

Dec. 13, 1960

D. G. BOSSE
MIXING APPARATUS

2,964,301

Filed June 5, 1957

3 Sheets-Sheet 1

Fig. 1

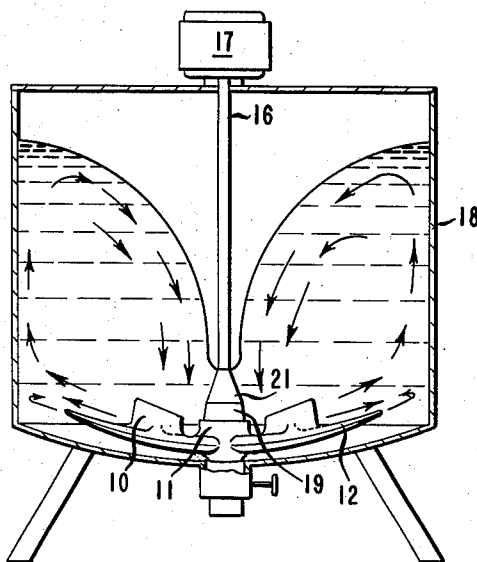


Fig. 2

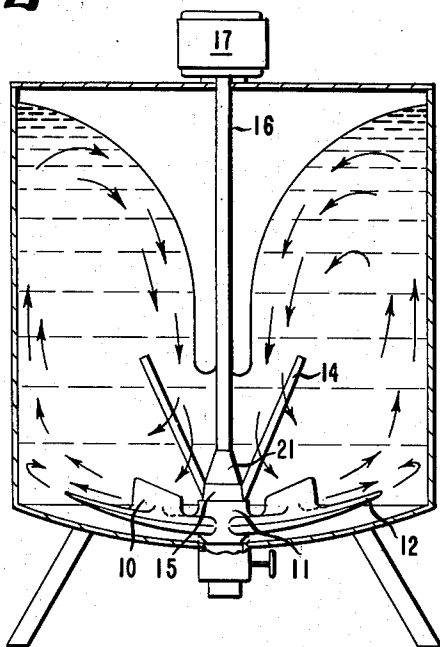
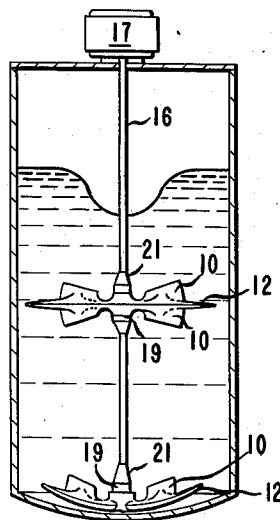


Fig. 3



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Fig. 4

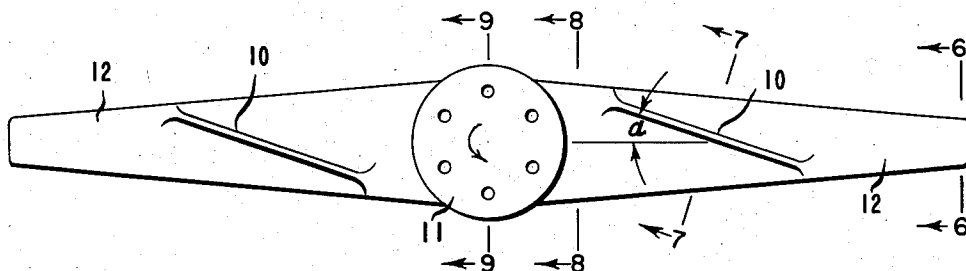


Fig. 5

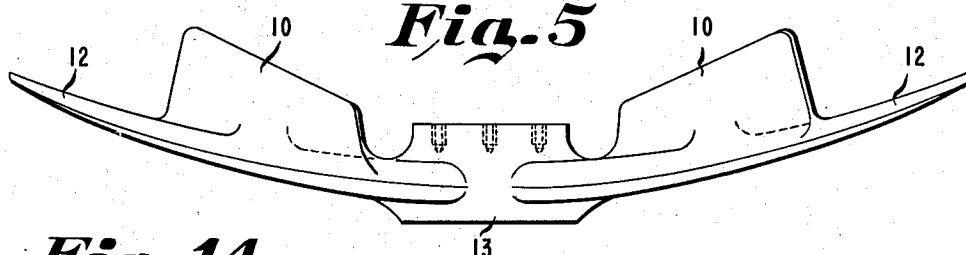


Fig. 14

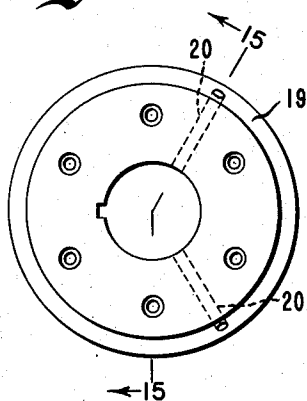


Fig. 15

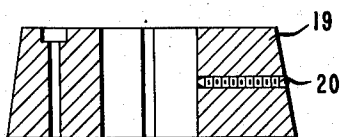


Fig. 6



Fig. 7

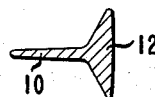


Fig. 8

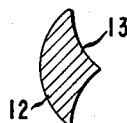
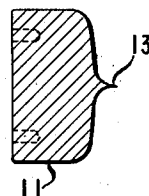


Fig. 9



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Fig. 10

Fig. 13

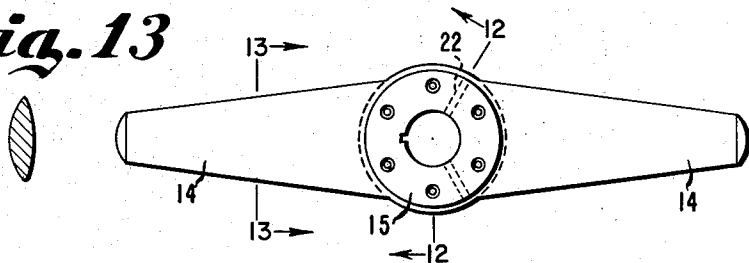


Fig. 12

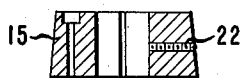


Fig. 11

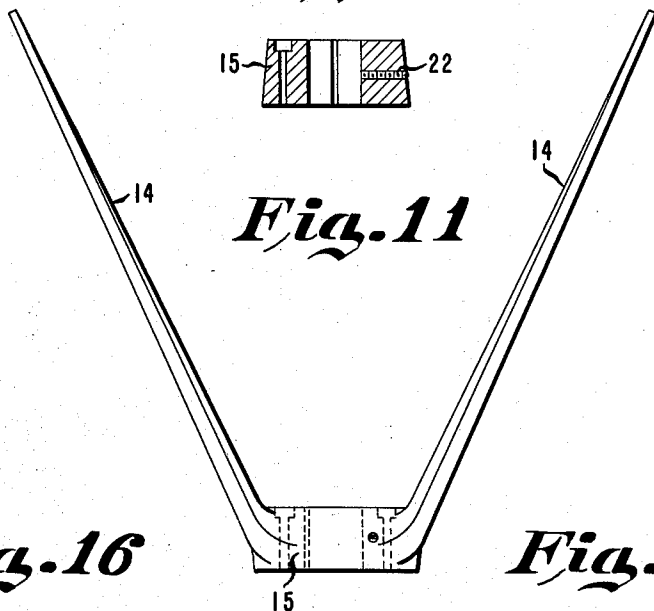


Fig. 16

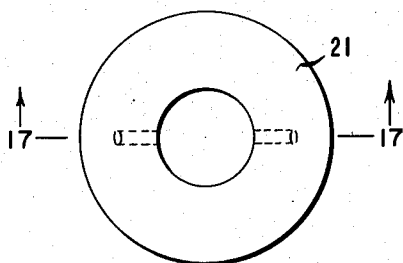
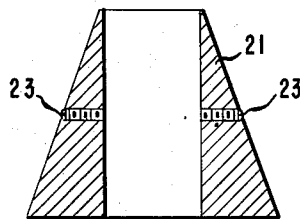


Fig. 17



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MIXING APPARATUS

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10 Claims. (Cl. 259—107)

This invention relates to a mixing apparatus and more particularly to an agitator assembly with a primary impeller consisting of a pumping section and a streamlined sweep section.

For many applications conventional fluid agitators have serious deficiencies. Most known agitators do not, for example, operate satisfactorily on fluids which vary widely in viscosity. Thus, they do not work well when they are used to agitate vehicles to which pigments are being added. Conventional agitators designed for use in low-viscosity fluids do not vigorously nor adequately agitate fluids having a high viscosity. Conversely, agitators designed to operate at a fixed speed in viscous fluids produce too violent mixing in low-viscosity fluids.

Agitators with short impeller blades, especially when they are used in fluid bodies having high viscosities, do not adequately circulate fluid near the side and top of the bodies. When conventional long-bladed impellers are used to get more complete circulation, the difference in speed between the impeller blades and the fluid body is so small that there is little agitation of the fluid. Also, if fluid bodies agitated by conventional agitators are rotated fast, they form deep concave vortices and have high freeboard requirements. Baffles, fastened to tank walls to improve the mixing of low-viscosity fluids do not greatly improve the mixing of fluids with high viscosities and, in addition, they cause dead zones.

Agitators consisting of several impellers set at different elevations in a tank are often used to improve mixing near the surface of a fluid body. Such conventional multiple-impeller agitators, however, cause relatively isolated mixing zones and poor vertical circulation. In addition, if the height of the fluid being agitated varies and some of the blades are partly exposed, such agitators often beat large quantities of air into the fluid.

Finely divided dry solids, such as pigments and low-density fluids, often float on the surface of agitated fluid bodies. The dry solids floating on the surface also often form into lumps which accumulate near the shaft of the agitator. These problems of dispersing dry solids and liquids can only be solved by vigorous top-to-bottom circulation; however, finely divided solids and undispersed liquids accumulate on and adjacent to baffles which are conventionally fixed to tank walls to improve vertical circulation.

I have discovered an agitator which can be operated successfully at constant speed in fluids having a wide range of viscosities. This agitator also causes excellent top-to-bottom circulation, incorporates little air in the agitated fluids and has low freeboard requirements.

The agitator of this invention employs a primary impeller comprising a pumping section consisting of at least two blades having a projected height of at least about 0.2 times their radial length and a sweep section consisting of at least two streamlined blades having a radial length of about from 1.2 to 2.0 times the radial length of the blades of the pumping section. Optionally, the aforementioned primary impeller can be used in combi-

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nation with a diagonal booster impeller which is positioned above the primary impeller and comprises at least two streamlined blades projecting upwardly at an angle of about from 10 to 80° with the axis of the agitator shaft.

The invention is described in detail hereinafter by reference to a preferred embodiment shown in the accompanying drawings wherein:

Fig. 1 is a cross-sectional side-elevation view of a mixing tank equipped with an agitator employing the primary impeller of this invention.

Fig. 2 is a cross-sectional vertical-elevation view of a mixing tank equipped with an agitator employing both a primary impeller and a diagonal booster impeller.

Fig. 3 is a cross-sectional vertical-elevation view of a mixing tank equipped with a compound agitator assembly employing several primary impellers of this invention.

Fig. 4 is a plan view of the primary impeller.

Fig. 5 is a side-elevation view of the primary impeller.

Figs. 6, 7, 8 and 9 are vertical cross-section views of the primary impeller along lines 6—6, 7—7, 8—8 and 9—9 respectively, in Fig. 4.

Figs. 10 and 11 are plan and side-elevation views, respectively, of the diagonal booster impeller.

Figs. 12 and 13 are cross-section views of the diagonal booster impeller along lines 12—12 and 13—13 in Fig. 10.

Figs. 14 and 15 are plan and cross-sectional vertical-elevation views, respectively, of the hub to which the primary impeller is fastened when the diagonal booster impeller is not used.

Figs. 16 and 17 are plan and cross-sectional side-elevation views, respectively, of the shaft cap for the agitator assembly.

In Figures 4 through 9 the pumping section of the primary impeller consists of blades 10. As the blades 10 rotate through a fluid medium, the fluid in the path of the blades is sharply displaced. This type of pumping action is called form drag and is contrasted with viscous drag where the fluid is moved by friction with a surface moving through the fluid.

The average projected height of blades 10 is at least about 0.2 and preferably about from 0.3 to 0.6 times their radial length. Radial length refers to the radial distance from the outer tip of the blades 10 to the rotational axis of the impeller. The radial length of the blades should be about from 0.3 to 0.7 and preferably about from 0.5 to 0.6 times the radius of the tank in which the impeller is used.

Various ancillary features have been incorporated in the blades 10 shown in Figs. 4 through 9. Blades 10 are cut away near the impeller hub 11 to minimize blade exposure when partially filled tanks are agitated at high velocities. Also, blades 10 are set at a trailing angle α , usually of less than about 45°, to the radial axis of blades 12 of the sweep section to improve self-cleaning of blades 10 and to get the maximum volume discharge capacity.

Blades 10 of the pumping section of the primary impeller are fastened to streamlined blades 12 of the sweep section which are fixed to hub 11 of the primary impeller. Streamlined as used herein refers to blades which are shaped to produce only a gradual change in the direction of fluid flowing over them. Streamlined blades move fluid primarily by the viscous drag of the fluid on the surface of the rotating blades and not primarily by sharply displacing the fluid as it flows around the blades. For best results, these streamlined blades have a projected height of less than 0.15 and preferably, about from 0.1 to 0.01 times their radial length. Streamlined blades 12 must have a radial length of about from 1.2 to 2.0, and preferably 1.4 to 1.6 times that of the blades 10 of the pumping section.

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To insure bottom cleaning, blades 12 are preferably positioned near the bottom of a tank and preferably have a contour substantially conforming to the bottom of the vessel in which they are used. Thus, slightly arched blades are usually used with dished-bottom tanks while straight blades are preferably used with flat-bottom tanks.

Valve cleaner blade 13 is fastened to hub 11 to prevent solids and immiscible liquids from accumulating in tanks which have bottom-center inlet or discharge valves. Blade 13 keeps such valves clean without interfering with their operation.

Figs. 10 through 13 show the diagonal booster impeller which, optionally, can be used with the primary impeller of this invention. The diagonal booster impeller comprises two streamlined blades 14 fastened to hub 15 and projecting upwardly at an angle of about from 10° to 80° and preferably 15° to 45° with the rotational axis of the impeller. This booster impeller acts on the fluid primarily by viscous drag and functions as a viscosity compensator. It forces fluid, which is displaced outwardly and then upwardly by the primary impeller, to continue up toward the surface of the fluid being agitated and thereby improves top-to-bottom circulation. Preferably, although not critically, blades 14 project along the inner edge of the return flow pattern which is formed in the circulating fluid by the same agitator without a diagonal booster impeller.

Although it is not critical, usually the radius of the diagonal booster impeller blades 14 measured from the agitator shaft perpendicularly to the tip of the blades 14 is less than about 0.8 and preferably about from 0.3 to 0.7 times the tank radius. Like blades 12 of the sweep section, blades 14 of the diagonal booster are streamlined and, for best results, have a thickness of less than about 0.15 and preferably 0.1 to 0.01 times their length. The length of blades 14 is measured from the blade tip along the blade to the rotational axis of the impeller and is governed by the aforementioned parameters, namely, the radius of the blades and their angle with the rotational axis.

The embodiments of the primary impeller and diagonal booster impeller described hereinbefore have only two blades per impeller. Impellers with greater than two blades, for example, 3 or 4 blades can be used; however, if a large number of blades are put on an impeller, particularly the pumping section of the primary impeller, its efficiency, particularly in unbaffled or partially baffled tanks, is markedly decreased.

The impellers of this invention can, for example, be cast or fabricated from glass, wood or steel, brass, aluminum or other metals.

The impellers of this invention can be used in open or closed tanks of almost any size and shape; however, they are particularly designed for vertical cylindrical tanks. Although the impellers of this invention are preferably used in unbaffled tanks, they can be used to advantage in tanks with baffles.

Figure 1, shows a dished-bottom tank equipped with the primary impeller of this invention. As shown in Fig. 1, agitator shaft 16, driven by motor 17, hangs inside and substantially concentric with tank 18. The primary impeller consisting of blades 10 of the pumping section and blades 12 of the sweep section is bolted to the bottom of shaft 16 through hub 19. Blades 10 of the pumping section are in direct contact with blades 12 of the sweep section. (See Figs. 14 and 15.) Hub 19 is keyed to shaft 16 and held by set screws 20. Cap 21 (see Figs. 16 and 17) is fitted on shaft 16 above hub 19 to improve the streamlining of the agitator and aid self-cleaning. Note that the distance between the bottom of sweep blades 12 and tank 18 preferably increases slightly toward the tip of blades 12. This increase is to compensate for the increase in linear speed, hence in viscous drag of the fluid under blades 12, away from the rotational axis of the impeller.

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Figure 2 shows an agitator assembly with a diagonal booster impeller. As shown in Figure 2, hub 11 of the primary impeller is bolted to hub 15 of the diagonal booster impeller. Hub 15 is keyed to shaft 16 and held by set screws 22 (see Fig. 12). Cap 21 fits over hub 15 of the diagonal booster impeller and is held by set screws 23.

The diagonal booster impeller is usually only used when the ratio of fluid height to tank diameter is greater than about 0.8 (compare Figs. 1 and 2). The diagonal booster impeller can, however, be used in all tanks at all liquid levels without significantly lowering the efficiency of the agitator.

Figure 3 shows a multiple-impeller agitator which is particularly useful for mixing fluid bodies which do not vary greatly in height and which have a high ratio of fluid height to diameter. As shown in Figure 3, the agitator has two primary impellers each consisting of a pumping section composed of blades 10 and a sweep section composed of sweep blades 12.

A cross-sectional view of the path taken by fluid agitated by the process of this invention is shown in Figures 1 and 2. Briefly, fluid near the bottom and center of the fluid body is forced outwardly over the surface of a layer of fluid which is moving primarily in an arcuate path. Next, the outwardly flowing fluid is forced upward in a spiral path along the edge of the fluid body to substantially the top of the body, then returned in a spiral path along a convex vortex toward the center and bottom of the fluid body. In Figs. 1 and 2, the arcuately moving layer of fluid is created by the blades 12 of the sweep section. This rotating layer of fluid prevents fluid from the pumping section from rapidly losing its angular momentum and thereby carries the fluid from the pumping section outwardly toward the wall of tank 18. This action of the sweep section increases with fluid viscosity; thus, the sweep section acts as a viscosity compensator. Also, the layer of arcuately moving fluid underneath blades 12 insures bottom cleaning. In high narrow fluid bodies, blades 14 of the diagonal booster impeller increase the vertical distance that fluid moves up along the wall of tank 18 before it returns along the convex vortex to the pumping section.

The circulation pattern described hereinbefore has several advantages. First, the layer of arcuately moving fluid at the bottom of the tank insures good bottom cleaning and forces the fluid pumped from near the bottom and center of the tank substantially all of the way across the bottom of the tank before it travels upward and, therefore, eliminates dead zones at the edges of the tank. The same desirable motion is not obtained with conventional agitators having long paddles which extend almost to the outer wall of the fluid. With long paddles, most of the pumping is done by the outer portion of the blades thus there is a large and relatively dead zone in the central portion of the fluid body. Forcing the fluid upwardly along the outer wall of the fluid body to substantially the top of the body insures good top-to-bottom circulation and mixes in dry powders and fluids on the surface of the fluid body.

The rapid upward flow of fluid along the edge of the fluid body and its rapid inward return to near the center and bottom of the fluid body greatly reduces the volume of displaced fluid, hence the freeboard requirements. Also, the convex vortex which is formed, particularly with viscous fluids, reduces the freeboard requirements, since, for a given fluid displacement, the fluid at the periphery of a convex vortex does not rise as high on the wall of a tank as that at the periphery of a concave vortex.

Agitators employing the impellers of this invention can be used to mix a wide variety of fluids ranging in viscosity, for example, from 1 to 20,000 centipoises. Furthermore, such agitators can be operated at constant speed over a wide range of fluid levels and viscosities

without a substantial change in overall mixing performance. For example, pigments can be added to an agitated vehicle without increasing the impeller speed as the pigment is added even though the viscosity is thereby greatly increased. The excellent top-to-bottom circulation of the fluids makes it possible to incorporate dry pigments and fillers in vehicles without having the dry solids form into dry lumps which either float on the surface of the agitated fluid or remain submerged in the central portion of the fluid mass until the agitator is stopped, then rise to the surface.

Agitators employing the impellers of this invention are particularly useful in preparing paints such as rubber-emulsion paints because they substantially eliminate aeration of the paints. Also, in all applications, agitators employing the impellers of this invention can be operated at relatively low speeds at a comparatively low power consumption.

The following examples are intended to illustrate the invention and not to limit it in any way.

Example I

An un baffled, dished-bottom, cylindrical tank having a diameter of 38 inches and a nominal working capacity of 150 gallons was fitted with a primary impeller similar to that shown in the accompanying drawings. The blades of the pumping section of the primary impeller had a radial length of about 10.6 inches and a projected height of 4.75 inches. The streamlined blades of the sweep section of the primary impeller had a length of 15.2 inches and were formed from $\frac{5}{8}$ inch bar stock which had been tapered at the leading and trailing edges.

The mixing apparatus described above was charged about two-thirds full with conventional rubber-base paint having a viscosity of about 700 centipoises comprising butadiene/styrene latex emulsion, casein, water and pigment. Next the agitator was rotated at 120 r.p.m. for about 8 hours. During the mixing a convex vortex formed in the fluid body. At the end of 8 hours the drop in gallon weight because of air incorporation was less than about 1%. Excellent top-to-bottom mixing with almost no aeration was also obtained when the tank was less than one-third full.

In contrast, the primary impeller of this example, was replaced with a conventional multiple-impeller agitator. This agitator had a primary impeller consisting of two flat blades, 17.5 inches long having a 35° upthrust and a projected height of 3 inches fastened to a hub at the bottom of the agitator shaft, and a secondary impeller consisting of two flat blades 12 inches long with a vertical height of two inches positioned on the shaft about 18 inches above the primary impeller. After this impeller had been rotated in the emulsion described above for 45 minutes at 80 r.p.m. the gallon weight of the emulsion dropped about 6%. The agitator and agitator speed used in the control represent the minimum that can be used to get satisfactory mixing.

The air in the fluid which causes the drop in gallon weight described hereinbefore is in the form of very fine bubbles which do not escape from the fluid for several days. When fluids such as paints are agitated with conventional impellers, the large amount of air which is beaten into the fluids makes it very difficult to fill standard containers, for, when the air finally escapes, less than the required volume of fluid remains.

Example II

Streamlined diagonal booster blades similar to those shown in Figures 10 through 13 were fastened to the agitator assembly described in the preceding example and aligned with the blades of the primary impeller. The blades were made of $2\frac{1}{2} \times \frac{1}{2}$ inch bar stock tapered at the leading and trailing edges. The angle between the blades and the agitator shaft was about 30° and the dis-

tance from the shaft perpendicular to the tip of the blades was about 10.6 inches.

A vehicle having a viscosity of about 20 centipoises consisting of alkyd resin and solvent, was charged to the 150 gallon tank equipped with the aforementioned agitator. Pigment consisting of calcium carbonate, titanium dioxide and diatomaceous earth was added to the vehicle rapidly while the agitator was rotated at 155 r.p.m. The resulting mixture had an effective viscosity, that is a viscosity at the operating conditions, of about 1000 centipoises and filled about one half of the volume of the tank. After about 7 minutes of mixing, the pigments were completely dispersed in the vehicle. No lumps of unmixed pigment were formed either during the mixing or after the agitator was stopped. During the mixing, the fluid formed into a convex vortex, the periphery of which rose only about 5.5 inches above the level of the unagitated mixture. The net power required to agitate the pigmented mixture was about $\frac{1}{2}$ horsepower.

For comparison, the procedure just described was repeated with the conventional multiple-impeller agitator used as the control in Example I. When pigment was added to the vehicle as described hereinbefore, about 6 to 8 gallons of lumps of dry pigment ranging up to 6 inches in diameter were formed. The lumps began to form as soon as the pigment was added and remained even after all of the pigment was added and the system had been agitated for over an hour. At 110 r.p.m. the fluid at the edge of the concave vortex in the half-filled tank rose greater than 18 inches and splashed out of the tank. The net power needed to agitate this mixture was about 1 horsepower.

I claim:

1. An impeller comprising a pumping section consisting of at least two blades having a projected height of at least about 0.2 times their radial length and a sweep section in contact with said pumping section, said sweep section consisting of at least two streamlined blades having a radial length of about from 1.2 to 2.0 times the radial length of said blades of said pumping section, said radial lengths being the distance from the rotational axis of said impeller to the outermost tip of said blades in said sweep section and said pumping section, respectively, each blade in said sweep section being paired with a blade in said pumping section and the number of blades in said sweep and pumping sections being equal.

2. An impeller comprising a pumping section consisting of at least two blades having a height of about from 0.3 to 0.6 times their radial length and a sweep section in contact with said pumping section, said sweep section consisting of at least two streamlined blades having a radial length of about from 1.4 to 1.6 times the radial length of said blades of said pumping section, said radial lengths being the distance from the rotational axis of said impeller to the outermost tip of said blades in said sweep section and said pumping section, respectively, each blade in said sweep section being paired with a blade in said pumping section and the number of blades in said sweep and pumping sections being equal.

3. An impeller comprising a pumping section, a sweep section and a hub, said pumping section consisting of at least two blades having a projected height of about from 0.3 to 0.6 times their radial length, said blades being cut away immediately adjacent to said hub at the center of said impeller and the upper edge of said blades being tapered toward said hub, said blades in said pumping section being fastened to two streamlined sweep blades at a trailing angle less than about 45° with the radial axis of said sweep blades, said sweep blades having a radial length of about from 1.4 to 1.6 times the radial length of said blades of said pumping section, said radial lengths being the distance from the rotational axis of said impeller to the outermost tip of said blades in said sweep section and said pumping section, respectively,

each blade in said sweep section being paired with a blade in said pumping section and the number of blades in said sweep and pumping sections being equal.

4. An agitator assembly comprising a shaft, a primary impeller fastened to said shaft which comprises a pumping section consisting of at least two blades having a projected height of at least about 0.2 times their radial length and a sweep section in contact with said pumping section, said sweep section consisting of at least two streamlined blades having a radial length of about from 1.2 to 2.0 times the radial length of said blades of said pumping section, said radial lengths being the distance from the rotational axis of said primary impeller to the outermost tip of said blades in said sweep section and said pumping section, respectively, and a diagonal booster impeller fastened above said primary impeller and comprising at least two streamlined blades projecting upwardly at an angle of about from 10 to 80° with the axis of said agitator shaft.

5. An agitator assembly comprising a shaft, a primary impeller fastened to said shaft which comprises a pumping section consisting of at least two blades having a projected height of about from 0.3 to 0.6 times their radial length and a sweep section in contact with said pumping section, said sweep section consisting of at least two streamlined blades having a radial length of about from 1.4 to 1.6 times the radial length of said blades of said pumping section, said radial lengths being the distance from the rotational axis of said primary impeller to the outermost tip of said blades in said sweep section and said pumping section, respectively, and a diagonal booster impeller fastened above said primary impeller comprising at least two streamlined blades projecting upwardly at an angle of about from 15 to 45° with the axis of said agitator shaft, said blades of said primary impeller and said booster impeller being in vertical alignment.

6. A mixing apparatus comprising a cylindrical tank and an agitator assembly substantially coaxial with said tank, said agitator assembly comprising a substantially vertical shaft and at least one primary impeller fastened to said shaft which comprises a pumping section consisting of at least two blades having a radial length of about from 0.3 to 0.7 times the radius of said tank and a projected height of at least about 0.2 times their radial length and a sweep section in contact with said pumping section, said sweep section consisting of at least two streamlined blades having a radial length of about from 1.2 to 2.0 times the radial length of said blades of said pumping section, said radial lengths being the distance from the rotational axis of said impeller to the outermost tip of said blades in said sweep section and said pumping section, respectively, each blade in said sweep section being paired with a blade in said pumping section and the number of blades in said sweep and pumping sections being equal.

7. A mixing apparatus comprising a cylindrical tank and an agitator assembly substantially coaxial with said tank, said agitator assembly comprising a substantially vertical shaft and at least one primary impeller fastened to said shaft which comprises a pumping section consisting of at least two blades having a radial length of about from 0.5 to 0.6 times the radius of said tank, and a projected height of about from 0.3 to 0.6 times their radial length and a sweep section, in contact with said pumping section, said sweep section consisting of at least two streamlined blades having a radial length of about from 1.4 to 1.6 times the radial length of said blades of said pumping section, said radial lengths being the distance from the rotational axis of said impeller to the outermost tip of said blades in said sweep section and said pumping section, respectively, each blade in said sweep section being paired with a blade in said pumping section and the number of blades in said sweep and pumping sections being equal.

8. A mixing apparatus comprising a cylindrical tank and an agitator assembly substantially coaxial with said tank, said agitator assembly comprising a substantially vertical shaft and a primary impeller fastened near the bottom of said shaft which comprises a pumping section consisting of at least two blades having a radial length of about from 0.3 to 0.7 times the radius of said tank and a projected height of at least about 0.2 times their radial length and a sweep section in contact with said pumping section, said sweep section consisting of at least two streamlined blades having a radial length of about from 1.2 to 2.0 times the radial length of said blades of said pumping section, said radial lengths being the distance from the rotational axis of said primary impeller to the outermost tip of said blades in said sweep section and said pumping section, respectively, and a diagonal booster impeller fastened above said primary impeller comprising at least two streamlined blades projecting upwardly at an angle of about from 10 to 80° with the axis of said shaft, said diagonal booster impeller having a diameter measured perpendicularly from said shaft to the tip of said blades of less than about 0.8 times the radius of said tank.

9. A mixing apparatus comprising a cylindrical tank and an agitator assembly substantially coaxial with said tank, said agitator assembly comprising a substantially vertical shaft and a primary impeller fastened near the bottom of said shaft which comprises a pumping section consisting of at least two blades having a radial length of about from 0.5 to 0.6 times the radius of said tank and a projected height of about from 0.3 to 0.6 times their radial length and a sweep section in contact with said pumping section, said sweep section consisting of at least two streamlined blades having a radial length of about from 1.4 to 1.6 times the radial length of said blades of said pumping section, said radial lengths being the distance from the rotational axis of said primary impeller to the outermost tip of said blades in said sweep section and said pumping section, respectively, and a diagonal booster impeller fastened above said primary impeller and comprising at least two streamlined blades projecting upwardly at an angle of about from 15 to 45° with the axis of said shaft, said blades of said diagonal booster impeller having a diameter measured perpendicularly from said shaft to the tip of said blades of about from 0.3 to 0.7 times the radius of said tank, said blades of said primary impeller and said blades of said booster impeller being in vertical alignment.

10. A mixing apparatus comprising a cylindrical tank and an agitator assembly substantially coaxial therewith, said agitator assembly comprising a substantially vertical shaft and a primary impeller fastened near the bottom of said shaft which comprises a pumping section consisting of at least two blades having a radial length of about from 0.3 to 0.7 times the radius of said tank and a projected height of about from 0.3 to 0.6 times their radial length, said blades being cut away immediately adjacent to said shaft and having their upper edge tapered toward said shaft, said blades of said pumping section being fastened to at least two streamlined sweep blades at a trailing angle of less than about 45° with the radial axis of said sweep blades, said sweep blades having a contour conforming substantially to that of the bottom of said tank and having a radial length of about from 1.4 to 1.6 times the length of said blades of said pumping section, said radial lengths being the distance from the rotational axis of said impeller to the outermost tip of said blades in said sweep section and said pumping section, respectively, each blade in said sweep section being paired with a blade in said pumping section and the number of blades in said sweep and pumping sections being equal.

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