

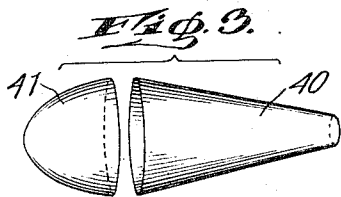
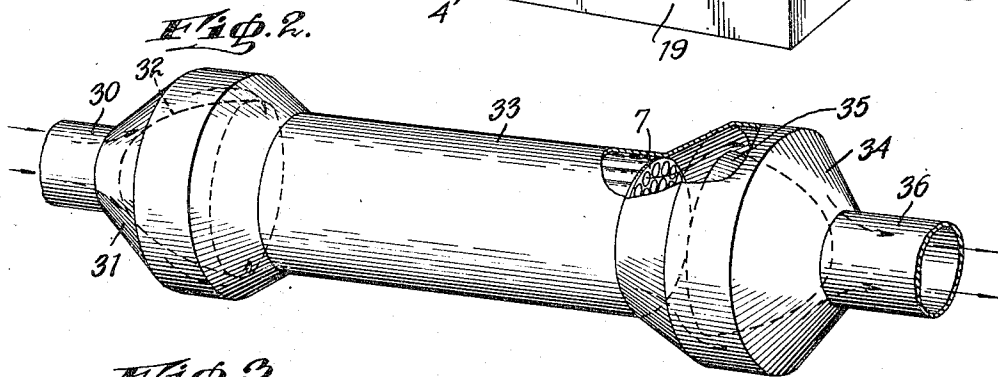
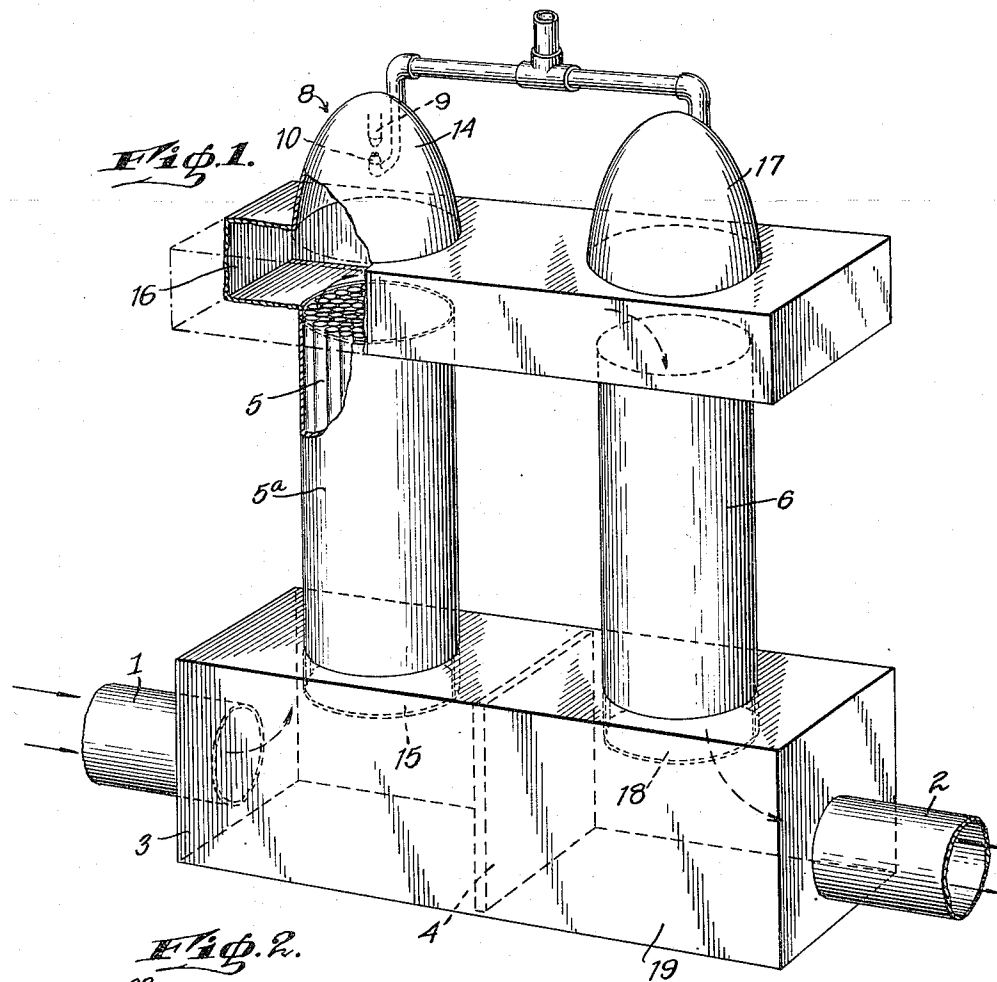
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AGGREGATION OF DISPERSOIDS

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AGGREGATION OF DISPERSOIDS

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My invention relates to aggregating dispersoids by means of sonic or supersonic sound waves, i. e. by wave motion in and of the mixture containing the dispersoid or dispersoids, with or without subsequent collection or separation of the aggregated dispersoids from their carrying medium.

By the term dispersoid I refer to a material or substance more or less distributed through a mass of another material or substance within which the dispersoid tends to aggregate into larger particles, or from which it tends to separate, either slowly or not at all under the conditions under which aggregation or separation is desired. Some examples are smoke (both chemical and of combustion), fly ash (which consists of particles of solid matter), dusts, fog and mist (which consist of liquid particles), clouds, and fumes.

The aggregation, collection or separation of dispersoids in accordance with my invention may be for any one of various purposes, or it may comprise a step toward or be an aid to the achievement of any one of various results; for example, improving the transparency of a mixture by aggregating the dispersoid particles into larger particles, either with or without considerable immediate or subsequent separation of the larger particles from the carrying medium; or separating one or more dispersoids from a carrying medium (e. g. a liquid or gas) for the purpose of abating a nuisance, or to clarify a carrying medium having commercial value; or separating to recover a dispersoid having itself a commercial value; etc.

The abatement of the smoke nuisance will serve as an example. Common smoke of combustion is considered to consist of small particles of either unburned carbon or ash or both. These particles are held suspended in the combustion gases (or in the atmosphere into which they may become dispersed) for so long, generally speaking, as the combustion gases (or air) are in rapid motion; with the passage of time, or as the combustion gases (or air) become more quiescent, the particles precipitate or deposit more or less; in general, the rate of precipitation and deposit under any given condition depends on the particle size and density. In many instances more than 50% of the so-called "fly ash" of the smoke of combustion consists of particles less than 30 microns in diameter (from 0.5 to 30 microns; 1 micron = $\frac{1}{25000}$ inch), and these exceedingly small particles can not be separated from combustion gases efficiently by any known mechanical means. By creating sound waves of high inten-

sity in the combustion gases however, i. e. causing wave motion in and of the combustion gases of considerable amplitude and of sonic or supersonic frequencies, initially small smoke particles can be aggregated into particles of larger and separable sizes; then by subsequent precipitation, deposit or other separation of these larger or aggregated particles the combustion gases can be freed of smoke to a corresponding extent.

I have found however that, for such quantities of mixtures as are encountered in practice, other things being the same, subjecting a dispersoid-containing mixture to the wave motion in a large number of chambers that, individually, are rather small in at least one direction more or less perpendicular to the direction of propagation of the wave motion, increases considerably the rate of aggregation as compared to the rate of aggregation in a single chamber of large size. Each chamber may be a passage through which the mixture flows during the aggregating action, the passages in effect dividing the total flow into a number of separate streams in the zone of treatment, although the same aggregating effect can be obtained in chambers in which the mixture is quiescent. The shape of the chambers at right angles to the direction of propagation of the wave motion, i. e. whether round, square or any other shape, is not of primary importance, although in practice I prefer shapes in which all dimensions (at right angles to the propagation) are small, such as rounds, squares, triangles, etc., and especially round and shapes approximating the round, so far as such shapes are obtained conveniently and economically. Generally speaking, the smaller the transverse dimension or dimensions the better is the result, providing all dimensions are large enough to permit the dispersoid particles to move freely; from theoretical considerations it appears that the best results should be achieved when every transverse dimension is equal to or less than one-half a wave length (i. e. one half the length of a wave of the wave motion employed to aggregate the particles), at least when the wave motion is directed into and the dispersoid enters the chamber through an open end of the chamber; for quite short waves however, practical considerations may dictate the use of transverse dimensions larger than this, while in the case of longer waves, the dimensions can approximate more closely the theoretical optimum, as will be understood; taking the various factors into consideration I contemplate that in practice dimensions less than about three inches and

greater than about one-fourth of an inch will be best for most situations at least, with special preference to dimensions of the order of one inch for most ordinary uses, although both larger and smaller dimensions may be used as appears above. Likewise the shape of a chamber in the general direction of the wave propagation within it is not of primary importance; e. g. the chamber walls may be parallel to the direction of propagation, or the chamber may taper along either straight or curved lines (e. g. may be an exponential tube or "horn"). In practice, preferably, the walls of the chambers are made as rigid as reasonably convenient in order to minimize the loss of wave energy through the creation of motion in the walls, and ordinarily (for example, when deposit of aggregates within the chambers themselves is not desired) I prefer that the walls of the chambers be as smooth and continuous as reasonably possible for the same purpose. When a plurality of such chambers are supplied from a single external source of wave motion, the walls of the chambers may be thin, and the chambers packed closely together at, at least, their ends which face the source of the motion, in order that the greatest amount of the energy of each wave from the source may enter them directly. I consider that ordinarily optimum results in any one chamber are obtained when the axis of the chamber is at right angles to the wave front within it; however a group of straight chambers (e. g. tubes) can be placed with their axes parallel to each other, even when the group is supplied from a single source of wave motion producing waves of curved (e. g. spherical) fronts. Further, confining the wave motion within the chambers so far as reasonably possible, as by reflection or by the use of two opposed sources, and thereby producing standing waves or beat notes, conserves the energy of the wave motion.

I believe that the better result of the division is due in part at least, to the fact that while the aggregation is proceeding the division tends to maintain the dispersoids distributed through the whole volume of the carrying medium subject to the wave motion. Also when a source of wave motion producing waves having curved fronts, supplies a considerable area, I believe that the joint action of a plurality of chambers subdividing that area, produces an effect approximating that of flat or plane wave fronts, and that in part at least the improved result may be due to this. However the whole action of the passage of wave motion through areas that are relatively small is of such a complex nature that it is difficult, if not impossible, to ascribe to each of its components the exact part which the respective component plays in the present instance.

My invention accordingly comprehends dividing, as it were, whatever sized wave-motion-treating chamber may be necessary for the quantity of mixture to be treated, into a plurality of smaller chambers, each having preferably at least one dimension of the size indicated, and in each chamber treating a portion of the whole mixture. Further, it comprehends provision for and the use of standing waves with the foregoing. And as before indicated also, the aggregation may be either with or without precipitation or other separation of the dispersoids from carrying mediums. Where separation is desired, separation may be by precipitation or other deposit of the dispersoids within the small chambers where the aggregation occurs (from which chambers the

deposits can be removed either continuously or from time to time by any suitable means), or by passing the mixture through the small aggregating chambers at velocities adequately high to prevent deposits therein of considerable quantities of the dispersoids and the provision of other means, farther along, wherein the dispersoid aggregates are permitted or induced to separate from the carrying medium.

Preferably I employ chambers in the form of tubes.

It is to be understood that in this specification and in the claims which follow it, I use the term "sound waves" as meaning waves of and within the mixtures or the mediums in which the dispersoids are suspended, regardless of the frequency; i. e. regardless of whether the frequency is audible to the human ear or is inaudible.

The accompanying drawing illustrates the foregoing diagrammatically. Each of the three figures of the drawing represents an apparatus for the aggregation and precipitation of dispersoids from a flowing stream of the mixture, and in each instance it can be assumed that the apparatus is used in a horizontal, vertical, or any intermediate position.

Fig. 1 illustrates both aggregating and separating the dispersoids from a medium carrying them. As an example, the mixture can be considered to be the ordinary products of combustion flowing from a furnace, stove, boiler, or the like, i. e. a mixture of combustion gases, ash and fine fuel. The mixture enters the apparatus illustrated through the pipe 1 and passes out through the pipe 2; the latter may be a pipe leading to a smoke stack or chimney, or it may be a chimney or stack itself. The sizes of the pipes 1 and 2 (i. e. their cross areas) may be determined in accordance with prior practices, being sufficient to conduct the quantity of mixture to be handled at the chosen pressures and velocities. The enclosure 3 to the left of the partition 4 is primarily a passageway for convenience to conduct the mixture to the first of the groups 5 and 6 of the aggregating chambers; as shown however, the chamber 3 may be made somewhat greater in cross section than the conductor 1, so that the velocity of the flow of the mixture is somewhat lower in the chamber 3 than in the pipe 1, to the end that more or less of such of the particles of the smoke (ash and fine fuel) as are of separable size, may precipitate before entering the aggregators.

The aggregator 5 comprises primarily a group of round, usually fairly smooth surfaced, say metal, tubes open at both ends, and the walls of which may be only sufficiently thick to make each tube substantially rigid under the pressure exerted on them by the wave motion within them. As illustrated, these tubes may be placed one against another with their axes parallel. With such an arrangement not only does each tube provide a passage for the mixture within itself, but as a group the tubes may provide additional passages for the mixture, between tubes (each of somewhat triangular cross section) which, being left open at their ends (Fig. 1), also can serve as aggregating chambers, thus utilizing substantially the whole of the volume at 5; on the other hand the ends (e. g. both ends) of any such between-tube passages as there may be in any instance, may be closed, as indicated at 7 in Fig. 2, whenever necessary or desirable for any reason, such as to avoid loss of energy in deposits accumulating therein, etc. An outer

wall 5a (e. g. a cylinder) can be placed around the group of tubes to prevent the escape of mixture and sound energy, as shown.

A source 8 of wave motion is placed opposite one end of the group of tubes 5, and is placed sufficiently far from the ends of the various tubes to permit the flow of the mixture from the tubes, or in some other way an escape passage or passages are provided for the mixture. The form of this source is not of primary importance. Ordinarily I use a so-called Hartmann-Trolle air jet oscillator which (as is well known) consists primarily of a block 9 provided with a cavity and a nozzle 10 through which steam, air or other gas is blown into the cavity; the frequency of the resulting sound waves, so-called, i. e. wave motion in the surrounding atmosphere, may or may not be above audibility and depends on cavity dimensions, gas pressure, etc., as also is well known. Usually I place a, say substantially parabolic, reflector 14 around the oscillator 9—10 to collect the wave motion from the source 8 into a beam and direct the beam substantially along the axes of the tubes or other passages and the axis around which the tubes or other passages are grouped, thereby directing into the tubes as much of the wave energy of the source as possible. Either sonic or supersonic frequencies may be used. Generally speaking the higher frequencies permit the use of greater amounts of energy than low frequencies but at the same time the higher frequencies are subject to greater losses of energy per unit length of travel than low frequencies. Ordinarily I contemplate the use of frequencies within the range of from about 1,000 to about 150,000 cycles per second, and more preferably frequencies of from 3,000 to 30,000 cycles per second. In the present instance it can be assumed that the waves produced at 9—10 have a frequency of about 12,000 to 24,000 cycles per second. The rate at which energy is put into the source 8, and by it given out to the contents of the group of passages 5, is of course to be sufficient to aggregate a material part of the dispersoids at any time within these passages, so that the contents of the various passages are not only subjected to sound waves but are subjected to dispersoid-aggregating sound waves. The wave length at any frequency will depend of course on the nature and condition of the mixture passing through the apparatus. It can be assumed that in the present instance the wave length is between four-fifths of an inch and one inch. On such an assumption I would preferably make each of the cylindrical pipes of the group 5 about four-fifths of an inch to one inch in diameter internally, i. e. of a diameter equal to about the length of one wave. As before indicated, tubes of smaller diameter may be more effective, but then the tubes (as well as any open passageways between the tubes) would be more difficult to clear off any dispersoids that might deposit within them. Similarly tubes larger than one inch can be used. In the present instance, for illustration purposes, it is desired that the various passages be kept as free as possible of deposits. Whatever diameter of tube is chosen therefore (in the present instance), such a number of tubes are used in the group 5 that the velocity of the mixture through the passages of the group is so high that at most only the minimum amount of deposit of dispersoid occurs within these passages. Generally speaking, the lengths of the tubes of the group 5 are determined by the extent to which aggre-

gation of the dispersoids within the group is desired, consideration also being given however to such facts as that the wave motion from the source 8 loses energy as it passes through the tubes, and also to external factors that may enter into the matter, e. g. space available, convenience of construction, etc. Whenever however the desired degree of aggregation can not be secured in one group of passages, the mixture can be passed through two or more groups or aggregators in series, as indicated in the present instance by the use of the two aggregators 5 and 6.

At the opposite end of the tube group 5 is placed a reflector 15, of suitable shape to reflect emerging waves back into the tubes as will be understood. For example, the reflector may be a flat sheet of metal held rigidly in place perpendicular to the axes of the tubes of the group 5. The reflector 15 is placed sufficiently far from the group 5 to permit the mixture to flow into the tube group, or other means is provided for the flow of the mixture into the tubes. By proper placements of the reflector 15 and the source 8 of the wave motion (dependent principally on the wave length employed, and as will be understood) the maximum amount of the energy of the source 8 will be delivered into the passages of the group 5 and also standing waves of the maximum amplitudes will be created within those passages.

A chamber or passage 16 is provided to receive the mixture passing from the group of passages 5. There being in the instance illustrated a second aggregator 6 for reasons before explained, this chamber 16 leads the mixture to the second aggregator. In the present instance this chamber 16 is larger in cross section than the sum of the cross areas of all the passages in the tube group 5, so that the mixture flows more slowly in this chamber and accordingly permits the precipitation therein of at least some of the dispersoids that have been aggregated in 5 to perceptible size. Where separation of the dispersoid or dispersoids from their carrying medium is not desired, or where a preliminary aggregator such as 5 does not aggregate to separable sizes, this latter feature of the intermediate chamber 16 may be omitted. Speaking more generally however regarding passageways such as 16 between successive aggregators, if separation of the dispersoid from the carrying medium is desired I prefer to provide behind each aggregator aggregating to separable sizes, in advance of the next in the series, a separator (either one of the reduced-velocity precipitator type like 16 or otherwise), to remove from the flowing mixture either some or all of the dispersoids that have reached a readily separable size up to that point. The primary purpose of this is to reduce as much as conveniently possible to the deposit of dispersoids in the subsequent aggregators.

From the chamber 16 the mixture (or rather the gaseous carrying medium and presumably a remnant of the initial dispersoids) enters the aggregator 6. This second aggregator may be quite or substantially like the aggregator 5. The group of tubes comprising 6 is supplied with wave motion by a source 17 allocated especially to them, and is provided with reflector 18 at their opposite ends. The source 17 and reflector 18 may be like 8 and 15, and similarly placed with respect to the tube group. As indicated, it is not of primary importance, at least in instances such as that illustrated, whether the source of the wave motion faces against the direction of the flow of the mixture, or faces in the same direc-

tion. At the outlet of the last aggregator 6 is placed a separator 19 to collect and separate from the gases or carrying medium, so far as desired and reasonably possible, such of the dispersoids as are of separable sizes on leaving the last of the aggregators. This is to prevent the aggregated particles from passing into the pipe, chimney or stack 2, and, like 3 and 16, can be omitted if separation of dispersoids from the carrying medium is not desired. The separator 19 can be of the same type as 16, i. e. a chamber of such size in effective cross section that the velocity of the gases therein is low enough to permit aggregates to precipitate, or it can be a separator of any other type that is suitable for the purposes in hand.

In the operation of an apparatus like that of Fig. 1 therefore, the mixture to be cleared enters through the pipe 1, and is cleaned of its dispersoids more or less as it flows through the apparatus continuously. In the present instance the mixture deposits in the chamber 3 any particles already sufficiently large to precipitate at the lower velocities reasonably possible in a chamber at 3. Within the group of passages at 5 the flow is divided into a number of separate streams, and each stream is subjected to dispersoid-aggregating sound waves (i. e. wave motion of and in the carrying medium of the mixture itself), and is subjected to particularly intense wave motion due to the creation of standing waves within these passages by the use of the reflector 15 to supplement the wave source 8. Due to the division of total mixture between the various passages (chambers) the aggregation of small particles of the dispersoids of the mixture into larger particles proceeds at a higher rate than otherwise. The high velocity of the mixture in the passages at 5 tends to sweep the dispersoids, both aggregated and unaggregated, along with the carrying medium, and hence prevents deposits in those passages. As the mixture passes through the chamber 16, particles previously aggregated to sizes large enough to precipitate at the lower velocity of this chamber, fall to its floor. Within the passages of the group or aggregator 6, the mixture, or remnant of the mixture, is again subjected to dispersoid-aggregating sound wave motion, as a result of which there is further aggregation of dispersoids. Within the chamber 19 there occurs precipitation of those particles which, on leaving 6, have reached sufficient size to precipitate from the carrying medium (combustion gases) at the reduced gas velocity prevailing in the chamber 19. As a result, the combustion gases pass into the pipe, chimney or stack 2 free of more or less of the ash and fine fuel initially entrained in them, the extent to which these gases are freed of these dispersoids depending on the extent to which dispersoids have been aggregated in the chambers at 5 and 6 and separated out by the separators 3, 16 and 19. Generally speaking, any aggregated particles not separated out at 3, 16 and 19, will fall to the ground more promptly after leaving the chimney or stack than otherwise; i. e. the ash and fine fuel of the smoke will be less widely distributed than though there were no aggregation before leaving the chimney or stack.

Fig. 2 illustrates a form of apparatus which differs from the form of Fig. 1 principally in that two wave motion sources or generators are used with a group of passages in lieu of a single generator, or a single generator and a reflector.

Two such sources facing each other through the same chamber or group of chambers, and of the same or substantially the same frequency, produce of course within that chamber or group of chambers either standing waves, or substantially the same effect in the form of beat notes traveling the chamber or chambers more or less slowly.

In the example illustrated, combustion gases with entrained ash and fuel particles enter the apparatus through the pipe 30 and pass into a chamber 31 containing a source 32 of wave motion, which may be quite like the wave generator 8 of Fig. 1. The flow of mixture may be continuous as before, although this is not necessary in either Fig. 1 or Fig. 2. The volume of chamber 31 (not counting the volume of the source 32) may be great enough to reduce the mixture velocity to a point where particles already ready of precipitable size will be deposited, as in the case of chamber 3 of Fig. 1. The flow continues through a group of passages 33 which may be like the group 5 of Fig. 1, and of sizes determined on the same principles. The wave generator 32 faces toward the pipes at one end of the group. From the passages at 33 the flow of the mixture passes into a chamber 34 containing the second wave motion generator 35, which may be similar to 32 and which faces toward the opposite end of the passage group 33. The volume of chamber 34 (not counting the volume of the source 35) may be great enough to induce precipitation through reduction of velocity as in chambers 16 and 19 of Fig. 1. From the chamber 34 the combustion gases, more or less deprived of solid particles, pass to 36 which may be a pipe, chimney or stack, or which may lead to another group of passages or an aggregator of another form. It can be assumed that the generators or sources 32 and 35 produce waves of the same or substantially the same frequency.

Except for the fact that both of the opposing wave motions proceed from sources of sound energy, and for such differences in wave form and interaction as will result from the two sources producing wave motion of different frequencies (which will be understood), the operation of the apparatus of Fig. 2 is so like the action at and near the passage group 5 of Fig. 1 that no further description of the operation of Fig. 2 is needed.

It will be understood that collected solids may be removed from the various collection chambers, e. g. 3, 16, 19, 31, 34 in any one of various manners.

Fig. 3 illustrates diagrammatically that there may be a source of sound energy for each chamber, and also one of the possible forms of tapered chamber with one of the possible dispositions of a sound energy source with respect to a tapered chamber. It can be assumed that there are a number of the chambers shown which divide the total flow of the mixture among themselves, each provided with an energy source as shown. Briefly the chamber 40 is tapered continuously from one end to the other along straight lines and receives sound waves from the source 41 which may be of the same kind as the source 8 of Fig. 1. In the present instance the source 41 delivers its waves into the large end of the chamber; with such an arrangement it will be observed that the tapering can be used to offset more or less the tendency of the energy intensity of a wave to fall as the wave moves through

the chamber from the source 41, or even to concentrate the active energy. At least theoretically however, the wave source can be at either or both ends. The direction of flow of the mixture through the tube is not of primary importance. If however the sound source is at the (or a) large end of the tapered chamber, and the mixture flows from this large end toward the smaller section, it will be observed that the taper can be used to more or less maintain the initial energy density (or, conceivably, even produce greater energy densities) as the sizes of the dispersoid particles increase by aggregation. Standing waves and beat pulsations may be produced in the tapered form of chamber, as will be understood from the foregoing.

It is to be understood that my invention is not limited to the details of construction and operation illustrated in the accompanying drawing and described above, except as appears hereafter in the claims.

I claim:

1. The method of aggregating dispersoids of a quantity of a mixture which consists in dividing said quantity among a plurality of chambers grouped around an axis, producing dispersoid-aggregating sound wave motion, and collecting such motion into a beam and directing said beam substantially along said axis into said chambers.

2. The method of aggregating dispersoids of a

quantity of a mixture which consists in dividing said quantity among a plurality of chambers the axes of which are substantially parallel to each other, producing dispersoid-aggregating sound wave motion, and collecting such motion into a beam and directing said beam substantially parallel to said axes into said chambers.

3. Dispersoid-aggregating apparatus comprising walls providing a plurality of closely disposed passages the axes of which are substantially parallel to each other, means providing a flow of mixture for division among and flow through said passages, and a single source, adjacent one end of said plurality of passages, to produce dispersoid-aggregating sound waves in all the passages of said plurality.

4. The combination with the subject matter of claim 3, of means to collect sound wave motion of said source into a beam and direct said beam in a direction substantially parallel to said axes into said passages.

5. The combination with the subject matter of claim 3, of means to collect sound wave motion of said source into a beam and direct said beam in a direction substantially parallel to said axes into said passages, and means at the opposite end of said plurality of tubes to propagate sound waves into said passages in a direction toward said source.

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