March 18, 1941. I. S. BRUMAGIM 2,235,604

RADIAL PROPELLER AGITATOR

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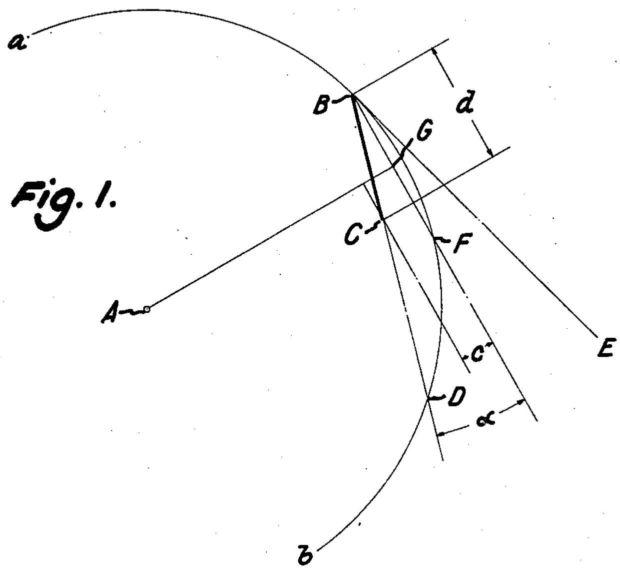

Fig. 1.

Fig. 2.

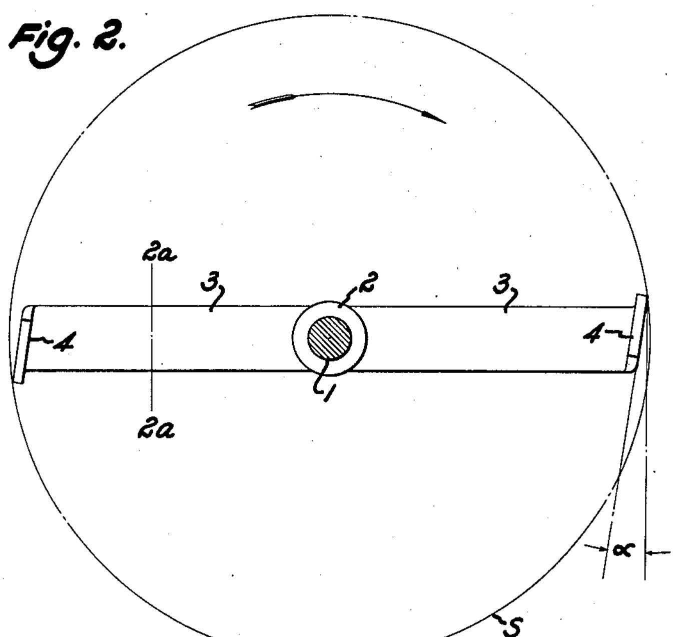

Fig. 2a.

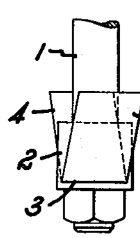

Fig. 4.

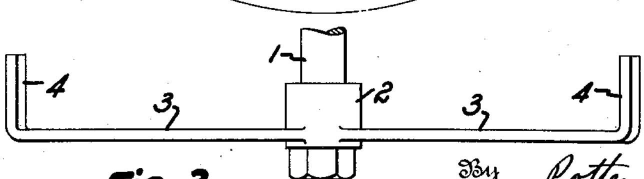

Fig. 3.

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Fig. 5.

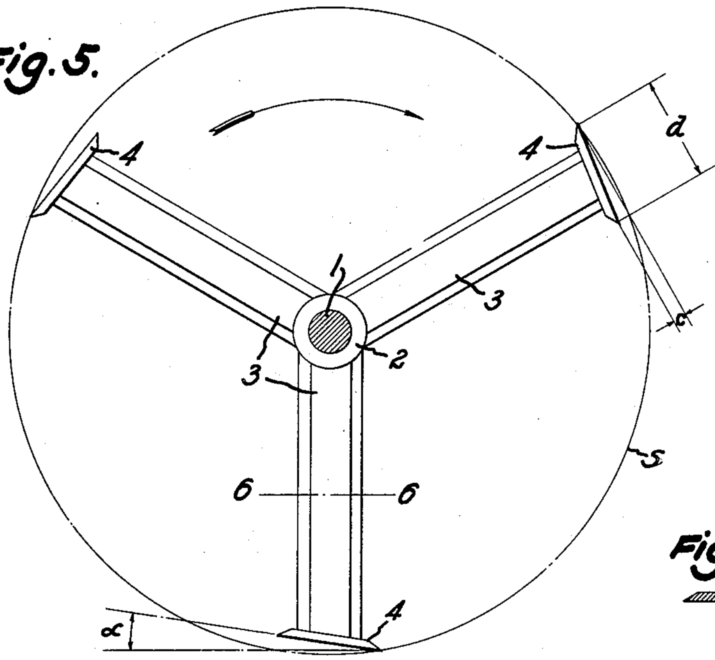

Fig. 6.

Fig. 7.

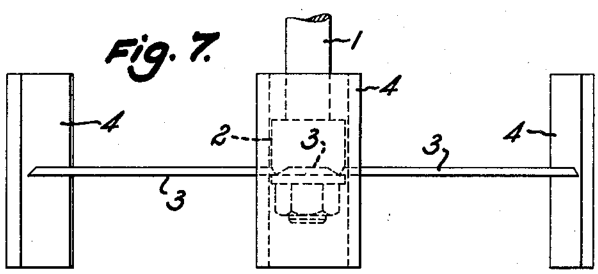

Fig. 8.

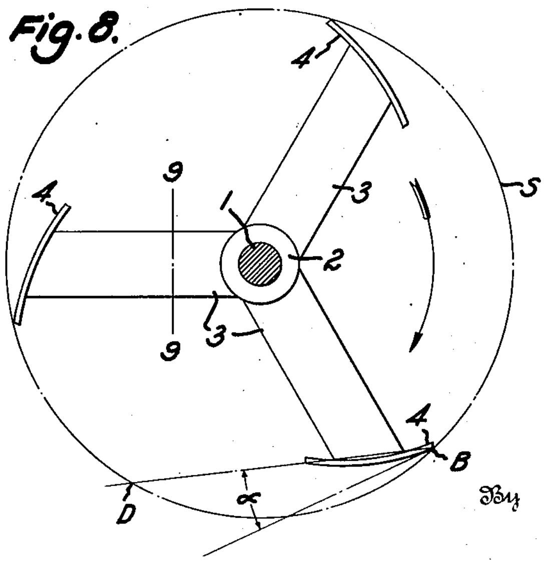

Fig. 9.

Fig. 10.

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RADIAL PROPELLER AGITATOR

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Fig. 11.

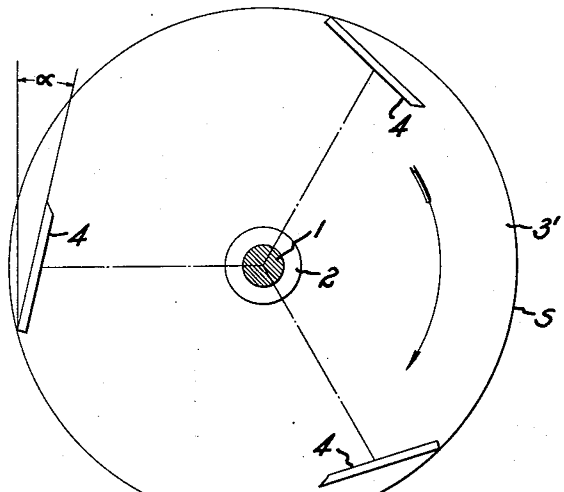
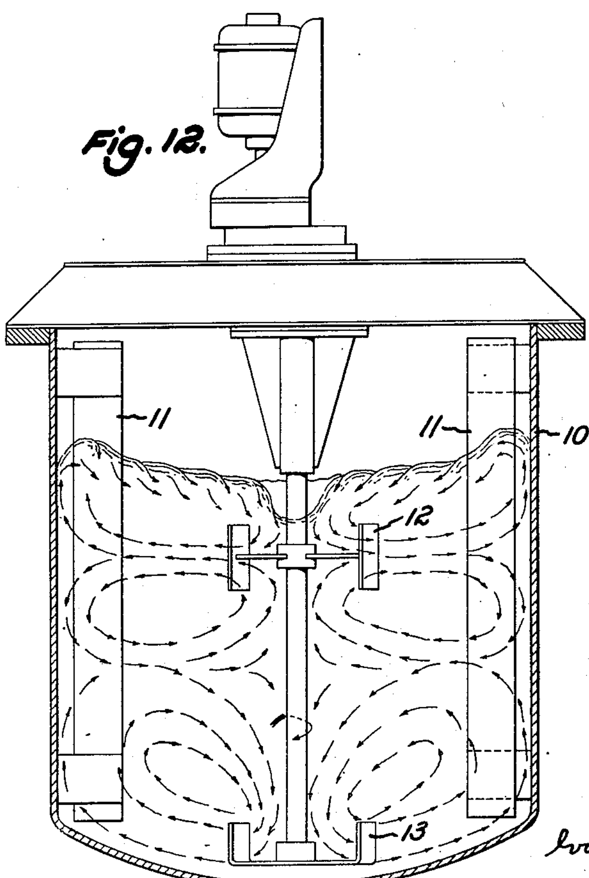


Fig. 12.



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RADIAL PROPELLER AGITATOR

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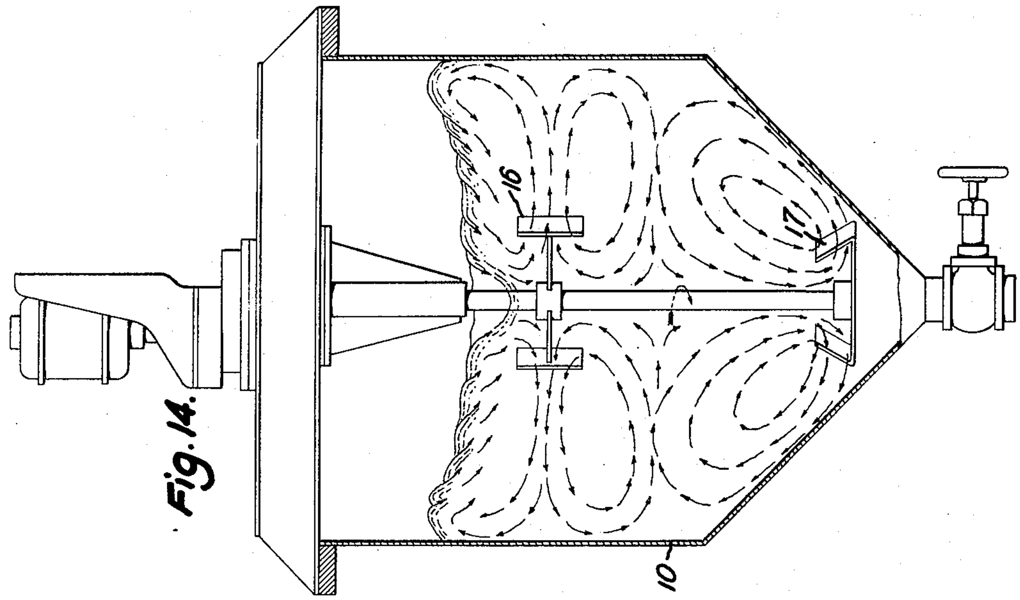

Fig. 14.

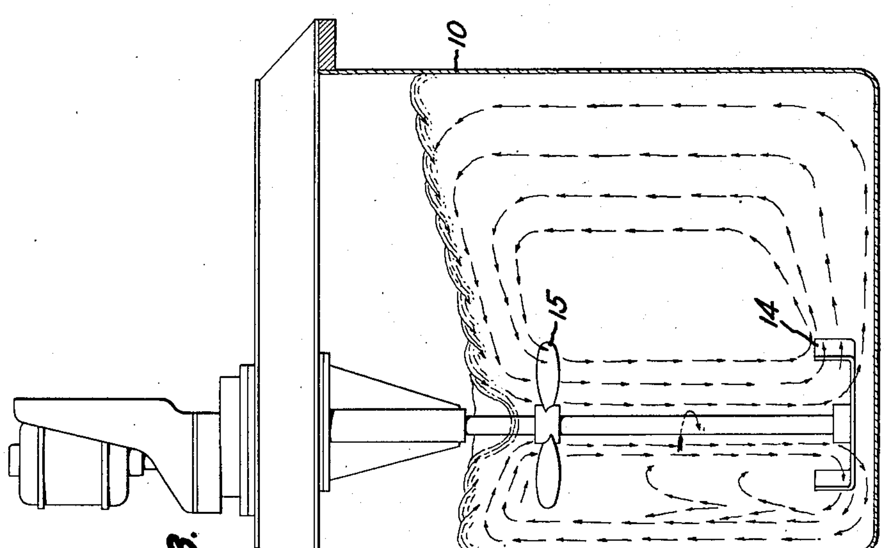

Fig. 13.

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UNITED STATES PATENT OFFICE

2,235,604

RADIAL PROPELLER AGITATOR

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Application April 9, 1940, Serial No. 328,771

6 Claims. (Cl. 259—107)

This invention relates to a novel agitator and is particularly directed to a radial propeller agitator suitable for agitating, blending, dissolving or gasifying liquids, mixtures of liquids and solids, and liquids and gases, by inducing flow in a body of liquid directed radially from the agitator hub.

There are two general types of agitators, namely, slow speed agitators and high speed agitators.

The slow speed agitator is that type of agitator which is designed to actually reach the major portion of the material as the agitator is revolved. In this general class of agitators are included paddles of sufficient length to extend approximately the full diameter of the tank, anchor type agitators, spiral ribbon screws operating near the outer periphery of the container, and various combinations or adaptions of the specific types mentioned above. The slow speed agitator can be used in pastes and solids as well as liquids and does not require that the content be circulated.

The high speed agitator is that type of agitator which is designed to contact the material only within a small area of the container. Due to their small diameters these agitators may be operated at relatively high speeds. The effectiveness of this type of agitator depends (1) on violent agitation within the small area of applied agitation and (2) effective circulation or flow of all the content of the container into and away from the area of applied agitation. Agitators belonging to this class are the mixing propeller, mixing turbine and the mixing impeller.

A mixing propeller is an agitator consisting of a propeller similar to that used in marine service. This agitator usually has from two to four blades, each blade curved to cut through the material in the manner of a screw; the pitch varying from the tip of the blade to the hub in such a manner as to give a constant thrust throughout the whole radius of the blade. The material is thus propelled in a direction parallel to the agitator shaft and subjected to severe turbulence and cutting at the point of contact with the blades. Normal operating speeds are between 150 and 1800 R. P. M. Normal peripheral speeds are between 900 and 5000 F. P. M., but in especial cases the peripheral speed may be much greater than 5000 F. P. M.

A mixing turbine is an agitator consisting of a turbine similar to the turbine wheel used in turbine pumps or steam turbines, usually surrounded by stator blades to deflect the predominantly tangential direction of flow imparted by the turbine wheel from tangential to radial flow movement. The material is thus moved radially from the hub and subjected to severe turbulence, with little if any cutting action at the points of contact with the turbine blades and stators. Common turbine design consists of a number of spirally curved blades emanating from a common hub. Mixing turbines follow this basic principle of turbine design. Mixing turbines are usually provided with shrouds enclosing the blades. Where a turbine is mounted adjacent to the tank bottom the shroud is usually placed on top of the blades only, the tank bottom acting as an effective shroud for the bottom of the turbine blades. The shroud usually consists of a circular piece having an outside diameter equal to diameter of the wheel and an inside diameter approximately two-thirds the diameter of the wheel. Normal operating speeds are between 40 and 400 R. P. M.; normal peripheral blade speeds are between 300 and 900 F. P. M.

A mixing impeller is an agitator consisting of blades extending radially from a common hub; the blades are either straight or curved, usually mounted parallel to the hub but in many applications at an angle up to 45° from the hub, or axis of rotation. This agitator is similar in agitating action to the turbine and is governed by identical limitations in speed of rotation and peripheral speed as the turbine. Stators are not ordinarily used with this agitator, but baffles must be used to obtain effective agitation.

The agitator of the invention is typically a high speed agitator but differs radically from the types of high speed agitators of the prior art both in structure and in principle of operation.

A principal object of this invention is to provide a high speed-type agitator which will impart flow to the material undergoing treatment in a direction predominantly radial to axis of rotation solely by the action of the propeller blades.

Further objects of the invention are to provide an agitator simple in construction and economical to build; an agitator so constructed as to confine the source of flow propulsion and turbulence to the agitator blades (i. e. the blade supporting means are constructed to impart a minimum of flow or turbulence to the material); an agitator which can be operated at speeds ranging from 300 to 3600 R. P. M.; an agitator which can be operated at peripheral blade speeds ranging from 900 to 20,000 F. P. M.; an agitator which is constructed in such a manner as to facilitate easy cleaning; an agitator with elements so placed as to be self-cleaning in operation; an agitator constructed to impart a normal flow so nearly approaching a radial direction with reference to the axis of rotation as to make the use of stators unnecessary; an agitator so constructed as to give greater free area for input flow; an agitator so constructed as to operate most efficiently at peripheral speeds of blade or cutting speeds between 900 and 20,000

F. P. M., thereby serving to provide a maximum dispersion of gases injected or induced into the liquid and to provide a maximum disintegration of solid lumps or particles, resulting in the rapid production of finely dispersed slurries of insoluble solids, in the rapid solution of soluble solids and in the rapid emulsification of immiscible liquids.

The improved agitating device of this invention comprises a rotatable shaft, and blades so mounted on suitable connecting means and so positioned and shaped with respect to the axis of rotation that predominantly radial flow is imparted to liquid material solely by the displacing effect of the blade faces.

The invention will be more particularly described with reference to the accompanying drawings in which:

Fig. 1 is a diagram illustrating the blade position characterizing the invention;

Fig. 2 is a plan view; Fig. 2a is a section on line 2a—2a of Fig. 2; Fig. 3 is a side view, and Fig. 4 is an end view of an agitator embodying the principles of the invention;

Fig. 5 is a plan view; Fig. 6 is a section on line 6—6 of Fig. 5, and Fig. 7 is a side view of another embodiment of the invention;

Fig. 8 is a plan view of a further embodiment of the invention;

Figs. 9 and 10 are cross-sections of two different forms of blade supporting members;

Fig. 11 is a plan view of another embodiment of the invention; and

Figs. 12, 13 and 14 are representations of several types of installations including agitators embodying the principles of the invention.

The characteristic position and configuration of the blades can best be described with reference to Fig. 1 and the following definitions;

The center line of the shaft A, referred to herein as "the axis of rotation;"

The circle described by the outer or trailing edge B of the blade in rotating about the axis of rotation, referred to herein as "the blade circle" (*ab* in Fig. 1);

The tangent to the blade circle at the outer or trailing edge of the blade, referred to herein as "the blade tangent" (BE in Fig. 1);

The chord of the blade circle which passes through the leading C and trailing B edges of the blade, referred to herein as "the blade chord" (BD in Fig. 1);

The chord of the blade circle which bisects the angle between the blade tangent and the blade chord, referred to herein as "the bisector chord" (BF in Fig. 1);

The line running from the axis of rotation to the bisector chord and perpendicular to both the axis of rotation and the bisector chord, referred to herein as "the blade radius" (AG in Fig. 1);

The projection of the blade upon the blade radius, referred to herein as "the tangential component" of the blade (*c* in Fig. 1);

The projection of the blade upon the bisector chord, referred to herein as "the radial component" of the blade (*d* in Fig. 1);

The angle between the blade chord and the bisector chord, the tangent of the angle being the ratio of the tangential component of the blade to the radial component of the blade, referred to herein as "the peripheral angle of incidence" of the blade (α in Fig. 1).

It is an essential and characteristic feature of the agitator of the invention that the blades thereof are positioned to have a "peripheral angle of incidence," as defined above, which is not in excess of 30° and which, in general, is preferably between 5° and 10°. The blade face should not substantially exceed one-half the length of the blade chord, as defined above and, in general, a blade of half the length of the blade chord is preferred. The blade face may be straight or curved and the curve may be circular, elliptical or in any other desired form, but no portion of the blade face should have a radius of curvature substantially less than the radius of the blade circle. In general, the tangential component of the blade should not exceed one-fifth the blade radius, and preferably it is from one-tenth to one-twentieth of the blade radius. As will be seen from the drawings, and particularly Figs. 3, 7, 12, 13 and 14, the length of the blade members in the axial direction, that is, in the direction parallel to the axis of rotation of the agitators, is substantially less than the radius of the blade circle.

The importance of the dimensions described and defined above, and particularly of the "peripheral angle of incidence," the "tangential component" and the "radial component" of the blade, is due to the fact that these dimensions are directly related to the principle of operation and the efficiency of the blade.

The peripheral angle of incidence *d* determines the radial outward displacement imparted to the liquid at each revolution of the blade and the degree to which the actual displacement of the liquid approaches true radial flow. The resultant displacement of the liquid or the direction of flow will be at right angles to the blade face or at an angle to the blade radius equal to the angle of incidence, that is, it will deviate from a true radial direction by the angle α. The velocity of flow imparted to the liquid is a function of the peripheral speed and the angle of incidence of the blade.

The velocity of flow imparted to the liquid is a function of the peripheral blade speed and the peripheral angle of incidence of the blade. If P is the peripheral speed in feet per minute, the velocity of flow V imparted to the liquid is given by the formula

$$V=\frac{Pc\cos\alpha}{d}$$

In the form of the agitator shown in Figs. 2–4, 1 is the shaft, 2 is the agitator hub, 3 are the blade arms and 4 are the blades. The blade circle is indicated at *s*, and the peripheral angle of incidence of the blade is indicated by α. In this form the blades and blade arms are formed by a flat bar. The arm section, as shown in Fig. 2a, is positioned to present its smallest dimension in the direction of rotation to minimize the resistance of the blade arms to rotation.

In the agitator of Figs. 5–7, the arms 3 are formed as a three-armed spider cast or fabricated integrally with the hub 2. By beveling the blade arms 3, as shown in these figures, the arms can be given increased strength without increasing the resistance to motion in the rotational direction. In Fig. 5, the tangential component *c* and the radial component *d* of the blades are indicated.

In Fig. 8 is shown an agitator in which the blades 4 have curved faces. As was explained above, the blade chord BD in this form of blade is defined by the line passing through the trailing and leading edges of the blade.

As has been indicated above, the shape of the blade arms is an important factor in the efficiency of the agitator. Consideration must be given to the amount of rotary movement imparted to the liquid by the leading face of the blade arm, the amount of rotary movement imparted to the liquid by frictional contact with the faces of the arm parallel to the blade circle, and the amount of flow in the direction of the axis of rotation induced by the blade arm. It is, therefore, essential that the overall cross-section be a minimum within good engineering practice, and that, where substantial thicknesses are required, the arm be stream-lined in the direction of rotation, for example, by giving the arms an elliptical cross-section, as shown in Fig. 9, or by more rigorously stream-lining the arms as shown in Fig. 10.

The long faces of the arms shown in Figs. 2a and 6, and the long axes of the arms shown in Figs. 9 and 10, should be substantially parallel to the blade circle, as otherwise flow of the material will be induced in a direction parallel to the shaft. For the same reason, the long faces of the arms shown in Figs. 9 and 10 should be substantially identical and symmetrical.

In Fig. 11, the blades are connected to the shaft by a connecting plate 3', which takes the place of the blade arms shown in the other figures. This construction is effective for some purposes, although the rotary flow imparted by frictional contact with the plate faces is somewhat high in comparison with that induced by the individual blade arms shown in the other figures.

The agitator is normally located in a vessel or container with the axis of rotation substantially vertical and the blade circle horizontal. The location, however, is not restricted to this position; the axis of rotation may be horizontal or at an angle therefrom. Fig. 12 shows the agitator mounted in a cylindrical tank with the axis of rotation vertical and on the center line of the tank 10. Vertical baffles 11 are used in this particular case to eliminate whirling of the material.

The upper agitator member 12 is similar to the agitator of Figs. 5–7 while the lower agitator member 13 is similar to the agitator of Figs. 2–4.

Normally a single agitator located in the bottom of the container is sufficient to create flow through the whole material. However, in tanks in which the depth is considerably greater than the diameter, it is necessary to mount one or more agitators on the agitator shaft above the bottom agitator. The flow is thrown outward to the wall of the container where it is deflected upward and downward to meet and intermingle with the flow of the agitators adjacent, from whence it returns toward the center of the vessel and is induced along the shaft.

Agitators mounted in the bottom of the vessel are usually the single type of Figs. 2–4, that is, the blade extends in one direction only from the blade circle. Agitators for mounting other than adjacent to the tank bottom are usually of the dual type, of Figs. 5–7, that is, the blades extend upward and downward from the blade circles. The dual agitator induces flow from both directions along the shaft and is especially adapted for mounting away from the bottom of the container. The relative directions of flow induced by the single and dual types are indicated by arrows, Figs. 9 and 10.

Fig. 13 shows agitators 14 and 15 mounted in a cylindrical tank 10 with the axis of rotation vertical and parallel to the center line of the tank but off the center line. No anti-swirl baffles are necessary as the off center location sufficiently restricts the tendency for the content to whirl. The agitator may be mounted on the center line of square or rectangular containers without the use of anti-swirl baffles. It may be mounted vertically or substantially off vertical in horizontal cylindrical tanks without the use of anti-swirl baffles.

In Fig. 13 a single radial propeller agitator 14 is mounted on a vertical shaft adjacent to the bottom and a mixing propeller 15 is mounted above on the same shaft. The material is moved downward parallel to the shaft by the mixing propeller and is induced into the radial propeller agitator where it is forced radially outward to the vessel wall, thence up the vessel wall to the surface. This combination is especially practical where definite strata of liquids form due to a difference of specific gravity between the elements to be blended. The radial propeller agitator can be operated efficiently at mixing propeller speeds, which makes this combination far more efficient than a similar combination of mixing turbine and mixing propeller.

The blade surface, in general, is composed of elements substantially parallel to the axis of rotation, the movement of material thereby imparted being in a direction parallel to the blade circle. It is often advantageous, however, to position the blade at an angle to the axis of rotation thereby imparting a direction of flow upward or downward (assuming the blade circle to be horizontal) at an angle from the blade circle substantially equal to the angle which the blade face makes with the axis of rotation. It is often advantageous to create a flow with an impulse upward alternating with a downward impulse. This condition is obtained by positioning the blades, one positioned at an angle outward, the next at an angle inward from the parallel to the axis of rotation.

The use of blades positioned at an angle from the axis of rotation is commonly applied to containers with hemispherical or cone bottoms. The agitator located as near the bottom as possible and the blades positioned to impart a flow parallel to the bottom slope (cone bottom) or tangential to the bottom curve (hemispherical).

The use of such an agitator is shown in Fig. 14 wherein the upper agitator member 16 is similar to the agitator of Figs. 5–7, while the lower agitator member 17 is similar to the agitator of Figs. 2–4, but with the blade faces positioned at an angle to the axis of rotation to impart an upward component of flow to the material.

In normal installations, two or three agitator blades are sufficient but where conditions make it desirable a greater number may be used. As many as twenty-four blades may be used in the larger sizes of agitators.

It will be apparent from the foregoing description that the agitator of the invention may be given a wide variety of forms and used in a wide variety of relations without departing from the novel principles of the invention and that the invention broadly comprises a radial propeller agitator for liquids including a shaft, blade supporting means radially carried by the shaft and having a section, advantageously stream-lined, in the direction of rotation so small that substantially no motion is imparted thereby to the liquid under treatment, and blade members carried by the supporting means, which are inclined at an appreciable peripheral angle of incidence, as defined herein, not greater than 30° and advantageously between about 5° and 10° whereby preponderantly radial motion is imparted to a liquid solely by the action of the blades.

I claim:

1. A mixer for liquids comprising a container and a high speed radial propeller agitator suspended in said container comprising a shaft, blade supporting means radially carried by said shaft and having a section in the direction of rotation so small that substantially no motion is imparted thereby to a liquid under treatment, and blade members carried by said supporting means, said blade members being inclined at an appreciable peripheral angle of incidence not greater than 30°, whereby to impart preponderantly radial outward motion to a liquid solely by the action of the blades, no portion of the face of said blades having a radius of curvature substantially less than the radius of the blade circle, the length of said blade members in the axial direction being substantially less than the radius of the blade circle, the path of radial flow from the shaft to each of said blade members being entirely unobstructed, and the maximum diameter of said agitator not exceeding one-half the minimum dimension of said container in the plane of rotation of said agitator.

2. A mixer for liquids comprising a container and a high speed radial propeller agitator eccentrically suspended in said container comprising a shaft, blade supporting means radially carried by said shaft and having a section in the direction of rotation so small that substantially no motion is imparted thereby to a liquid under treatment, and blade members carried by said supporting means, said blade members being inclined at an appreciable peripheral angle of incidence not greater than 30°, whereby to impart preponderantly radial outward motion to a liquid solely by the action of the blades, no portion of the face of said blades having a radius of curvature substantially less than the radius of the blade circle, the length of said blade members in the axial direction being substantially less than the radius of the blade circle, the path of radial flow from the shaft to each of said blade members being entirely unobstructed, and the maximum diameter of said agitator not exceeding one-half the minimum dimension of said container in the plane of rotation of said agitator.

3. A mixer for liquids comprising a container and a high speed radial propeller agitator suspended in said container comprising a shaft, blade supporting means radially carried by said shaft and having a section in the direction of rotation so small that substantially no motion is imparted thereby to a liquid under treatment, and blade members carried by said supporting means, said blade members being inclined at an appreciable peripheral angle of incidence between about 5 and 10°, whereby to impart preponderantly radial outward motion to a liquid solely by the action of the blades, no portion of the face of said blades having a radius of curvature substantially less than the radius of the blade circle, the length of said blade members in the axial direction being substantially less than the radius of the blade circle, the path of radial flow from the shaft to each of said blade members being entirely unobstructed, and the maximum diameter of said agitator not exceeding one-half the minimum dimension of said container in the plane of rotation of said agitator.

4. A mixer for liquids comprising a container and a high speed radial propeller agitator suspended in said container comprising a shaft, blade supporting arms radially carried by said shaft and having a stream-lined section in the direction of rotation so that substantially no motion is imparted thereby to a liquid under treatment, and blade members carried by said supporting means, said blade members being inclined at an appreciable peripheral angle of incidence not greater than 30°, whereby to impart preponderantly radial outward motion to a liquid solely by the action of the blades, no portion of the face of said blades having a radius of curvature substantially less than the radius of the blade circle, the length of said blade members in the axial direction being substantially less than the radius of the blade circle, the path of radial flow from the shaft to each of said blade members being entirely unobstructed, and the maximum diameter of said agitator not exceeding one-half the minimum dimension of said container in the plane of rotation of said agitator.

5. A mixer for liquids comprising a container and a high speed radial propeller agitator suspended in said container comprising a shaft, blade supporting means radially carried by said shaft and having a section in the direction of rotation so small that substantially no motion is imparted thereby to a liquid under treatment, and blade members carried by said supporting means, said blade members being inclined at an appreciable peripheral angle of incidence not greater than 30°, whereby to impart preponderantly radial outward motion to a liquid solely by the action of the blades and being inclined at an appreciable angle to the plane of rotation to impart an axial component of motion to a liquid, no portion of the face of said blades having a radius of curvature substantially less than the radius of the blade circle, the length of said blade members in the axial direction being substantially less than the radius of the blade circle, the path of radial flow from the shaft to each of said blade members being entirely unobstructed, and the maximum diameter of said agitator not exceeding one-half the minimum dimension of said container in the plane of rotation of said agitator.

6. A mixer for liquids comprising a container and a high speed radial propeller agitator suspended in said container comprising a shaft, a flat plate radially carried by said shaft and blade members carried by said plate, said blade members being inclined at an appreciable peripheral angle of incidence not greater than 30°, whereby to impart preponderantly radial outward motion to a liquid solely by the action of the blades, no portion of the face of said blades having a radius of curvature substantially less than the radius of the blade circle, the length of said blade members in the axial direction being substantially less than the radius of the blade circle, the path of radial flow from the shaft to each of said blade members being entirely unobstructed, and the maximum diameter of said agitator not exceeding one-half the minimum dimension of said container in the plane of rotation of said agitator.

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