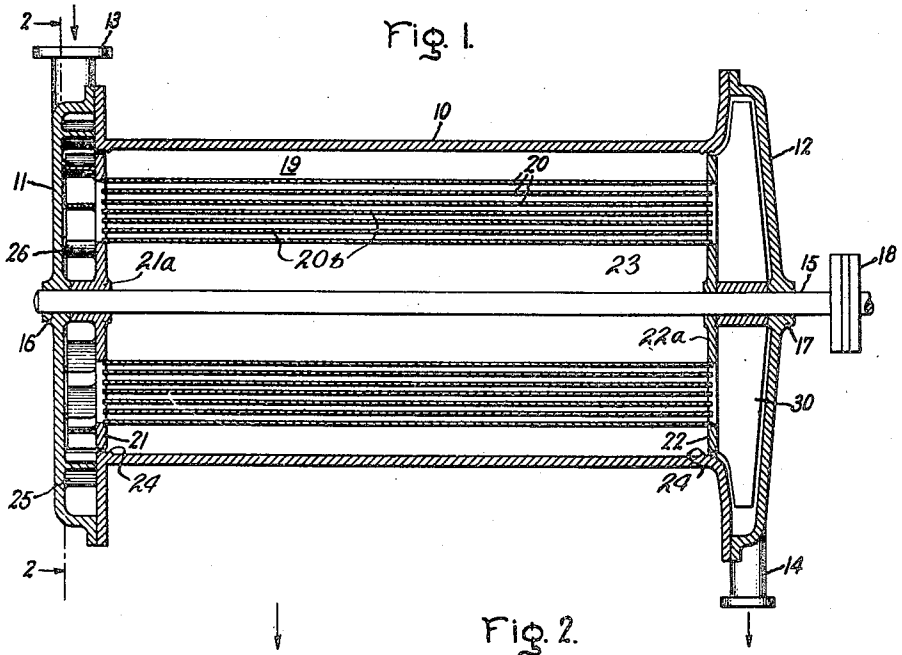
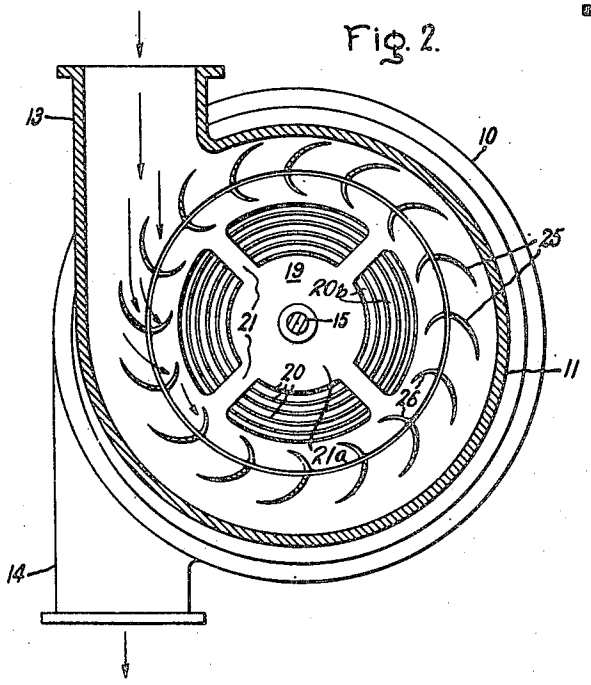


Fig. 2.



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CENTRIFUGAL FLUID PURIFIER

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3 Claims. (Cl. 233—17)

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The invention relates to fluid purifying apparatus, particularly centrifuge apparatus for removing fine particles from a gas or other fluid by the action of centrifugal force.

The principal object is to provide an improved high speed spinning cylindrical wall form of fluid purifying apparatus capable of subjecting particles carried in an annular column of fluid along the inner surface of the spinning cylindrical walls to an intense centrifugal field such as, for example, several thousand times that of gravity so as more effectively to deposit the fine particles on the spinning walls.

Another object is to provide an improved form of high speed multi-tubular spinning wall apparatus capable of purifying large volumes of air at a low cost and particularly adapted for removing fine particles such as those of tobacco smoke.

The fine smoke particles in a fluid such as air contained in any closed space normally tend to disappear mainly by gravity settlement according to equation:

$$dlnn/dt=-Av/V \qquad (1)$$

where n is the number of smoke particles per cm., t is the time in seconds, V is the volume of the vessel in cm.^{3}, v is the velocity in cm./sec. with which the particles fall in undisturbed air under the influence of gravity and A is the horizontal cross section of the vessel, or the projected area of the walls of the vessel on a horizontal plane.

This equation is based upon the assumption that there are sufficiently strong convection currents in the fluid to keep it well mixed at all times. However, if the fluid is made to move rapidly, for example, by rotating a fan within the vessel, the rate of disappearance of the smoke is not materially affected until relatively high velocities are obtained. At very high velocities the smoke particles may be diffused in appreciably increased amount to the walls and be deposited even on vertical walls on which gravity settling cannot occur. Such diffusion is most rapid in the case of fine particles for the Brownian movement of these fine particles is much greater than that of large particles. The effect of the mechanical motion of the fluid increasing the smoke particle diffusion results from the fact that the fluid currents carry the smoke particles to within a fraction of a millimeter of the surface so that the smoke particles can diffuse the small remaining distance. Without such strong agitation there would be a relatively thick layer

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or shield of quiet fluid near the surface through which the particles would have to diffuse.

If still higher velocities are used and the fluid is made to rotate at high speed in a cylindrical vessel by a rotor inside of it provided with radial vanes, then centrifugal force tends to force the heavier particles outward through the rotating fluid. However, near the cylindrical walls the fluid is not rotating, being held by viscosity near the stationary surfaces. Thus as the particles slow up in their rotary motion before they reach the walls the centrifugal effect is greatly reduced. Consequently only relatively large particles of several microns diameter can be effectively removed by the centrifugal force produced by whirling a fluid in a stationary vessel.

In purifying air containing smoke in accordance with the principle of the present invention, the walls of the vessel through which the air is passed rotate at high speed so that smoke particles in the annular rotating sheet of air closely adjacent to the wall surfaces are exposed to the action of an intense centrifugal force. Thus the invention may be carried out in a simple form by rotating a cylinder at high speed about a central axis and the air from which the smoke is to be removed passed in a thin annular rotating sheet adjacent the inner surface of the cylinder in a direction parallel to the axis. Under these conditions the smoke is made to disappear according to the following equation

$$n=n_0e^{-2\pi RNvx/\phi} \qquad (2)$$

where n_0 is the number of smoke particles per cm.^{3} in the smoke entering the cylinder, n is the number per cm.^{3} in the smoke leaving the cylinder, R is the radius and x the length of the cylinder in cm., φ is the rate of flow of gas through the cylinder in cm.^{3} per second, V is the velocity of fall of the smoke particles in cm./sec. in the centrifugal field which exists in the annular rotating sheet of air adjacent the inner surface of the rotating cylinder and in the simple form of apparatus described above, N is a number equal to 1. In general, N would represent the number of coaxial cylinders that are used for the collection of smoke.

Hence a further object of the invention is to provide an improved form of fluid purifying apparatus having a high speed rotor consisting of a nested series of thin coaxial cylinders of increasing radius spaced only slightly apart and interconnected together so as to provide a multiplicity of closely adjacent annular walls between which a substantial flow of fluid in thin coaxial

annular columns may be passed and thereby subject to an extremely high centrifugal force.

Further objects and advantages of the invention will appear in the description of the accompanying drawings in which Fig. 1 is a longitudinal sectional view of a high speed spinning multi-tubular cylindrical wall fluid purifying apparatus embodying the improvements of the present invention in a preferred form, and Fig. 2 is a cross sectional view along the line 2—2 of Fig. 1 showing more clearly the details of construction.

As shown in Fig. 1 the improved fluid purifying device is provided with a stationary outer shell 10 interconnecting the inlet casing 11 and the outlet casing 12 through which the fluid or gas to be purified is circulated. The inlet casing 11 is provided with an offset inlet pipe connection 13 and the outlet casing 12 is provided with a similar outlet pipe connection 14. A drive shaft 15 is rotatably mounted in the bearing 16 and 17 formed centrally in the corresponding inlet and outlet casings 11 and 12. The drive shaft 15 is connected to be rotated at high velocity by an electric motor or other suitable motive power, not shown, through the driving coupling 18.

The multi-tubular rotor 19 consisting of a plurality of nested closely adjacent cylinders 20, each formed of relatively thin material, is mounted for rotation with the shaft 15 by means of the two suitably formed mounting spiders 21 and 22, preferably with each of the thin cylinders 20 welded to each spider so as to insure rigidity of the multi-tubular rotor structure. The innermost one of the cylinders 20 with the spider hubs 21*a* and 22*a* welded to the ends thereof forms an elongated axial cylindrical drum 23 surrounded by the adjacent nested coaxially aligned cylinders 20 so as to provide concentric thin annular flow passages 20*b* extending between the opposite ends of rotor 19. Each of the mounting spiders 21, 22 likewise is rigidly secured to the shaft 15, preferably by welding with the periphery of each spider at the opposite ends of the rotor extending into a substantially fluidtight running fit with the sealing rings 24 provided for sealing the opposite ends of the multi-tubular rotor 19 with respect to the inlet and outlet casings 11 and 12.

As more clearly shown in Fig. 2, when used for purifying air or other gas the inlet casing 11 may be provided with a series of expansion vanes or blades 25 which cooperate with the corresponding rotating expansion blades 26 carried by the mounting spider 21 so as to expand the gas admitted through the inlet pipe 13 into the inlet casing 11 before the gas is passed in thin annular columns through the multiple annular passages between the coaxial cylinders 20.

The mounting spider 22 at the outlet end of rotor 19 also may be provided with a series of blades 30 extending outwardly at a suitable angle within the outlet casing 12 so as to produce a recompression of the gas before it is exhausted through the outlet pipe 14. Furthermore the blades 30 and the outlet casing 12 can also serve as centrifugal fluid flow inducing means for producing a flow of gas in thin multiple annular sheets through the hollow rotor 19 formed by shaft 15 and the several coaxial cylinders 20.

In operation when the drive shaft 15 of rotor 19 is driven at high speed, the centrifugal blower action produced by blades 30 serves to reduce the pressure within the outer shell 10 so that the gas will be drawn into the inlet casing 11 through the inlet pipe 13. The expansion of the incoming

gas through the blades 25 and 26 delivers some power to the rotor 19 which at least can partly compensate for the power used in recompressing the gas at the opposite end. In this way the gas such as air enters and leaves the rotor 19 with relatively low velocity and within the rotor is under subatmospheric pressure and has a high velocity of rotation but not as great a longitudinal velocity (in the direction of the axis of the rotor). Thus such a construction can increase the overall efficiency of the device.

If desired, the fluid may be delivered through the inlet pipe connection 13 at sufficient pressure and velocity such that the reaction produced by directing the fluid through vanes 25 upon blades 26 will provide all the power required for spinning the rotor 19 and the fluid then allowed to exhaust axially through the rotor 19 without the provision of any recompression blades 30. Furthermore, it will be understood that other suitable means for obtaining the axial flow of fluid in thin concentric rotatable columns through the multiple annular passages between the concentric cylinders 20 and for spinning the rotor 19 may be employed if desired.

With a rotor consisting of a series of thin coaxial cylinders of increasing radius spaced a few millimeters apart, for example, with a rotor having 10 coaxial cylinders with an average radius $R=10$ cm. and the length of the cylinders $x=30$ cm., we find that Equation 2 becomes

$$n=n_0e^{-18800v/\nu} \qquad (3)$$

Now if we consider air as containing smoke consisting of spherical particles having a density 0.9 gram per cm.^{3} we can calculate from Stokes law that

$$v=1.06\times10^6 r_s^2(g/g_1) \text{ cm./sec.} \qquad (4)$$

Where the acceleration g is given by:

$$g=4\pi^2R\nu^2 \qquad (5)$$

where ν is equal to the revolutions per second and $g_1=980$ the normal acceleration of gravity and r_s is the radius of the smoke particles. If we consider that the rotor is revolving at 5000 R. P. M. or $\mu=83$ R. P. S., we obtain $g=2.77\times10^6$ or 2850 times gravity. This gives for smoke particles of radius r_s, $v=3.0\times10^9 r_s^2$.

If we consider smoke particles $r_s=3\times10^{-5}$ cm. this gives $v=2.7$ cm./sec. A smoke with this particle size is most difficult to remove from air by a filter and yet with this high centrifugal force in a device having the construction described above the particles can be made to move 2.7 cm. per second, nearly 3000 times their normal speed. Introducing this value of v in Equation 3 we obtain for the effectiveness of this centrifuge for removing this smoke

$$n=n_0e^{-51000/} \qquad (6)$$

This means that if we pass 10 liters per second (which corresponds to 21 cu. ft. per minute) we would remove 99.4 per cent of all the smoke particles. These calculations show that by means of the construction I have provided very large quantities of air can be purified effectively, even if the particles are very fine.

I give the foregoing calculations merely as an example. It is clear that still greater volumes of fluid can be handled by using larger rotors and larger numbers of coaxial cylinders. Higher speeds of rotations may also well be used. The smoke particles deposited upon the cylinders 20 may be readily removed by periodic flushing with water or other suitable solvent.

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

1. A fluid purifying device having in combination a multi-tubular rotor comprising an axial cylindrical drum and a plurality of adjacent nested substantially imperforate cylinders surrounding said drum in coaxial alignment for rotation therewith, enclosing means having a substantially fluidtight running seal with the opposite ends of said rotor for passing concentric columns of fluid through said cylinders for rotation therewith, and means for spinning said rotor at high velocity to establish high centrifugal forces in the rotating fluid inside each of said cylinders for diffusing fine particles therefrom to the inside wall of the corresponding cylinder.

2. A gas purifying device having in combination a multi-tubular rotor comprising a plurality of coaxial closely spaced substantially imperforate cylinders forming thin annular flow passages extending between the ends of said rotor, means including an outlet casing having a substantially fluidtight running seal with one end of said rotor and blades carried by said rotor inside said casing and extending radially from the corresponding end of said passages for producing a flow of gas in coaxial annular columns through said passages, and means for spinning said rotor to rotate said gas columns at high velocity to establish high centrifugal forces therein for diffusing fine particles from each of said columns to the outer wall of the corresponding passage.

3. A centrifuge device for removing smoke particles from air having in combination a multi-tubular rotor comprising a plurality of nested coaxial closely adjacent and substantially imperforate cylinders, said cylinders forming a plurality of concentric thin annular passages extending between the opposite ends of said rotor, means including a casing at each end of said rotor and having a substantially fluidtight running sealing therewith for producing a flow of air in nested thin annular columns through said passages, and means for spinning said rotor to rotate said air columns at high velocity to establish high centrifugal forces therein adjacent the inner wall of each of said cylinders for diffusing fine smoked particles from the corresponding air column thereon.

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Certificate of Correction

Patent No. 2,485,390 October 18, 1949

IRVING LANGMUIR

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 4, line 60, Equation 6, for "$n=n_0e^{-51000/}$" read $n=n_0e^{-51000/\varphi}$;

and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of March, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.