April 6, 1954

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2,674,499

ELEVATION OF GRANULAR SOLIDS

Filed April 16, 1951

2 Sheets-Sheet 1

Fig. 1

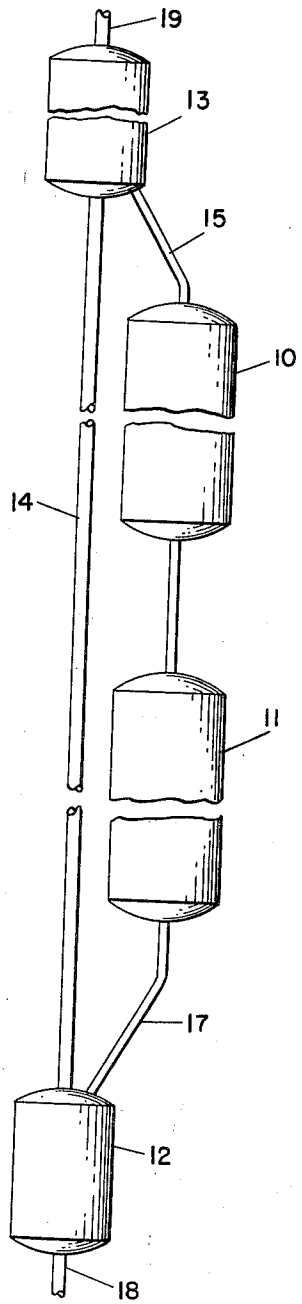


Fig. 2

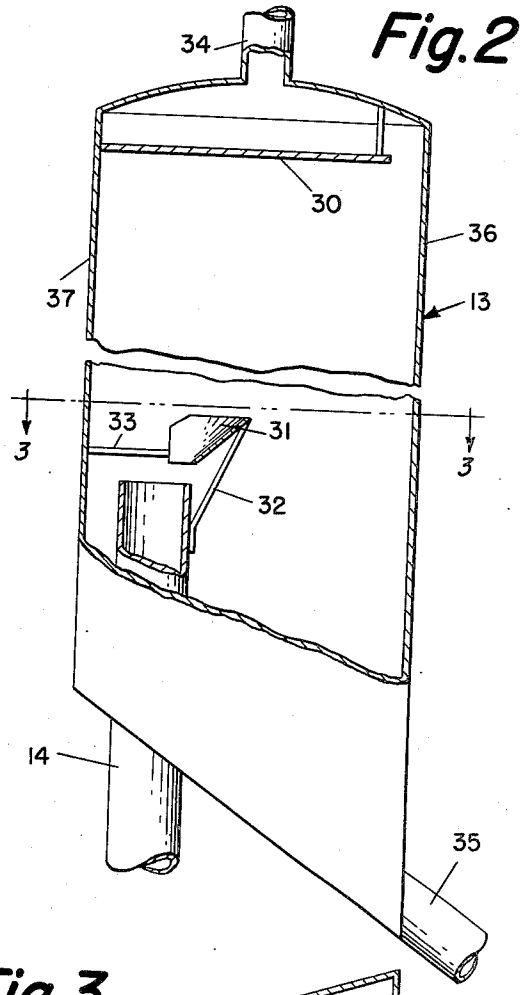
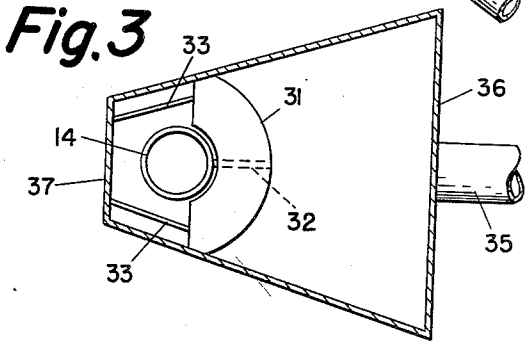


Fig. 3



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Fig. 4

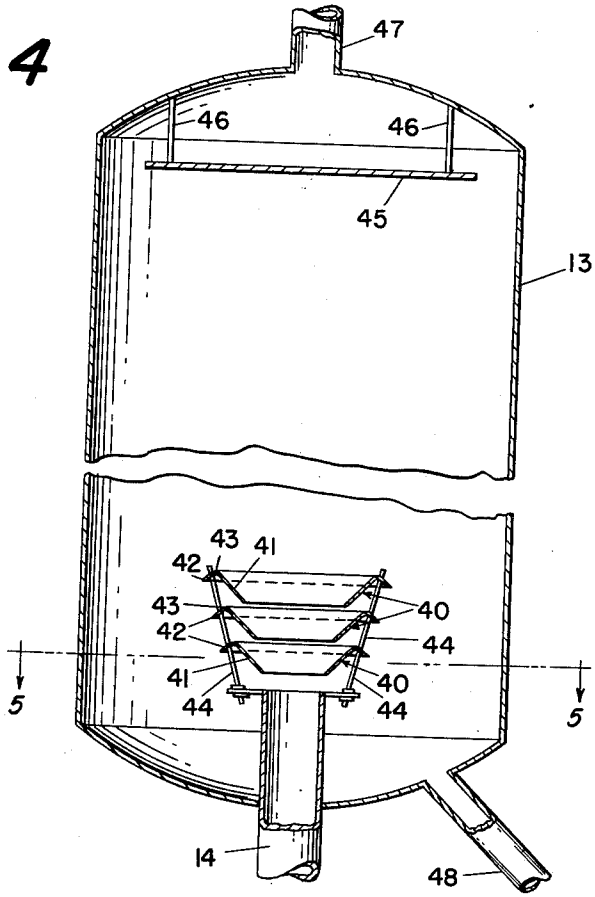
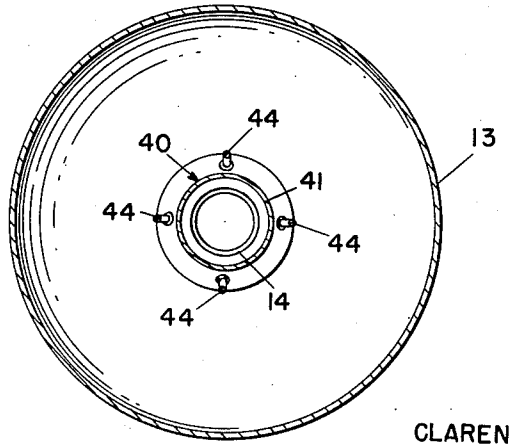


Fig. 5



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UNITED STATES PATENT OFFICE

2,674,499

ELEVATION OF GRANULAR SOLIDS

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Application April 16, 1951, Serial No. 221,285

6 Claims. (Cl. 302—59)

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This invention relates to the elevation of granular solids by means of a lifting gas and more particularly to the separation of solids from gas after such elevation.

According to the present invention granular solids are suspended in lifting gas and elevated through a confined zone to an expansion zone providing space for substantial lateral expansion of lifting gas. After discharge from the confined zone, gas and solids pass through the expansion zone as a rising stream. The solids in the rising stream are concentrated near the center thereof, whereas the lifting gas in the rising stream expands toward the periphery thereof and outwardly therefrom.

In the method of the present invention the lifting gas at the periphery of the rising stream is interrupted in its vertical upward movement and is passed upwardly and laterally as an inclined stream away from the rising stream. This interruption of the upward movement of the lifting gas is accomplished substantially without interruption of the vertical upward movement of the solids in the rising stream; that is, the removal of the gas from the rising stream is selective. As the rising stream passes upwardly beyond the level at which a portion of the gas is removed from the periphery, the remainder of the lifting gas expands laterally toward the periphery of the rising stream more rapidly than it would expand if the first named portion of the lifting gas had not been removed.

The method of the present invention, as described above, advantageously provides for a more rapid lateral expansion of the rising stream of gas and solids than can be obtained according to prior art methods. This lateral expansion is advantageous in that it results in a more rapid deceleration of the solids in the rising stream so that these solids reverse direction and fall back toward the bottom of the expansion zone more rapidly than they otherwise would. Also the more rapid lateral expansion of the lifting gas tends to cause the solids in the rising stream to be deflected laterally so that they have less tendency, after deceleration of the upward velocity to zero, to fall backward directly on the solids rising from beneath. It is advisable to avoid having the solids fall directly back in this way because excessive attrition of the solids is thereby also avoided.

A more rapid deceleration of the rising stream also is effective to decrease attrition since the solids do not rise as high on the average in the expansion zone and therefore have less far

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to fall before coming to rest on a surface beneath the top of the lift conduit. It is advisable to minimize the distance through which the granular solids fall before striking a rigid surface, because the degree of attrition which occurs upon their striking the surface is proportional to that distance.

The method of the present invention is applicable to granular solids generally and is particularly advantageous, for reasons as pointed out above, for use in the elevation of granular solids which are subject to substantial attrition upon striking rigid solid surfaces. Examples of types of granular solids which can be advantageously elevated according to the present invention are granular solid catalysts such as silica-alumina catalysts suitable for use in hydrocarbon conversion and inert refractory contact material such as is frequently used in noncatalytic conversion of hydrocarbon materials. Other types of granular solids can be elevated according to the present invention.

The method of the present invention is particularly advantageously used with mixtures of coarse granular solids, which mixtures contain for example a major proportion of solids which are too large to pass a 20 mesh U. S. sieve series screen. In the elevation of such mixtures, it is necessary because of the coarse nature of the particles, to employ lifting gas at relatively high velocity. The use of such velocity tends to result in a relatively high attrition of the solids unless measures are taken, such as the method of the present invention, to reduce the attrition.

The lifting gas which is used according to the method of the present invention can be any suitable lifting gas. It can be either a material which is unreactive with the solids which are to be lifted, or it can be a material which reacts in the presence of the granular solids to form vaporous conversion products. Examples of the first type of lifting gas are steam, air, or flue gas as used in the elevation of granular contact material used in hydrocarbon conversion. An example of the second type of lifting gas is vaporized hydrocarbon as used in elevation, at hydrocarbon conversion temperatures, of granular contact material capable of promoting hydrocarbon conversion.

According to the present invention granular solids are elevated through an elongated confined zone before being discharged into the expansion zone as described above. The invention is particularly advantageous when used in lifting

operations wherein the length of the elongated zone is at least 50 times the major dimension of the cross section of the confined zone. When solids are lifted through such elongated confined zones a relatively high velocity of lifting gas must be employed, with resulting high attrition unless measures, such as the method of the present invention, are used to reduce attrition. In many industrial processes it is necessary to elevate solids at relatively high rates through distances of 100 feet or more and the method of the present invention can be advantageously used in many such applications.

The invention will be further described with reference to the attached drawings. Figure 1 is a schematic diagram of a system of apparatus employing a gas lift from a low level in the system to a high level therein. Figure 1 does not show any details of the apparatus employed according to the present invention and merely illustrates the type of system to which the invention is advantageously applied. Figure 2 is a sectional elevational view showing details according to the present invention, of a disengaging vessel providing an expansion zone into which solids and gas are discharged from the top of a confined lift conduit. Figure 3 is a sectional plan view of the disengager shown in Figure 2. Figure 4 is a sectional elevational view of another type of disengager to which the invention may be applied. Figure 5 is a sectional plan view of the disengager shown in Figure 4.

Referring now to Figure 1, there are shown therein reaction vessels 10 and 11, a gas lift engaging vessel 12, a gas lift disengaging vessel 13, and a lift conduit 14 communicating at its lower end with engaging vessel 12 and communicating at its upper end with disengaging vessel 13.

In operation granular solids gravitate downwardly from disengaging vessel 13 through line 15 into reaction vessel 10 which may be, for example, a hydrocarbon conversion reactor. After gravitating downwardly through vessel 10, the solids pass therefrom into vessel 11 which may be, for example, a regenerator as used in a hydrocarbon conversion process. The solids gravitate through vessel 11 and therefrom through line 17 into engaging vessel 12. Lifting gas is introduced into engaging vessel 12 through line 18 and rises through lift conduit 14 carrying suspended solids with it. Lifting gas and granular solids are discharged from the top of the lift conduit 14 into disengaging vessel 13 and pass upwardly therein as a rising stream of gas and solids.

By virtue of the fact that disengaging vessel 13 provides an expansion space, the lifting gas expands and decelerates in disengaging vessel 13. The solids also decelerate and fall backward from the rising stream into the bottom of the disengaging vessel 13 and are removed downwardly through line 15. The lifting gas is removed separately from the solids through line 19.

Referring now to Figures 2 and 3, there is shown in these drawings disengaging vessel 13 above and communicating with the upper end of lift conduit 14. The disengaging vessel shown in Figures 2 and 3 has a shape which is particularly well adapted for use in apparatus providing a plurality of disengaging chambers within a single disengaging vessel. Such apparatus is useful in certain industrial applications, as discussed in copending application, Serial No. 203,323 of Clarence H. Thayer, filed December 29, 1950.

Disengager vessel 13 provides therein a space directly above the upper end of lift conduit 14. Lift conduit 14 being shown as cylindrical in Figure 2, the space above the top of the lift conduit 14 is a cylindrical space extending upwardly to transverse baffle 30. Vessel 13 also provides an expansion space laterally disposed with reference to the space directly above the top of the lift conduit. Within this expansion space an inclined baffle 31 is supported by rods 32 and 33. This baffle has the shape of a portion of an inverted frustoconical section. The side of the frustoconical section is inclined downwardly toward the space directly above the top of the lift conduit. The baffle 31 extends a little less than half way round the periphery of the space directly above the top of the lift conduit and at no point does it extend into that space. Also shown in Figure 2 are an outlet 34 for lifting gas at the top of vessel 13 and an outlet 35 for granular solids at the bottom of vessel 13.

In operation granular solids and lifting gas are discharged from the upper end of lift conduit 14 and pass through the space directly above the top of the lift conduit as a rising stream of gas and solids. The solids in the rising stream are concentrated at the center thereof, and do not substantially impinge on the baffle 31. The lifting gas on the other hand, as it rises from the top of the lift conduit 14 expands laterally toward the baffle 31 and a portion of that lifting gas is removed from the periphery since it impinges on the under side of baffle 31 and is deflected upwardly and laterally away from the rising stream. The remainder of the lifting gas as it passes above the lower edge of the baffle 31 expands toward the periphery of the rising stream to take the place of the lifting gas which has been removed. As the rising stream passes upwardly in vessel 13 it decelerates and the solids fall backwardly therefrom toward sidewall 36 of the vessel 13. The solids fall into the bottom of vessel 13 and are removed through line 35. The lifting gas passes around and above the baffle 30 and is removed substantially separately from the main bulk of the granular solids through outlet 34. The portion of lifting gas which is removed underneath baffle 31 passes around the upper edge of that baffle and upwardly through the disengaging vessel 13 and is commingled in the upper portion of vessel 13 with the remainder of the lifting gas and passes therewith through outlet 34. By this time, however, the lifting effect of the removed portion of the lifting gas has been dissipated and the original removal of this lifting gas has caused the solids to rise less far in the vessel 13 than they would if the gas were not removed under baffle 31.

Figures 4 and 5 illustrate a form of disengaging vessel 13 which differs from the disengaging vessel shown in Figures 2 and 3 in that lift conduit 14 in Figures 4 and 5 is positioned centrally with regard to the disengaging vessel rather than at the side thereof as in Figures 2 and 3, and also in that the baffles used as shown in Figures 4 and 5 to deflect a portion of the lifting gas in the rising stream extend around the entire periphery of the space directly above the lift conduit. In Figures 4 and 5 there are shown also a plurality of baffles 40, the baffles being vertically spaced apart. Each baffle has an inner portion in the shape of an inverted frustoconical section 41 and

an outer portion in the shape of an upright frustoconical section 42. The two frustoconical sections in each baffle 40 are connected at their tops by a smoothly curved surface 43. The base diameter of the inverted frustoconical section in each baffle above the lowermost baffle is greater than the base diameter of the inverted frustoconical section of the adjacent baffle therebeneath and the base diameter of the inverted frustoconical section of each baffle above the lowermost baffle is less than the diameter of the top of the inverted frustoconical section of the adjacent baffle therebeneath.

Also shown in Figures 4 and 5 are supports 44 providing the desired spacing of the baffles 40 from each other and from the top of lift conduit 14. Transverse baffle 45 is supported from the top of vessel 13 by means of support rods 46. Also shown in Figure 4 are the gas outlet 47 at the top of the vessel 13 and a solids outlet 48 from the bottom of vessel 13.

The operation of the apparatus shown in Figures 4 and 5 is similar to the operation of the apparatus shown in Figures 2 and 3, one difference being that with the apparatus of Figures 4 and 5, lifting gas is removed from around the entire periphery of the rising stream of gas and solids as that stream passes through the central apertures of the baffles 40. Another difference is that with the apparatus of Figures 4 and 5, the lifting gas which is removed and passes underneath each baffle 40 is reversed in its direction of vertical movement after it is passed upwardly and laterally beneath the inner frustoconical section, and after such reversal is passed downwardly and laterally underneath the outer frustoconical section. This type of operation is preferred in that it minimizes the tendency of the lifting gas to rejoin the rising stream passing above the baffles 40.

In Figure 4, the smoothly curved connecting portions 43 of the baffles 40 have the general shape of an upper portion of a torus coaxial with the lift conduit, that upper portion being the portion lying above the intersection of a horizontal plane with the torus. It is to be understood that, according to the invention, the connecting portions 43 can be used in the absence of the upright frustoconical sections 42, in which case the connecting portions 43 provide, for the upper portion of each baffle, an outwardly and downwardly turned lip, which in turn provides a reversal of direction of vertical movement for the gas removed beneath each baffle.

The apparatus and operation as described above in connection with Figures 4 and 5 represent the application of the present invention to a type of apparatus wherein the disengaging vessel provides an expansion space which completely surrounds the space directly above the top of the lift conduit. The apparatus and operation as described in connection with Figures 2 and 3, on the other hand, represent the application of the invention to a type of apparatus wherein only a portion of the space directly above the top of the lift conduit communicates with an expansion space providing a significant degree of lateral expansion. Referring to Figure 3, lift conduit 14 being adjacent sidewall 37 of disengager 13, the only substantial lateral expansion provided for is toward the wall 36 of vessel 13. According to the present invention, the inclined baffle which is used to remove a portion of the lifting gas preferably extends completely around that portion of the space directly above

the top of the lift conduit which communicates with the expansion space providing space for substantial lateral expansion of lifting gas. Baffle 31 shown in Figure 3 has this preferred construction.

Baffles 40 which are used according to the present invention and which are of inverted frustoconical section are inclined at an angle with the horizontal within the approximate range of 30° to 60°. They also preferably have outer upright frustoconical portions which are inclined to the horizontal within the approximate range of 30° to 60°. Baffle 31 has a like inclination to the horizontal and may be provided (although it is not so shown) with an extension like those provided for baffles 40, having a like degree of inclination.

The horizontal distance of the outermost portion of each baffle from the longitudinal axis of the lift conduit is preferably within the approximate range 1.0 to 2.5 times the major dimension of the top of the lift conduit, in order that the removed lifting gas will be deflected to a point which is laterally spaced far enough from the rising stream so that the removed gas will not have a disadvantageously great tendency to rejoin the rising stream.

As the rising stream of gas and solids passes upwardly through the expansion zone in operation according to the present invention, the central solids stream gradually widens and expands laterally beyond the space directly above the top of the lift conduit. The rate of expansion varies with the operating conditions. The baffle plate used according to the present invention does not extend into the space occupied by the central solids stream. For any set of operating conditions, a person skilled in the art can, in the light of the present specification, determine the position of the baffle plate which provides substantial interruption of vertical upward movement of lifting gas without substantial interruption of upward movement of solids.

The vertical level at which a baffle according to the present invention is positioned can vary. The level is preferably one at which the central solids portion of the rising stream has expanded laterally relatively little. If the baffle is positioned at a level where the central solids stream has expanded laterally to a relatively great degree, there is a greater tendency for stray solid particles to strike the baffle surface, with resulting greater attrition of particles and erosion of the baffle. Generally, it is preferred for the above reason that the vertical distance from the bottom of the baffle to the top of the lift conduit should not be substantially greater than ten times the major dimension of the cross section of the top of the lift conduit.

More preferably, the bottom of the lowermost baffle plate, or of the single baffle plate if only one baffle plate is used, is vertically spaced apart from the upper end of the lift conduit a vertical distance within the approximate range 0.1 to 1.0 times the major dimension of the top of the lift conduit.

The baffle 31 or 40 according to the present invention is vertically spaced apart from the rigid surface providing an upper boundary of the space directly above the top of the lift conduit, such surface for example as the baffle plate 30 in Figure 2, a distance great enough to allow, above the baffle, a sufficient space for reversal of direction of movement of solids. A person skilled in the art can, in the light of the present specifica-

tion, determine what this distance should be for a given set of operating conditions.

A baffle having given dimensions can be moved upwardly or downwardly relative to the top of the lift conduit to compensate for changes in operating conditions. For example, if the velocity of the gas-solids rising stream is decreased, with resulting more rapid lateral expansion of the central solids stream, the baffle can be moved downwardly to prevent the solids for impinging thereon. Means for vertical adjustment of the baffle not being herein claimed and being within the skill of the designer, is not shown.

The following example illustrates the invention:

A gas lifting operation was carried out in apparatus including a disengaging vessel substantially as shown in Figures 4 and 5. An eight-inch diameter cylindrical lift conduit was used, the top of the conduit being positioned about 17.5 feet beneath a transverse baffle such as the baffle 45 shown in Figure 4. The lowest baffle plate had base diameter of about 8.7 inches and the bottom of the lowest baffle plate was spaced apart from the top of the lift conduit, a vertical distance of about 2.5 inches. The intermediate baffle plate had base diameter of about 9.7 inches and had its bottom spaced about 4 inches vertical distance from the bottom of the lowest baffle plate. The highest baffle plate had base diameter of about 10.7 inches and had its bottom spaced about 4 inches vertical distance from the bottom of the intermediate baffle plate. Each baffle plate was slightly less than 4 inches in vertical height, from the bottom thereof to the highest point of the smoothly curved connecting portion thereof. The angles of inclination of both frustoconical portions of each baffle were about 45° with the horizontal. The overall width of the lowest baffle was about 20 inches; of the intermediate baffle, about 21 inches; and of the highest baffle, about 22 inches. All three baffles were concentric with the lift conduit.

The operation of the disengager described above with the three inclined baffle plates in place was compared with that of the same disengager with all three baffle plates removed. In each case, the disengager was used as part of a gas lift system including an engager vessel, wherein solids were suspended in lifting gas, and a lift conduit extending upwardly from the engager to the disengager. The solids elevated were cracking catalyst pellets, a major proportion of which were large enough to be retained on a 20 mesh U. S. sieve series screen, and substantially all of which were small enough to pass a 3 mesh U. S. sieve series screen. Compressed air was used as the lifting gas. In each case, the maximum height of rise of solids above the top of the lift conduit was measured. It was found that at the same lifting gas and solids rates, the height of rise of solids above the top of the lift conduit was about 1.5–2.0 feet less when the baffle plates were in place than when they were not. For example, when the lifting gas and solids rates were such as to provide a solids velocity at the top of the lift conduit of about 31 feet per second, the following were the heights of rise:

	Feet
Without baffle plates	11.5
With baffle plates in place	9.5

The solids velocity given above was calculated according to the following formula:

$$u_s = ug - 9.9\sqrt{\frac{D_s d_s}{dg}}$$

Where u_s is solids velocity in feet per second, ug is lifting gas velocity calculated by dividing the measured lifting gas rate in cubic feet per second by the average cross-sectional area of the lift conduit in square feet, D_s is average particle diameter of the lifted solids in feet, and d_s/dg is the ratio of densities of the lifted solids and of the lifting gas.

When a plurality of baffle plates are employed according to the present invention, it is preferred that the vertical distance between the bottom of each of the upper baffle plates and the bottom of the adjacent baffle plate therebeneath should be within the approximate range 0.1–1.0 times the major dimension of the cross section of the upper end of the lift conduit.

The invention claimed is:

1. In apparatus for elevating granular solids by means of a lifting gas through a lift conduit and into a disengaging vessel providing therein a vertically elongated space directly above the top of the lift conduit and providing, surrounding and in communication with said space, a vertically elongated expansion space for expansion of lifting gas, the improvement which comprises: a plurality of vertically spaced apart, concentric baffle plates each within said expansion space and positioned adjacent and surrounding said space directly above the top of the lift conduit, each baffle plate having an inner inverted frustoconical portion inclined at an angle with the horizontal within the approximate range 30° to 60° and an outer upright frustoconical portion joined at its top to the top of said inverted frustoconical portion by a smoothly curved surface, the base diameter of the inverted frustoconical portion of each baffle plate above the lowermost baffle plate being greater than the base diameter of, and less than the top diameter of, the inverted frustoconical portion of the adjacent baffle plate beneath, the bottom of each baffle plate being vertically spaced apart, from the bottom of the adjacent baffle plate beneath, a distance within the approximate range 0.1–1.0 times the major dimension of the cross section of the upper end of said lift conduit, and the bottom of the lowermost baffle plate being vertically spaced apart from the upper end of said lift conduit a distance within the approximate range 0.1–1.0 times said major dimension, and the base diameter of said upright frustoconical portion being within the approximate range 2–5 times said major dimension.

2. In apparatus for elevating granular solids by means of a lifting gas and for separating granular solids from lifting gas after such elevating, which apparatus comprises a lift conduit and disengaging chamber within which the upper discharge end of said lift conduit is positioned, said disengaging chamber providing above said upper discharge end of said lift conduit a space for upward travel of granular solids and lifting gas and providing, laterally positioned with regard to said space for upward travel, a space for downward travel of granular solids, said disengaging chamber having outlets for granular solids and lifting gas, the improvement which comprises: a baffle plate within said disengaging chamber and positioned between said space for upward travel and said space for downward travel, said baffle plate being downwardly inclined toward said space for upward travel, the lower end of said baffle plate being spaced above said upper discharge end of said lift conduit and adapted to interrupt the vertical upward movement of lifting gas at the

periphery of the stream of lifting gas rising through said space for upward travel.

3. Apparatus according to claim 2 wherein said baffle plate extends partially a substantial distance around the periphery of said space for upward travel.

4. Apparatus according to claim 2 wherein said baffle plate extends substantially entirely around the periphery of said space for upward travel.

5. Apparatus according to claim 2 wherein said baffle plate has an inverted frustoconical portion extending substantially entirely around the periphery of said space for upward travel, the lower end of said portion being adapted to interrupt the vertical upward movement of lifting gas at the periphery of said stream, and has an upright frustoconical portion whose top is connected by a smoothly curved portion to the top of said inverted frusto-conical portion.

6. Apparatus for elevating granular solids by means of a lifting gas and for separating granular solids from lifting gas after such elevating which

comprises: a lift conduit; a disengaging chamber communicating with the upper end of said lift conduit; means for passing lifting gas and solids upwardly through said lift conduit and therefrom into said disengaging chamber as a rising stream; baffle means for deflecting lifting gas from the periphery of said rising stream laterally away from the longitudinal axis of said rising stream, while substantially uninterruptedly passing the solids in said rising stream upwardly past said means; and means for removing lifting gas and solids from said disengaging chamber.

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