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SONIC FLOCCULATOR AND METHOD OF FLOCCULATING SMOKE OR THE LIKE

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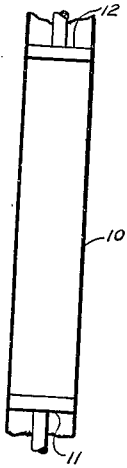


Fig 1

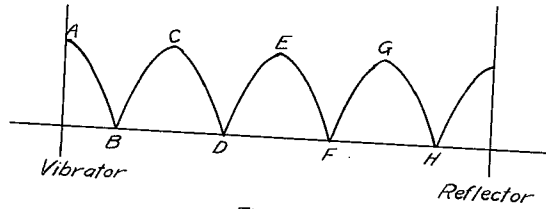


Fig 2

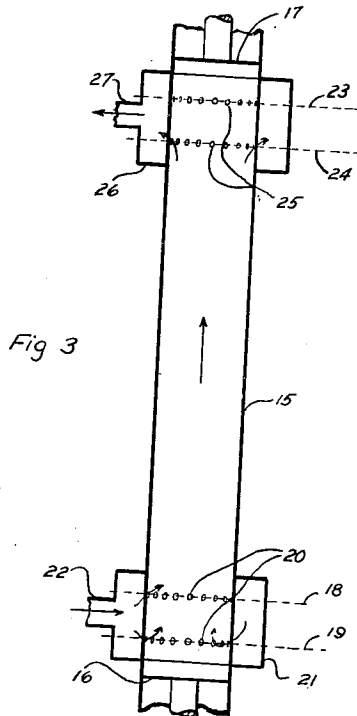


Fig 3

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SONIC FLOCCULATOR AND METHOD OF
FLOCCULATING SMOKE OR THE LIKE

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to the Government of the United States as rep-
resented by the Secretary of the Interior, and
his successors in office

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7 Claims. (Cl. 183—114)

(Granted under the act of March 3, 1883, as
amended April 30, 1928; 370 O. G. 757)

This invention relates to the art of flocculating aerosols and to a sonic flocculator as well as to a method of flocculating smoke or the like.

Dispersions consisting of finely subdivided solid or liquid material suspended in a gaseous medium, such as air, are known as aerosols. They are classified according to their respective modes of origin, nature and appearance as smoke, fume, dust, fog, mist or cloud. Aerosols resulting from combustion or from destructive distillation are commonly called smoke, while fume is usually produced by chemical action or by volatilization. Dusts may be formed by natural or mechanical processes of disintegration and dispersion. In smoke and fume the particles may be either solid or liquid, while dust consists only of solid particles. Cloud, mist and fog are aerial systems consisting mainly of dispersed water or of some other volatile liquid. The great majority of all persistent aerial systems are smokes or fumes such as those formed by chemical processes, electrical or mechanical pulverization, volatilization or combustion. The present invention and the principle thereof apply generally to the flocculation of aerosols, and particularly to the flocculation of the persistent aerial systems which are commonly known as smokes or fumes.

A characteristic property of disperse systems is the Brownian motion or the random motion of the dispersed particles resulting from numerous collisions with the molecules of the medium. The displacement of a particle in air by this motion is about eight times what it would be in water as a medium. One of the most important results of Brownian motion is the continuous and spontaneous flocculation shown by most aerosols. The particles stick together when Brownian motion brings them in contact. Probably a high percentage of the collisions are effective. Adherence also results from the majority of collisions between particles with various surfaces. Some aerosols, such as quartz and limestone dusts, do not show spontaneous flocculation. The abnormal behavior of such aerosols is attributed to a layer of adsorbed gas that prevents the colliding particles from sticking. Obviously, this continuous and spontaneous flocculation of most aerosols does not occur with sufficient rapidity to prevent damage to adjacent property, such for example, as damage caused by smelter fumes.

It has been found that apparently any aerosol can be flocculated in a relatively brief interval by subjecting it to the influence of high frequency sound waves. The equipment required consists primarily of a vibrator for producing the

sound waves and a resonating chamber for producing the sound field. A magnetostrictive vibrator may be used for generating the sound waves. The sound field may be produced in essentially the same way as in the familiar Kundt dust-tube experiment. (Kundt, A., Poggendorf's Annalen der Physik, vol. 127, 1866, p. 497; also Rayleigh, Lord, Theory of Sound: vol. 2, 1896, 2d ed., p. 57). The resonating chamber may be a cylinder adjusted to resonance with the vibrator by means of a movable reflecting disc disposed at one end of the cylinder. When the resonating column is adjusted to resonance, the radiated and reflected waves interfere in such a way as to produce a standing wave pattern of nodes and antinodes. The nodes are positions of minimum and the antinodes, of maximum sound amplitude of vibration.

When an aerosol of ammonium chloride, for example, is confined in the resonating chamber and subjected to the influence of the sound field, flocculation occurs. As soon as the sound field is set up, the aerosol begins to flocculate and usually first appears as fine flakes, plainly visible to the naked eye. After a brief turbulent motion, these flakes collect at the antinodal positions and form large curtain-like flocs. As these flocs become large, they settle to the bottom, and finally the fume becomes completely flocculated. Most of the flocculated material settles to the bottom of the chamber, but some of it may remain suspended at the antinodal positions.

In flocculating an aerosol in this manner it is advantageous to be able to pass the aerosol through the resonating or flocculating chamber in a continuous stream. This procedure may result in a considerable loss of sound energy through the inlet and outlet ports. The purposes of this invention are to provide a method of as well as a means for passing an aerosol through the flocculating chamber of a sonic flocculator in a continuous stream without at the same time allowing an appreciable loss either in efficiency of the sound generating apparatus, or in sound energy through the inlet and outlet ports of the flocculating chamber.

The features of the invention are illustrated in the accompanying drawing, wherein:

Fig. 1 is a diagrammatic sectional view illustrating a sonic flocculator comprising a cylindrical flocculating chamber having a vibrator at one end and a reflector at the other;

Fig. 2 is a view illustrating the pressure amplitude along the flocculating chambers shown in Figs. 1 and 3; and

Fig. 3 is a diagrammatic sectional view of a sonic flocculator in accordance with this invention.

A simple sonic flocculator is illustrated in Fig. 1, as comprising a cylindrical flocculating chamber 10 with a vibrator 11 at one end thereof and a reflector 12 at the opposite end. When a device, of this kind is used for flocculating an aerosol, the reflector 12 is adjusted toward or from the vibrator to a position at which standing waves are produced when sound waves are generated by the vibrator at the desired frequency which should be high, that is approximately 4000 cycles per second or greater. For some aerosols, such as tobacco smoke, where the particle size is very small, the minimum effective frequency is near 7000 cycles per second. Frequencies of this order may be readily obtained with magnetostrictive vibrators, as is well understood in this art. When an aerosol is introduced into the chamber 10 and a sound field of high frequency standing waves is established in this chamber, flocculation takes place in a brief interval. When the vibrator 11 has about the same cross sectional area as the flocculating cylinder or chamber 10, the sound waves are essentially plane, that is, they have a substantially planar front, and there is a loop or antinode in the standing wave system at one quarter of a wave length from the reflector 12. Other loops or antinodes are located at intervals of one half wave length. The distance from the vibrator 11 to the nearest loop is slightly less than or slightly greater than one quarter of a wave length, the deviation being determined by the ratio of the amplitude of the vibrator 11 to the amplitude of the gas at the loops. When the waves in the flocculating chamber do not have a planar front, lateral vibrations are possible and when this occurs the loops are greater than one half wave length apart. The location of the loops can be calculated, knowing the dimensions of the flocculating chamber and the wave length, but it is usually simpler to locate the loops experimentally. It will be evident, therefore, that it is advantageous to provide a vibrator having about the same cross sectional area as the flocculating chamber. When this is done, the resonating column substantially fills the flocculating chamber and vibrations of sufficient intensity to produce flocculation throughout the chamber are assured without resorting to the expedient of unduly increasing the frequency to provide adequate intensity in some areas and greater intensity than is required in others.

If the aerosol is supplied to or gaseous media is passed from the flocculating chamber through openings in the side walls thereof, considerable sound energy may be lost through such openings. If the waves generated by the vibrator 11, for example, are plane sinusoidal waves, the pressure amplitude at any point along the flocculating chamber may be represented by the curve in Fig. 2. The nodes of the standing wave system are at the points A, C, E and G, and the loops or antinodes are at the points B, D, F and H.

The sound energy escaping through a hole in the wall of the flocculating chamber is proportional to the square of the pressure amplitude; consequently the location of the inlet and outlet ports in the walls of the flocculating cylinder is very important. A minimum amount of energy will be radiated through the holes if they are located at the loops, or points B, D, F and H. The ratio of energy radiated through a hole at B to that which would be radiated by the same

hole located at C, providing the radius of the hole, a , is small with respect to the wave length, is:

$$\frac{W_B}{W_C} = \pi^2 \frac{a^2}{\lambda^2}$$

For a frequency of 13.5 kilocycles, the wave length is about 1 inch. For a hole having a diameter of $\frac{1}{8}$ inch ($a = \frac{1}{16}$ inch)

$$\frac{W_B}{W_C} = .00965$$

or the loss of sound through a hole with its center at C is about 100 times what it would be at B.

An important feature of this invention is the location of the inlet and outlet ports at the loops of the standing wave system, at points where the axis of the hole is normal to direction of vibration of the gas. This fundamental principle is embodied in the sonic flocculator shown in Fig. 3. This sonic flocculator comprises a vertically disposed, substantially cylindrical flocculating chamber 15 having a suitable vibrator 16 at its lower end and a reflector 17 at its upper end. At the lower end of the flocculating chamber, the planes of the loops or antinodes of the standing wave system are indicated by the dotted lines 18 and 19 and the inlet ports 20 are disposed in rings about the flocculating chamber at the planes of these loops. Preferably, an annular chamber 21 is disposed about the inlet ports 20 and provided with an inlet port 22. Similarly, at the upper end of this flocculating chamber, the planes of loops of the standing wave system are indicated by the dotted lines 23 and 24 and the outlet ports 25 are disposed about the flocculating chamber in rings located at these positions. Preferably, an annular chamber 26 is disposed about the outlet ports 25 and provided with a discharge port 27.

In using this flocculator a suitable sound field, comprising a high frequency standing wave system is established in the flocculating chamber 15, and an aerosol may be passed continuously through the port 22 into the annular chamber 21 from which it passes through the inlet ports 20 and upwardly through the flocculating chamber. The influence of the sound field produces flocculation in a brief interval and the gases and some flocculated particles escape through the outlet ports 25 into the annular chamber 26 from which they are discharged through the port 27. Thus, the flocculation of an aerosol may be carried on continuously with assurance that only a negligible amount of sound energy will be lost through the ports of the flocculating chamber.

While the invention has been illustrated as embodied in a flocculator having a cylindrical flocculating chamber, the principal of the invention is applicable to resonant chambers of any shape. If the flocculation chamber is not substantially cylindrical, the pattern of the loops is more complicated and the proper points to locate the inlet and outlet ports may be more difficult to determine.

It should be understood that the present disclosure is for the purpose of illustration only and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

The invention described herein, if patented, may be manufactured and used by or for the Government for governmental purposes without the payment to me of any royalty thereon.

What I claim is:

1. A sonic flocculator of the class described, comprising means for establishing a sound field, comprising a high frequency standing wave system, and a chamber disposed about said sound field for confining an aerosol substantially in said field, said chamber having one or more ports each disposed substantially at and across any one of one or more antinodes of the standing wave system, each of said one or more ports extending only a relatively small distance away from the antinode at which it is located, so that each of said one or more ports provide for passage of a steady stream of gas or smoke and remain substantially impervious to sound energy from said standing wave system.

2. A sonic flocculator of the class described, comprising means for establishing a sound field, comprising a high frequency standing wave system, and a chamber disposed about said sound field, said chamber having one or more ports disposed with their flow axes substantially normal to the direction of radiation and reflection of the standing waves of said sound field, each of said ports being located substantially at and across any one of one or more of the antinodes of the standing wave system, each of said one or more ports extending only a relatively small distance away from the antinode at which it is located, so that each of said one or more ports provide for passage of a steady stream of gas or smoke and remain substantially impervious to sound energy from said standing wave system.

3. A sonic flocculator of the class described, comprising means for establishing a high frequency standing wave system, means for conducting an aerosol into said sound field, the latter means comprising a flocculating chamber substantially enclosing said field, a substantially annular chamber disposed about said flocculating chamber, and means for supplying an aerosol from said annular chamber to said flocculating chamber in one or more streams each confined to a flow area disposed substantially at and across any one of one or more antinodes of said standing wave system and extending only a relatively short distance on either side of the antinode at which it is located, so that said one or more streams provide for passage of an aerosol in a steady stream and remain substantially impervious to sound energy from said standing wave system of said sound field.

4. A sonic flocculator of the class described, comprising means for establishing a sound field of high frequency standing waves, means for conducting an aerosol through the sound field, the latter means comprising a flocculating chamber substantially enclosing the sound field, said flocculating chamber having one or more inlet ports each disposed substantially at and across any one of one or more antinodes of the standing waves of the sound field, said one or more inlet ports extending only a relatively small distance away from said one or more antinodes at which each is located, so that said one or more inlet ports provide for passage of an aerosol in a steady stream and remain substantially impervious to

sound energy from said standing wave system, a substantially annular chamber disposed about said inlet ports for supplying an aerosol thereto, said flocculating chamber also having one or more discharge ports spaced along said chamber from said inlet ports, each of said discharge ports being disposed substantially at and across any one of one or more antinodes of the standing waves of the sound field which are spaced from the antinodes at which the inlet port or ports are located, said one or more discharge ports also extending only a relatively small distance away from said one or more antinodes at which each is located, so that said one or more discharge ports provide for passage of a steady stream of gas or smoke and remain substantially impervious to sound energy from said standing wave system, and a substantially annular chamber disposed about said discharge ports for receiving gaseous media from said flocculating chamber.

5. The method of the class described, which comprises establishing a high frequency resonating column in an aerosol, conserving sound energy by confining the resonating column in a substantially enclosed space and supplying the aerosol to the resonating column in one or more streams each delivered substantially at and across any one of one or more of the antinodes of the resonating column, and confining the flow area of each of said one or more streams to a space extending only a relatively small distance away from the antinode at which it is located, so that each of said streams remains substantially impervious to sound energy from said resonating column.

6. The method of the class described, which comprises establishing a high frequency resonating column in an aerosol, conserving sound energy by confining the resonating column in a substantially enclosed space and passing gaseous media from the resonating column in one or more streams each discharged substantially at and across any one of one or more of the antinodes of the resonating column, and confining the flow area of each of said streams to a space extending only a relatively small distance away from the antinode at which it is located, so that each of said streams remains substantially impervious to sound energy from said resonating column.

7. The method of the class described, which comprises establishing a high frequency resonating column in an aerosol, conserving sound energy by confining the resonating column in a substantially enclosed space, supplying the aerosol to the resonating column and passing gaseous media therefrom in a plurality of streams each located substantially at and across only one of one or more of the antinodes of the resonating column, and confining the flow area of each of said streams to a space extending only a relatively small distance away from the antinode at which it is located, so that each of said streams remains substantially impervious to sound energy from said resonating column.

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