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(54) Title: APPARATUS AND METHOD FOR SOLVENT EXTRACTION PROCESSING

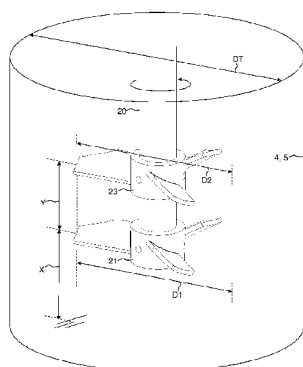


FIGURE 7

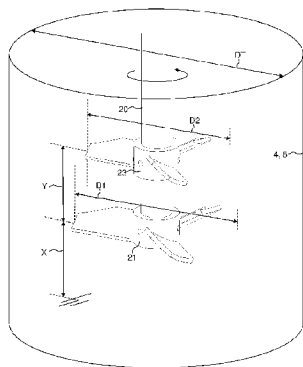


FIGURE 8

(57) Abstract: An auxiliary stirrer tank for a solvent extraction system includes a tank that receives immiscible liquids for agitating together to facilitate mass transfer of a material and a shaft positioned within the tank that is rotatable within the tank via a drive mechanism. A first set of blades are attached to the shaft at a first location on the shaft. Blades of the first set of blades are spaced apart from one another about a diameter or periphery of the shaft at the first location and extend a first distance outwardly from the shaft. A second set of blades are attached to the shaft at a second location on the shaft. The blades of the second set of blades are spaced apart from one another about a diameter or periphery of the shaft at the second location and extend a second distance outwardly from the shaft.

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STIRRER FOR SOLVENT EXTRACTION PROCESSING

FIELD OF INVENTION

The present invention relates to solvent extraction processing. In some embodiments of
5 a solvent extraction processing method and in some embodiments of an apparatus for
extraction of minerals or other material, multiple spaced apart impellers having different
diameters are utilized to perform the stirring of the liquids in an auxiliary mixing tank. The
liquids being mixed together may be immiscible liquids and be mixed to facilitate a mass
transfer of at least one desired material from one liquid to another liquid for subsequent
10 processing and extraction of that at least one desired material.

BACKGROUND OF THE INVENTION

Liquid-liquid mixing may be used in a number of industrial settings. U.S. Patent Nos.
7,50,120, 5,662,861, 5,511,881, 4,567,401, 4,123,357, 3,663,178, 3,559,959, 3,544,079,
15 3,489,526, 3,162,510, 3,013,866, 2,665,196, and 2,029,690, U.S. Patent Application
Publication No. 2001/0036126, and German Patent No. DE 1 619 779 disclose
examples of liquid-liquid mixing methods and apparatuses.

Solvent extraction may be used for extracting mineral or other material. For extracting a
20 particular mineral such as copper, gold, molybdenum, uranium, silver, nickel, cobalt, or
other mineral, a solvent extraction process may include an aqueous solution that
includes the mineral and an organic solvent that includes an extractant. For instance, the
aqueous solution may be formed from an acidic or alkaline solution being used to leach
a particular mineral from an ore for extracting that mineral from the ore. The organic
25 solvent is selected so that it can be mixed with the aqueous solution so that the solvent
can extract the desired mineral from the aqueous solution. The organic solution with the
desired mineral may then be separated from the aqueous solution by phase separation
(due to their immiscible nature) and be subsequently processed to extract the mineral
from the organic solvent. For instance, the organic solution may be mixed with another
30 type of acidic aqueous solution so that copper can be separated from the organic
solution and captured within the acidic aqueous solution to form a mineral loaded
electrolyte solution that may be subsequently sent to an electrowinning stage where the
mineral may be extracted from the solution and electroplated onto a cathode.

35 Liquid-liquid mixing that is often used to facilitate the extraction of a mineral or other
material from one liquid so that mineral is captured within the other liquid can have

certain drawbacks. For instance, some systems may create excessive shear that will cause fine droplets that will stabilize during mixing and result in a loss of the desired material to be extracted. Other systems may create low shear environments that can cause inefficient mixing between liquids that result in phase separation.

5

We have determined that a new solvent extraction process and apparatus for such processing is needed that can improve the efficiency and yield for solvent extraction processing of minerals or other materials. We have determined that it would be preferable that embodiments of our apparatus and method provide an improved yield while also reducing operational costs associated with their use as compared to conventional systems.

10

OBJECTS OF THE INVENTION

It is therefore, an object of the invention, to provide an auxiliary stirring device for use in solvent extraction which consumes only a fraction of the power typically required for conventional auxiliary stirring devices.

15

It is also an object of the invention to provide an auxiliary stirring device for use in solvent extraction which maintains optimal mixing conditions with a much lower impeller tip speed than what is typically required for conventional auxiliary mixing devices.

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It is another objective of the invention to provide an auxiliary mixing device for use in solvent extraction, which is configured to maintain a liquid dispersion with a uniform droplet size distribution of one liquid phase into a second liquid phase.

25

It is a further objective of the invention to maintain droplet sizes within the dispersion which promote mass-transfer reactions.

It is yet another objective of the invention to reduce entrainment losses without creating finer droplets.

30

These and other objects of the invention will be apparent from the drawings and description herein. Although every object of the invention is believed to be attained by at least one embodiment of the invention, there is not necessarily any one embodiment of the invention that achieves all of the objects of the invention.

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SUMMARY OF THE INVENTION

An auxiliary tank for a solvent extraction system is provided. Embodiments of the tank may include a tank, a shaft positioned within the tank, a first set of blades attached to the shaft at a first location on the shaft and a second set of blades attached to the shaft at a second location on the shaft. The tank receives immiscible liquids for agitating together to facilitate mass transfer of a material. The liquids include a first liquid and a second liquid. The shaft is rotatable within the tank. The blades of the first set of blades are spaced apart from one another about a diameter or periphery of the shaft at the first location of the shaft. Each of the blades of the first set of blades extends a first distance outwardly from adjacent the shaft. The blades of the second set of blades are spaced apart from one another about a diameter or periphery of the shaft at the second location of the shaft. The blades of the second set of blades extend a second distance outwardly from adjacent the shaft. The second distance may be larger or smaller than the first distance. In some alternative embodiments, it is contemplated that the first and second distances may be the same.

In some embodiments, the first liquid may be an organic solvent and the second liquid may be an aqueous solution and the liquids may be mixed to facilitate a mass transfer of a material within the aqueous solution so that the material is transferred from the aqueous solution to the organic solvent. For instance, the aqueous solution may be an acidic or alkaline solution that includes a metal that is desired to be recovered and the organic solvent may be an organic solvent that includes an extractant that helps facilitate transfer of the metal from the aqueous solution to the organic solvent.

In some embodiments the first set of blades may be blades of a first impeller attached to the shaft at the first location to attach the blades to the shaft. The first impeller may have a first diameter. The second set of blades may be blades of a second impeller attached to the shaft at the second location to attach the blades to the shaft. The second impeller may have a second diameter that is larger or smaller than the first diameter of the first impeller. In some embodiments the first diameter may be between 5% and 25% larger than the second diameter. In other embodiments, the second diameter may be 5% to 25% larger than the first diameter. Of course, other embodiments may utilize impellers of diameters that differ by larger amounts or smaller amounts.

It should be understood that the first location at which the first set of blades are located or attached to the shaft may be above the second location at which the second set of

blades are attached to the shaft in some embodiments. Alternatively, embodiments may be configured so that the first location at which the first set of blades are located or attached to the shaft may be below the second location at which the second set of blades are attached to the shaft.

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he shaft may have any of a number of configurations. For instance, the shaft may be elongated vertically so that a first end of the shaft is adjacent a bottom of the tank and a second end of the shaft extends above the tank and is coupled to a drive mechanism for driving rotation of the shaft for rotating the first and second sets of blades. The first location may be a first vertical position within the tank and the second location may be at a second vertical position within the tank. The first vertical position within the tank may be at a middle depth of a first liquid phase portion of a liquid height of the liquids within the tank of one of the first liquid and the second liquid and the second vertical position may be at a middle depth of a second liquid phase portion of the liquid height of the liquids within the tank of the other of the first and second liquids. The first liquid phase may be located above the second liquid phase and extend from the top of the liquid height within the tank to a position below the top of the liquid height. The second liquid phase portion may be located from below the first liquid phase portion to a bottom of the tank.

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In some embodiments, the blades of the first set of blades may be directly attached to the shaft. The blades of the second set of blades may also be directly attached to the shaft. Of course, other embodiments may be configured so that an impeller body or other first intermediate structure is configured for engaging the blades of the first set of blades for attaching those blades to the shaft. A second intermediate structure or impeller body may also be configured for engaging the blades of the second set of blades for attaching those blades to the shaft.

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T

he blades of the first and second sets of blades may be in any of a number of possible configurations. For example, the blades may be pitched blades or may be elongated so that a horizontal length of each blade is substantially greater than a width or thickness of the blade. In some embodiments, the blades may be hydrofoils. It should be understood that the blades may be in any of a number of different shapes or sizes to meet a particular design objective.

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An auxiliary stirrer tank is also provided that includes a tank that receives immiscible liquids for agitating together to facilitate mass transfer of a material and a shaft positioned within the tank that is rotatable within the tank. The immiscible liquids may comprise a first liquid and a second liquid. A first set of blades is attached to the shaft at a first location on the shaft. Blades of the first set of blades are spaced apart from one another about a diameter or periphery of the shaft at the first location of the shaft. A second set of blades is attached to the shaft at a second location on the shaft. Blades of the second set of blades are spaced apart from one another about a diameter or periphery of the shaft at the second location of the shaft. The first set of blade has at least one of: (i) blades having a greater projected height than the blades of the second set of blades, (ii) blades having a greater degree of pitch than the blades of the second set of blades, (iii) blades having a greater width than the blades of the second set of blades, (iv) blades having a greater length than the blades of the second set of blades, and (v) more blades than the second set of blades.

A solvent extraction system is also provided. The system includes a mixer tank that mixes a first liquid with a second liquid. The first liquid may be immiscible with the second liquid. At least one first stirrer tank may receive the mixed liquids from the mixer tank. It should be understood that the at least one first stirrer tank may be at least one first auxiliary stirrer tank in some embodiments of the system. For some embodiments, the at least one first auxiliary stirrer tank may be an embodiment of the auxiliary stirrer tanks discussed above or discussed more fully below.

In some embodiments of the system, each of the at least one first stirrer tank includes a tank, a shaft positioned within the tank, a first set of blades attached to the shaft at a first location on the shaft and a second set of blades attached to the shaft at a second location on the shaft. The tank receives the mixed immiscible liquids for agitating the first and second liquids together to facilitate mass transfer of a material between the first and second liquids. The shaft is rotatable within the tank. The blades of the first set of blades are spaced apart from one another about a diameter or periphery of the shaft at the first location of the shaft. Each of the blades of the first set of blades extends a first distance outwardly from adjacent the shaft. The blades of the second set of blades are spaced apart from one another about a diameter or periphery of the shaft at the second location of the shaft. The blades of the second set of blades extend a second distance outwardly from adjacent the shaft. The second distance is larger or smaller than the first distance.

Embodiments of the system may also include one or more second stirrer tanks that received the mixed liquids from the at least one first stirrer tank. It should be understood that the at least one second stirrer tank may be at least one second auxiliary stirrer tank in some embodiments of the system. For instance, each of the at least one second stirrer tank includes a tank that receives the first and second liquids from the at least one first stirrer tank for agitating the first and second liquids together to facilitate mass transfer of the material between the first and second liquids, a shaft positioned within the tank that is rotatable within the tank, a first set of blades attached to the shaft at a first location of the shaft and a second set of blades attached to the shaft at a second location of the shaft. The blades of the first set of blades are spaced apart from one another about a diameter or periphery of the shaft at the first location of the shaft and extend a first distance outwardly from adjacent the shaft. The blades of the second set of blades are spaced apart from one another about a diameter or periphery of the shaft at the second location of the shaft and extend a second distance outwardly from adjacent the shaft. The second distance is greater than the first distance.

The system may also include at least one settler tank that receives the first and second liquids from the at least one second stirrer tank for settling of the first and second liquids for a predetermined time period for separating and outputting of the first and second liquids.

It should be appreciated that the at least one first stirrer tank and the at least one second stirrer tank may be configured to be an embodiment of a stirrer tank as discussed above or as discussed more fully below. For instance, the first set of blades of the at least one first stirrer tank can be blades of a first impeller attached to the shaft at the first location to attach the blades to the shaft. The first impeller may have a first diameter. The second set of blades of the at least one first stirrer tank may also be blades of a second impeller attached to the shaft at the second location to attach the blades to the shaft. The second impeller can have a second diameter that is larger or smaller than the first diameter. The first set of blades of the at least one second stirrer tank may be blades of a third impeller attached to the shaft of the at least one second stirrer tank at the first location of the shaft of the at least one second stirrer tank to attach the blades to that shaft. The third impeller can have a third diameter. The second set of blades of the at least one second stirrer tank may be blades of a fourth impeller attached to the shaft of the at least one second stirrer tank at the second location of the shaft of the at least one second stirrer tank to attach the blades to that shaft. The fourth impeller may have a fourth diameter

that is larger or smaller than the third diameter. In some embodiments of the system, the fourth diameter may be equal to the second diameter and the first diameter may be equal to the third diameter. In yet other embodiments it is contemplated that each of the at least one first stirrer tank may have one or more other impellers vertically spaced from the first and second impellers and each of the at least one second stirrer tank may also have one or more other impellers vertically spaced from the third and fourth impellers.

It should be appreciated that the first location of the shaft of the at least one first stirrer tank can be above the second location of the shaft of the at least one first stirrer tank and the first location of the shaft of the at least one second stirrer tank may be above the second location of the shaft of the at least one second stirrer tank. The first distance of the blades of the first set of blades of the at least one first stirrer tank can be smaller than the second distance of the blades of the second set of blades of the at least one first stirrer tank and the first distance of the blades of the first set of blades of the at least one second stirrer tank can be smaller than the second distance of the blades of the second set of blades of the at least one second stirrer tank.

In some embodiments of the system, each of the at least one first stirrer tank may have a shaft that is elongated vertically such that a first end of the shaft is adjacent a bottom of the tank and a second end of the shaft extends above the tank and is coupled to a drive mechanism for driving rotation of the shaft for rotating the first and second sets of blades. The first location may be at a first vertical position within the tank and the second location can be at a second vertical position within the tank. The first vertical position within the tank may be at a middle depth of a first liquid phase portion of a liquid height of the liquids within the tank of one of the first liquid and the second liquid and the second vertical position can be at a middle depth of a second liquid phase portion of the liquid height of the liquids within the tank of the other of the first and second liquids. The first liquid phase can be located above the second liquid phase and extend from the top of the liquid height within the tank to a position below the top of the liquid height and the second liquid phase portion may be located from below the first liquid phase portion to a bottom of the tank.

Additionally, embodiments of the system may be configured so that for each of the at least one second stirrer tank, the shaft is elongated vertically such that a first end of the shaft is adjacent a bottom of the tank and a second end of the shaft extends above the tank and is coupled to a drive mechanism for driving rotation of the shaft for rotating the

first and second sets of blades. The first location may be at a first vertical position within the tank and the second location can be at a second vertical position within the tank. The first vertical position within the tank can be at a middle depth of a first liquid phase portion of a liquid height of the liquids within the tank of one of the first liquid and the second liquid and the second vertical position may be at a middle depth of a second liquid phase portion of the liquid height of the liquids within the tank of the other of the first and second liquids. The first liquid phase could be located above the second liquid phase and extend from the top of the liquid height within the tank to a position below the top of the liquid height and the second liquid phase portion may be located from below the first liquid phase portion to a bottom of the tank.

In some embodiments of the system, the first set of blades of the at least one first stirrer tank are directly attached to the shaft of the at least one first stirrer tank at the first location and the second set of blades of the at least one first stirrer tank are directly attached to the shaft of the at least one first stirrer tank at the second location. The first set of blades of the at least one second stirrer tank are directly attached to the shaft of the at least one second stirrer tank at the first location and the second set of blades of the at least one second stirrer tank are directly attached to the shaft of the at least one second stirrer tank at the second location.

or some systems, the first liquid can be an organic solvent and the second liquid can be an aqueous solution. The liquids may be mixed in the mixer tank and agitated in the at least one first stirrer tank to facilitate a mass transfer of the material within the aqueous solution so that the material is transferred from the aqueous solution to the organic solvent.

Other details, objects, and advantages of the invention will become apparent as the following description of certain present preferred embodiments thereof and certain present preferred methods of practicing the same proceeds.

30

BRIEF DESCRIPTION OF THE DRAWINGS

Present preferred liquid-liquid mixing apparatuses and solvent extraction systems are shown in the accompanying drawings and certain present preferred methods of practicing the same are also illustrated therein. It should be understood that like reference numbers used in the drawings may identify like components.

Figure 1 is a block diagram providing a fragmentary view of an exemplary solvent extraction system.

5 Figure 2 is a block diagram of an exemplary embodiment of an auxiliary stirrer tank that may be used in embodiments of the system.

Figure 3 is a perspective view of a first exemplary embodiment of an impeller that may be utilized in embodiments of the auxiliary stirrer tank.

10 Figure 4 is a perspective view of a second exemplary embodiment of an impeller that may be utilized in embodiments of the auxiliary stirrer tank.

Figure 5 is a flow chart illustrating an exemplary embodiment of a method that may be used for solvent extraction processing.

15 Figure 6 is a schematic diagram showing an impeller arrangement for an auxiliary stirrer tank according to an exemplary solvent extraction system.

20 Figure 7 is a schematic diagram showing an impeller arrangement for an auxiliary stirrer tank according to another exemplary solvent extraction system.

Figure 8 is a schematic diagram showing an impeller arrangement for an auxiliary stirrer tank according to yet another exemplary solvent extraction system.

25 Figure 9 is a magnified image of droplets formed by auxiliary stirrer tanks according to embodiments of the invention.

Figure 10 shows up-pumping mixing characteristics of auxiliary stirrer tanks according to embodiments of the invention.

30 Figure 11 is a chart showing power draw for auxiliary stirrer tanks according to some embodiments of the invention.

35 Figure 12 is a chart showing power number for auxiliary stirrer tanks according to some embodiments of the invention.

Figure 13 is a chart showing droplet sizes which may be maintained by auxiliary stirrer tanks according to some embodiments of the invention.

Figure 14 is a chart showing phase separation time for auxiliary stirrer tanks according to
5 some embodiments of the invention.

Figures 15-20 illustrate detailed views of an impeller which may be utilized according to some embodiments of the invention.

10 DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Referring to Figures 1 and 5, a solvent extraction system 1 may include at least one liquid-liquid mixing circuit. Such a circuit may include a mixer tank 3. The mixer tank 3 may mix liquids together via pump mixing. A first pump may pump a first liquid, such as an organic solution for example, to the mixer tank 3. A second pump may pump a
15 second liquid such as an aqueous solution that includes a desired material, such as a pregnant leach solution that contains copper, for example. Alternatively, the mixer tank 3 may receive the liquids for mixing via a gravity feed system or may be configured to otherwise mix liquids via impeller rotation. It should be understood that the first and second liquids may be immiscible liquids.

20 The first and second pumps may feed the two different liquids at a predetermined ratio, such as a 1:1 ratio, 1.1:1 ratio, 1.5:1 ratio, or a 2:1 ratio to the mixer tank 3 for mixing the aqueous solution with the organic solution. Of course, other ratios may be used as well. Both the first pump and the second pump may feed the first liquid and the second
25 liquid, respectively, to the mixer tank 3 in a continuous flow. By the action of the pumper impeller in the mixer tank 3 (e.g. shear force generated by the pumper impeller), the first or the second liquid may be dispersed as droplets and the other liquid will remain continuous depending on the aqueous to organic feed ratio, density, viscosity, and interfacial tension properties of each liquid and properties of the pumper impeller of the
30 mixer tank 3 (e.g. the type, diameter, geometry and location of the pumper impeller, etc.).

The first and second liquids are mixed together to facilitate mass transfer reactions so that a desired mineral within one liquid, such as an aqueous solution that is acidic that
35 was previously exposed to ore or other material to extract a desired mineral from the material may be transferred from the aqueous solution to an organic solvent solution or

other liquid. One liquid is dispersed as droplets while the other liquid is dispersed in a continuous flow to help facilitate the mass transfer reaction. After being mixed at the mixer tank 3 the liquids are fed to additional auxiliary tanks to undergo further stirring for a predetermined residence time to further facilitate the mass transfer of the desired mineral from one liquid to the other liquid.

For instance, after being mixed within the mixer tank 3 via pumping to a desired ratio, the overflow of the mixed first and second liquids may be passed to a first auxiliary stirrer tank 4. The overflow may be passed to the first auxiliary stirrer tank via one or more conduits that collect the overflow and permit the overflowed mixed liquid to move into the first auxiliary stirrer tank 4. An example of such a conduit may be at least one pipe or a collection of pipes that pass from the mixer tank 3 to at least one inlet of the first auxiliary stirrer tank 4.

The first auxiliary stirrer tank 4 may include a tank that has multiple axial type impellers that are rotated to agitate the mixed first and second liquids at a predetermined speed for a predetermined time period, or predetermined residence time. The predetermined speed is determined to keep the liquids, or phases, in dispersion such that there is no air entrainment and there are no sign of clear or separated aqueous or organic phases. In some instances, the dispersion may be referred to as a suspension. The predetermined time, or residence time, may be dictated by the flow rate, volume, and mass-transfer reactions that occur between the droplets phase and the continuous phase of the two liquids being mixed.

The impellers may be attached to the same shaft and that shaft may rotate to drive rotation of the impellers. A drive mechanism such as a motor may be attached to the shaft to drive rotation of the shaft to rotate the impellers. The shaft may extend vertically so that it is elongated vertically. The shaft may be positioned within a center portion of the tank and extend from the drive mechanism, which may be located at a position near or relatively near the top of the tank to a position adjacent the bottom of the tank. The agitation of the two liquids may keep the mixture of liquids from the mixer tank 3 in suspension. The tank may also include one or more baffles.

After being mixed within the first auxiliary stirrer tank, overflow of the two liquids within the auxiliary stirrer tank 4 may be passed to a second auxiliary stirrer tank 5 via one or more conduits that collect the overflow and permit the overflow to move into the second

auxiliary stirrer tank 5. An example of such a conduit may be at least one pipe or a collection of pipes that pass from the first auxiliary stirrer tank 4 to at least one inlet of the second auxiliary stirrer tank 5.

- 5 The second auxiliary stirrer tank 5 may be structured similarly to the first auxiliary stirrer tank and also include multiple axial type impellers that are rotated to agitate the first and second liquids. The impellers may be attached to the same shaft that is rotated via a drive mechanism to drive rotation of the impellers. The shaft may be a vertically elongated shaft that is positioned within the center of the tank, for example. The shaft
10 may extend from the drive mechanism located relatively near the top of the tank to adjacent the bottom of the tank. One or more baffles may be attached to a wall of the tank or a top or bottom of the tank.

- The liquids may be agitated within the second auxiliary stirrer tank for a predetermined
15 period of time with the impellers rotating at a predetermined speed. Thereafter, overflow may be passed to at least one settler tank of a settler stage 7 via one or more conduits that collect the overflow and permit the overflowed mixed liquid to move into the settler stage. An example of such a conduit may be at least one pipe or a collection of pipes that pass from the second auxiliary stirrer tank 5 to at least one inlet of at least one
20 settler tank of the settler stage 7.

- The liquids may be left in a settler tank for a predetermined period of time to permit the liquids to separate so that two distinct layers are formed as the first liquid may be immiscible with the second liquid and have a density that is greater or smaller than the
25 density of the second liquid. The denser liquid may sink to the bottom of the settler tank while the less dense liquid may settle above the denser liquid. The different liquids may then be output from the settler stage 7 and sent to another device for further processing. For instance, if the first liquid is an organic solvent, the organic solvent may be output to an organic phase output 9 and subsequently sent to another device for further
30 processing. The second liquid may be an aqueous liquid and passed through an aqueous liquid output 13 for further processing.

- Each of the first and second auxiliary stirrer tanks may be structured similarly to each other. For example, the first and second auxiliary stirrer tanks 4 and 5 may each be of a
35 configuration shown in Figure 2. Each tank may include an inlet 18 near a bottom of the tank or side of the tank and an outlet 19 at which overflow is fed to another device

located near a top of the tank. A shaft 20 that is elongated in a vertical direction so that a length of the shaft defines a height of the shaft may be positioned in the central portion of the tank or at the center of the tank. The shaft may extend from a drive mechanism (not shown) such as a motor that drives rotation of the shaft. First impeller 21 having a first diameter D1 may be attached to the shaft 20 adjacent a bottom portion of the shaft 20. A second impeller 23 having a second diameter D2 may be attached to the shaft 20 above the first impeller 21 so that the second impeller 23 is spaced apart from the first impeller a predetermined distance along the shaft 20. The first diameter D1 of the first impeller 21 is larger than the second diameter D2 of the second impeller 23. Each impeller may have the same number of blades of a same configuration, but the length of the blades of the second impeller may be shorter than the blades of the first impeller so that the second diameter D2 is shorter than the first diameter D1.

In some embodiments, it is contemplated that additional impellers may also be attached to the shaft. The use of additional impellers may be utilized when a tank is particularly tall to avoid stagnation zones. For instance, a third impeller may be positioned between the first and second impellers. As another example, a third and a fourth impeller may be positioned at spaced apart locations along the shaft between the first and second impellers. Each of the third and fourth impellers may be of a different configuration than the first and second impellers 21, 23 or may be of a same size and configuration as the first impeller 21 or second impeller 23.

In alternative embodiments, the impellers may be configured differently to ensure power from the moving shaft is imparted to the liquid via the blades of the impellers so that more power is imparted via the blades of the first impeller 21 as compared to the power imparted via the blades of the second impeller 23. For instance, the projected height H, or width, of the blades of the first impeller may be larger than the projected height, or width, of the blades of the second impeller 23 while the lengths of the blades of the first and second impellers 21, 23 may be the same (e.g. the diameter of the first impeller 21 is the same as the diameter of the second impeller 23). As another example, the first impeller 21 may include more blades than the second impeller 23 (e.g. the first impeller 21 may have six blades and the second impeller 23 may have four blades or the first impeller 21 may have four blades and the second impeller 23 may have three blades). As yet another example, the pitch of the blades of the first impeller may be the same or may be different than the pitch of the blades of the second impeller 23. For instance, the pitch of the blades of the first impeller may be at sixty degrees and the pitch of the

blades of the second impeller may be at forty-five degrees or thirty degrees. As yet another example, the first impeller may have blades utilizing a combination of such differences. For example, the first impeller may have four blades having a sixty degree pitch and have a first length and a first projected height and the second impeller may have three blades having a forty-five degree pitch and have a second length that is less than the first length and a second projected height that is less than the first projected height.

Of course, other variations in length, pitch, projected height or width, and blade number may be used in embodiments so that the first impeller 21 differs from the second impeller 23 so more power is imparted via the first impeller 21 than the second impeller 23.

The positioning of the impellers in the tank may be selected for being positioned at predetermined heights within the tank that correspond to positions within a full height of the mixed liquids retained and agitated within the tank. The impellers may be vertically spaced apart from each other along the length of the shaft 20 so that a series of blades or blades of each impeller are attached to the shaft at spaced apart locations along the diameter or periphery of the shaft 20 at a particular location on the shaft 20. For instance, the upper second impeller 23 may be positioned above the lower first impeller 21 so that a distance of between 65% and 75% of the first diameter D1 of the lower first impeller 21 along the shaft 20 separates the first and second impellers. In other embodiments, it is contemplated that the distance between the upper second impeller 23 and lower first impeller 21 may be 50% to 120% of the first diameter D1. In yet other embodiments, it is contemplated that the distance between the upper second impeller 23 and lower first impeller 21 may be 50% to 120% of the second diameter D2.

The mixed liquids may include a first liquid phase 25 and a second liquid phase 27. Each phase may exist after a phase separation time is reached within a tank so that the two immiscible liquids separate from each other after that time has passed. A higher density liquid will be within a lower second liquid phase 27 that is below the lower density liquid of the first liquid phase 25. The first liquid may be of a lower density than the second liquid and, as a result, be naturally inclined to travel to the top of the tank as the heavier second liquid to which the first liquid is immiscible is inclined due to gravity to sink to the bottom of the tank. If the ratios of the liquids are 1:1, then the first liquid phase 25 would be the upper half of the liquid height within the tank and the second liquid phase 27 would be the bottom half of the liquid height within the tank.

The first impeller 23 may be a predetermined amount larger than the second impeller to meet a particular design objective depending on the liquid to liquid ratios use in the mixing, the densities of the liquids, the residence time for the mixing of the liquids within a particular tank, and other properties of the liquids and design objectives of the system.

5 For example, the first diameter D1 of the first impeller 23 may be 15% or 10% larger than the second diameter D2 of the second impeller 25. As another example, the first diameter D1 of the first impeller 23 may be between 25% and 5% larger than the second diameter D2 of the second impeller 25. In another embodiment, it is contemplated that the first diameter D1 of the first impeller 23 may be larger than the second diameter D2
10 such that the power of the first impeller 23 is up to three times larger than the power of the second impeller 25, where power of an impeller is directly proportional to its diameter raised to its fifth power (e.g. the diameters of the first and second impellers are selected such that $D1^5 = 3 \times D2^5$ or $D1^5 = 2 \times D2^5$ or $D1^5 = 1.25 \times D2^5$).

15 As noted above, as an alternative to differing diameters between the first and second impellers 21, 23, it is contemplated that the projected height H or width, of the blades may be different to effect such a power distribution change. As yet another alternative, the pitch at which the blades of the first and second impellers are angled may differ to achieve such a power distribution difference. As yet another example, the number of
20 blades of the first impeller 21 may differ from the number of blades of the second impeller 23 to provide such a power distribution difference. It is also contemplated that combinations of changes in blade length, number, pitch angle, and projected height or width may also be utilized to provide such a power distribution difference between the first and second impellers 21, 23.

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In some embodiments, it is contemplated that the upper impeller may be of a larger diameter than the lower impeller. For instance, in systems where a less dense liquid may be present at a three to one ratio (e.g. 3:1 ratio) to a liquid it is immiscible with and is being mixed with, the upper impeller may be of a larger diameter than the lower impeller.
30 It should be understood that for such an embodiment, the first liquid phase 25 would extend for an upper 75% of the height of the liquid within the tank while the denser second liquid would be a second liquid phase 27 at the bottom 25% of the height of the liquid within the tank. The first larger diameter impeller for such an alternative embodiment would be located preferably at a fourth to a third of the first larger diameter
35 impeller from the free liquid-air interface or middle of the upper 75% of the height of the liquid within the tank (e.g. at a location that is at about the upper 37.5% of the upper

height of the liquid within the tank) and the second smaller diameter would be located at the 65% to 75% of the first larger impeller diameter away from the first larger impeller diameter or middle of the bottom 25% of the height of the tank (e.g. at a location at about the bottom 12.5% of the height of the liquid within the tank).

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It should be understood that the above noted positioning of the first and second impellers may be similar to what is positioned for the first and second impellers 21, 23 of different diameters noted above when the impellers have different numbers of blades, blades of differing projected heights or widths, blades of differing pitch, or combinations of differing projected heights, length, number and angle of pitch to provide a power distribution differential between the impellers.

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Of course, in alternative embodiments, it is contemplated that the first and second auxiliary stirrer tanks 4 and 5 may be of a different shape or a slightly different configuration. That being said, each tank may still include a vertically elongated shaft that extends into the tank near or at a central position of the tank and have at least two different spaced apart impellers attached thereto so that that rotation of the shaft may rotate the impellers. The impellers may each be of a different diameter, have blades of differing length, have blades of differing pitch, have blades of differing width or projected height or have different numbers of blades. For example, one impeller may have blades that extend outwardly from the shaft at a first distance and the other impeller may have blades or hydrofoils that extend outwardly from the shaft at a second distance that is smaller or larger than the first distance.

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In yet another alternative embodiment, the first and second impellers 21, 23 may have the same diameter but have blades of differing projected height, have different numbers of blades, have blades that are pitched at different angles, or combinations of such differences. For instance, in one embodiment, the first impeller 21 may be an embodiment of an impeller 22a shown in Figure 3 having a predetermined diameter and the second impeller 23 may be an embodiment of the impeller 22b shown in Figure 4 having a predetermined diameter that is equal to, greater than or less than the diameter of the first impeller 21. Of course, other impeller configurations for the first and second impellers 21, 23 may also be utilized.

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It should be understood that the blades of each impeller may be blades that are attached to the shaft 20. As an alternative to impellers, it should be appreciated that a series of

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hydrofoils or other types of blades may be directly attached to the shaft 20 in spaced apart locations around a diameter or perimeter of the shaft as a replacement for an impeller. A first series of spaced apart blades may be located at a position in which the first impeller 23 is located and a second series of spaced apart blades may be located at
5 a position in which the second impeller 25 is located, for example. For such embodiments, the lengths of the blades that extend horizontally or outwardly from the shaft may be larger for the first series of blades as compared to the lengths to which the blades of the second series of blades extend outwardly from the shaft 20. The first series of blades for such an embodiment would function similarly to the first impeller 23 and the
10 second series of blades would function similarly to the second impeller 25.

Any number of types of impellers or blades may be utilized in embodiments of the auxiliary stirrer tanks. For instance, the first and second impellers may each be a type of impeller 22a as shown in Figure 3, which includes a plurality of spaced apart pitched
15 blades that are part of the impeller and are attached to the shaft via attachment of the body of the impeller to the shaft. The blades are at a predetermined pitch, such as a pitch of thirty degrees, forty-five degrees or sixty degrees, and may extend outwardly from a central body of the impeller so that each of the blades extend outwardly from the shaft when attached to the shaft to define a length of the blade. Each blade may also
20 have a width W , or a projected height, as well. The impeller may include a hub having a central hole for receiving the shaft. The shaft may be attached to the impeller via any of a number of suitable fastening mechanisms such as welding, fasteners, adhesives, or any combination thereof.

As another example, the first and second impellers may each be structured similarly to the impeller 22b and have a diameter D defined by the outer edges of the blades, or hydrofoils, of the impeller 22b. The impeller 22b may include three blades that are each angled vertically so that they extend vertically at a pitch, such as a pitch of thirty degrees relative to a horizontal plane and have a droop angle. For instance, the blades may
30 have a droop angle of between one and ten degrees such as five degrees or ten degrees. It should be understood that the droop is the downward angle of a blade when looked at from the side of the blade. The blades of the impeller 22b may extend outwardly from a central body of the impeller 22b so that when the impeller 22b is attached to a shaft within a tank, the blades extend horizontally outwardly from the shaft
35 and have a projected height H that is the distance the blade extends vertically along the

height or length of the shaft 20 to which the impeller is attached. The projected height H of each blade may be less than the horizontal length of that blade.

Experimentation of embodiments of the solvent extraction process and auxiliary stirrer
5 tanks were conducted. The experimentation found that embodiments of the auxiliary
stirrer when used in a solvent extraction process permitted impellers of different
diameters at different vertical positions along the shaft to consume substantially less
power than other auxiliary stirrers that utilized two spaced apart impellers of the same
diameter. For instance, the speeds at which the impellers had to be rotated to provide a
10 desired mixing was substantially less than other stirrers. A decrease in power per
volume of liquid being mixed of between 50% and 90% was obtained from embodiments
of the auxiliary stirrer tank that utilized two spaced apart impellers of different diameters
in some experiments. Thus, embodiments of the auxiliary stirrer tank can provide an
operational savings on energy consumption of 90% in some embodiments. The
15 decrease in power consumption is due to a number of factors such as a needed speed
of rotation to provide a desirable mixing of the liquids. In one experiment, it was found
that use of impellers of different diameters at different heights along the shaft of an
auxiliary stirrer tank could be rotated at a speed that was 57% to 40% less than other
stirrer tanks.

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Experimentation also attempted to determine whether droplet sizing of one liquid being
mixed with another liquid was substantially changed for a desired mixing of the liquids.
Experimental results found that a mean droplet size was not drastically changed. Droplet
sizes between 300 and 383 micrometers via a Sauter mean droplet size calculation was
25 found to be usable for embodiments of the auxiliary stirrer tank that utilized different
diameter impellers. It is contemplated that droplets sized between 300 and 400
micrometers may be used in other embodiments of our auxiliary stirrer tank or system. It
is also contemplated that droplets of other size ranges could be used in other
embodiments as the droplet size range that is selected may depend on the liquids being
30 mixed, the flow rates, and the residence time designed for a particular system.

Experimentation was also conducted to assess a phase separation time. The phase
separation time for different embodiments of the auxiliary tank that utilized different
diameter impellers at different spaced apart locations of the shaft was found to be
35 between 150 and 200 seconds for different location and type of impellers under

optimized mixing conditions. No substantial change from those found in conventional systems was determined to exist based on these experimental results.

Experimentation that was conducted helped confirm that use of embodiments of the auxiliary stirrer tanks may be utilized to provide a substantial power savings of up to 90% as compared to conventional designs and also produced optimal mixing of different immiscible liquids such as an organic solvent and an acidic aqueous solution such as a pregnant leach solution, for example.

It should be understood that a number of different variations to the above discussed embodiments may be made to meet different design objectives. For instance, in some embodiments of the solvent extraction process, it is contemplated that the auxiliary stirrer tanks may operate in parallel instead of in series as noted above. Further, certain systems may be configured so that more than one first auxiliary tank and more than one second auxiliary tank may be provided to receive liquid from a mixer tank. As another example, different ratios of an organic solvent to an aqueous solution may be utilized for different mineral extraction processing, depending on the organic solvent that is selected for use and the mineral that is entrained within the aqueous solution that is desired to be extracted from that solution and entrained within the organic solution for subsequent processing. As yet another example, tanks for the different stirrer tanks may be any of a number of shapes and dimensions to meet a particular design objective. As yet another example, the shape and length of the shaft for rotating the impellers may be any of a number of different shaped and elongated shafts and the type of motor or other drive mechanism used to drive rotation of the shaft may be any of a number of different types of drive mechanisms for causing the shaft to rotate for driving rotation of the impellers attached to the shaft. As yet another example, the type of blades, shape of the blades, or number of blades attached to a shaft at different locations in series around a diameter or perimeter of the shaft may be any of a number of different types or numbers. For instance, the type of impellers, impeller manufacturer, shape of the blades of impellers and angles or pitch at which the blades may be positioned may be any of a number of possible options to meet a particular design objective. The number of blades that may be attached to a shaft may be any number that is found to meet a particular design objective. For instance, two sets of blades may be positioned around a periphery of the shaft at two different vertically spaced apart locations. Each set of blades may include two, three, four, five, six, eight or ten, blades attached to the shaft at spaced apart

locations so that the blades are positioned around the periphery or diameter of the shaft at a particular location along the height or length of the shaft.

The below examples refer to Figures 11 -14. For each of the below examples, a bench-scaled a solvent extraction system 1 was used. The bench-scaled a solvent extraction system 1 comprised three tanks – a primary mixer tank 3 for pumper-mixing of immiscible organic and aqueous phases to form an emulsion, and two auxiliary stirrer tanks 4, 5 which were provided downstream from and in series with the mixer tank 3 for auxiliary mixing and maintaining suspensions within the emulsion phase for a predetermined residence time. Two pumps moved organic (i.e., an extractant-kerosene mixture) and aqueous (i.e., a copper pregnant leach solution) fluids, respectively, in a desired ratio of 1:1 to the mixer tank 3 for pumper-mixing. The mixer tank 3 was agitated by a conventional radial impeller having a plurality of vertically-extending blades. The overflow of mixed organic and aqueous phases formed an emulsion which was sent to one of the two subsequent auxiliary stirrer tanks 4, 5. Each of the first 4 and second 5 auxiliary stirrer tanks comprised two axial-type impellers 21,23, which kept the emulsion stable (i.e., kept one phase in suspension of the other phase). Overflow from the first auxiliary stirrer tank 4 was delivered to a second auxiliary stirrer tank 5 having a similar configuration as the first auxiliary stirrer tank 4. The flowrate used during the experiments was 1.5 GPM each of aqueous and organic (Totalling 3 GPM throughput) and the sizes of the tanks 3, 4, 5 were chosen to match the residence time of industrial mixing tanks typically used in full-scale solvent extraction operations. The residence time in the primary mixer tank 3 (pumper mixing) was maintained at 48 seconds, and the residence time in each of the other two auxiliary stirrer tanks was 68 per tank. After the 184 second total residence time, the emulsion from the second auxiliary stirrer tank 5 overflowed to a settler stage 7, where both of the immiscible phases were separated and recycled back to their respective organic and aqueous phase holding tanks.

The diameter DT of the mixer tank 3 and auxiliary stirrer tanks 4, 5 was approximately 290 mm. The height of the liquid within each of the tanks 3, 4, 5 was maintained at approximately 230 mm in order to match tank residence times. Four baffles (not shown), each having a width of approximately 24.34 mm were evenly equipped to portions of each tank wall. Off-bottom clearances X were measured from the bottom of a respective auxiliary stirrer tank 4, 5 to the bottom of a respective impeller blade 21. Between impeller clearances (Y) were measured between respective impeller blades 21, 23. Figure 6 generally corresponds with the setups used for Examples 1 and 2. Figure 7

generally corresponds with the setups used for Examples 3 and 4. Figure 8 generally corresponds with the setups used for Examples 5 and 6.

EXAMPLE 1

5 Two identical six-blade impellers 21, 23 having 45 degree pitch blades were placed on a rotatable shaft 20 of an auxiliary stirrer tank 4, 5 for liquid-liquid mixing in a solvent extraction system 1. The diameters D1, D2 of the two impellers 21, 23 were 133.35 mm (or approximately 0.46 times the auxiliary stirrer tank diameter DT of the auxiliary stirrer tank). The lower first impeller 21 was positioned so that it was above the bottom of the
10 auxiliary stirrer tank 4, 5 by a vertical distance X of approximately 1/3 the auxiliary stirrer tank diameter DT. The upper second impeller 23 was positioned on the shaft 20 of the auxiliary stirrer tank above the first impeller 21 a vertical distance Y. Vertical distance Y was approximately 75% of the diameter D1 of the first impeller 21 (or, approximately 0.345 times the tank diameter DT). It was found that the two six-blade impellers 21, 23
15 provided surprisingly efficient mixing at a tip speed of approximately 0.83 m/sec, with no visible air entrainment. The power consumption per unit volume of fluid was very low, around approximately 0.158 Hp/1000 gallons. Very little shear was imparted to the organic and aqueous phases, and the mean droplet size of the dispersion (Sauter mean diameter) was approximately 334 μm . Reynolds number was calculated to be
20 approximately 15389, with a power number of approximately 1.54.

EXAMPLE 2

Two identical six-blade impellers 21, 23 having 45 degree pitch blades were placed on a rotatable shaft 20 of an auxiliary stirrer tank 4, 5 for liquid-liquid mixing in a solvent
25 extraction system 1. The diameters D1, D2 of the two impellers 21, 23 were 133.35 mm (or approximately 0.46 times the tank diameter DT of the auxiliary stirrer tank). The lower first impeller 21 was positioned so that it was above the bottom of the auxiliary stirrer tank by a vertical distance X of approximately 1/4 the diameter of the auxiliary stirrer tank diameter DT. The upper second impeller 23 was positioned on the shaft 20
30 of the auxiliary stirrer tank 4, 5 above the first impeller 21 by a vertical distance Y. Vertical distance Y was approximately 65% of the diameter D1 of the first impeller 21 (or, approximately 0.299 times the auxiliary stirrer tank diameter DT). It was found that the two six-blade impellers provided surprisingly efficient and optimal mixing at a tip speed slightly less than for Example 1 (approximately 0.77 m/s) with no visible air entrainment.
35 The power per unit volume of fluid consumption was still very low, and just above what required in Example 1 (approximately 0.183). Very little shear was imparted to the

organic and aqueous phases, and the mean droplet size of the dispersion (Sauter mean diameter) was approximately 348 μm . Reynolds number was calculated to be approximately 14182, with a power number of approximately 2.29.

5 EXAMPLE 3

Two identical hydrofoil impellers were used within an auxiliary stirrer tank 4, 5 for liquid-liquid mixing in a solvent extraction system 1. The diameter D1, D2 of each hydrofoil impeller 21, 23 was measured to be 116.84 mm, which was approximately 0.4 times the diameter DT of the auxiliary stirrer tank. A first hydrofoil impeller 21 was positioned on the shaft 20 of the auxiliary stirrer tank at a vertical distance X approximately 1/3 the auxiliary stirrer tank diameter DT from the bottom of the auxiliary stirrer tank. A second hydrofoil impeller 23 was positioned on the shaft 20 above the first hydrofoil impeller 21 by a vertical distance Y. Distance Y was approximately 75% of the diameter D1 of the first hydrofoil impeller 21 (or, approximately 0.3 times the auxiliary stirrer tank diameter DT). It was found that optimal mixing occurred at a tip speed of approximately 1.42 m/sec which consumed approximately double the power of Examples 1 and 2 (approximately 0.319 Hp/1000 gallons). Droplet sizes within the dispersion (Sauter mean diameter) were approximately 383 μm on average. Reynolds number was calculated to be approximately 22931, with a power number of approximately 0.82.

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EXAMPLE 4

Two identical hydrofoil impellers were used within an auxiliary stirrer tank 4, 5 for liquid-liquid mixing in a solvent extraction system 1. The diameter D1, D2 of each hydrofoil impeller 21, 23 was measured to be 116.84 mm which was 0.4 times the tank diameter of the auxiliary stirrer tank. A first hydrofoil impeller 21 was positioned on the shaft 20 of the auxiliary stirrer tank at a vertical distance X approximately 1/4 the tank diameter from the bottom of the auxiliary stirrer tank. A second hydrofoil impeller 23 was positioned on the shaft 20 of the auxiliary stirrer tank above the first hydrofoil impeller by a vertical distance Y. The vertical distance Y was approximately 75% of the diameter D1 of the first hydrofoil impeller D1 (or, approximately 0.3 times the auxiliary stirrer tank diameter DT). It was found that optimal mixing occurred at a tip speed of approximately 1.42 m/sec, which consumed approximately double the power of Examples 1 and 2 (approximately 0.342 Hp/1000 gallons). Droplet sizes within the dispersion (Sauter mean diameter) were approximately 346 μm on average. Reynolds number was calculated to be approximately 22931, with a power number of approximately 0.88.

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EXAMPLE 5

Two different sizes of hydrofoil impellers were used within an auxiliary stirrer tank 4, 5 for liquid-liquid mixing in a solvent extraction system. The diametrical size D1 of the first hydrofoil impeller 21 was measured to be approximately 134.11 mm (i.e., approximately 0.46 of the auxiliary stirrer tank diameter DT), and the diametrical size D2 of the second hydrofoil impeller 23 was 116.84, or 0.4 times the tank diameter DT of the auxiliary stirrer tank 4, 5. The first hydrofoil impeller 21 was positioned on the shaft 20 of the auxiliary stirrer tank a vertical distance X above the bottom of the auxiliary stirrer tank 4, 5. The vertical distance X was approximately 1/3 the auxiliary stirrer tank diameter DT. The second hydrofoil impeller 23 was positioned on the shaft 20 of the auxiliary stirrer tank above the first hydrofoil impeller 21 by a distance Y of approximately 65% of the diameter D1 of the first hydrofoil impeller 21 (i.e., approximately 0.299 times the tank diameter DT). It was found that the two differently-sized hydrofoil impellers provided optimal mixing at a tip speed of approximately 1.3 m/sec. Surprisingly efficient liquid-liquid mixing was established without causing excessive shear. Accordingly, the mean droplet size of the dispersion did not significantly differ from prior mixers. The mean droplet size (Sauter mean diameter) was measured to be approximately 297 μm . No air entrainment was observed, and the required power per unit volume was recorded to be 0.235 Hp/1000 gallons. Reynolds number was calculated to be approximately 24104, with a power number of approximately 0.60.

EXAMPLE 6

Two different sizes of hydrofoil impellers 21, 23 were used within an auxiliary stirrer tank 4, 5 for liquid-liquid mixing in a solvent extraction system 1. The diametrical size D1 of the first hydrofoil impeller 21 was measured to be 134.11 mm, or approximately 0.46 of the auxiliary stirrer tank diameter DT. The diametrical size D2 of the second hydrofoil impeller 23 was approximately 116.84, or approximately 0.4 times the tank diameter DT of the auxiliary stirrer tank. The first hydrofoil impeller D1 was positioned on the shaft 20 of the auxiliary stirrer tank a distance X, which was approximately 1/2 the tank diameter DT above the floor of the auxiliary stirrer tank 4, 5. The second hydrofoil impeller 23 was positioned on the shaft 20 of the auxiliary stirrer tank above the first hydrofoil impeller by a distance of Y, wherein Y equaled approximately 65% of the diameter D1 of the first hydrofoil impeller 21 (or, approximately 0.299 times the tank diameter DT). It was found that the two differently-sized hydrofoil impellers 21, 23 provided optimal mixing at a tip speed of approximately 1.62 m/sec. Surprisingly efficient liquid-liquid mixing was established without causing excessive shear. Accordingly, the mean droplet size of the

dispersion was not significantly different from conventional mixers. The mean droplet size (Sauter mean diameter) was measured to be approximately 331 μm . No air entrainment was observed, and the required power per unit volume was recorded to be 0.339 Hp/1000 gallons. Reynolds number was calculated to be approximately 30206
5 with a power number of approximately 0.44.

Figure 9 shows an image of droplets formed during auxiliary mixing of an emulsion using an auxiliary stirrer tank configuration according to one of the above examples.

10 Figure 10 shows CFD imagery showing the up-pumping ability of first 21 and second 23 impellers discussed herein. In use, fluids adjacent the shaft 20 move upward with an upward velocity, and fluids adjacent the outer portions of auxiliary stirrer tank 4, 5 move downwardly. This "up-pumping" differs from reversed "down-pumping" found in flotation cells and attrition scrubbers. The first 21 and the second 23 impellers in the embodiment
15 shown in Figure 10 are similar in size and geometry. As shown, the impellers 21, 23 may be located on the shaft 20 so as to be disposed within the approximate middle of upper and lower halves of an auxiliary stirrer tank (in relation to a 100% fill level).

Specific power draw as a function of tip speed for different auxiliary impellers is shown in
20 Figure 11. Power number for the above examples plotted against respective Reynolds number is shown in Figure 12. The power number when using two identical 6-bladed rotors (Examples 1 and 2) ranged between approximately 1.54-2.29; whereas the power number for two identical hydrofoil impellers (Examples 3 and 4) ranged between approximately 0.82 and 0.88. The power number for a smaller hydrofoil impeller above a
25 larger diameter hydrofoil impeller (Examples 5 and 6) varied between approximately 0.44-0.6.

As shown in Figure 13, the Sauter mean diameter droplet size distribution for each of Examples 1-6 lies between approximately 280 and 383 μm , which is a droplet size range
30 that is generally widely accepted by solvent extraction community for mass-transfer reactions to occur within a predetermined residence time. Phase separation time (i.e., the time when the two immiscible phases separate from each other) as it relates to tip speed is illustrated in Figure 14. As shown, phase separation times generally lie between about 150-200 seconds, depending on the location and/or type of impeller(s)
35 used under optimal mixing conditions.

Turning now to Figures 15-20, details of an impeller which may be practiced with the invention are shown. The impeller may be, for instance, utilized in the configurations shown in Figures 7 and/or 8. A pitch angle A of a blade may range between about 15 and 45 degrees with respect to an impeller axis; and more particularly, between about 25 and 35 degrees with respect to an impeller axis, such as approximately 30 degrees as shown. A lower leading edge portion of a blade may be offset a lateral distance B from an impeller axis. In some embodiments, distance B may be between about $1/4$ and $1/2$ a height H of the impeller; and more particularly, between about $1/3$ and $3/8$ a height H of the impeller, such as approximately $4/11$ times a height H of the impeller as shown. In some embodiments, distance B may be between about $1/50$ and $1/5$ a diameter U of the impeller; and more particularly, between about $1/25$ and $3/25$ a diameter U of the impeller, such as approximately $2/25$ times a diameter U of the impeller as shown. According to Figure 16, each blade of the impeller may be flared by an angle C. In some embodiments, angle C may be between about 1 and 10 degrees from horizontal; and more particularly between about 3 and 6 degrees from horizontal. For example, a blade may be flared upwardly by a rake angle C which is approximately 4.3 degrees from horizontal as shown. Rake angle C may be measured from an outer convex surface of the blade to a perpendicular of the impeller axis.

Figure 17 illustrates a bottom plan view of the impeller shown in Figures 15 and 16. Three blades may be evenly spaced circumferentially about a hub having a central hole for receiving a shaft. As shown, the axis of each blade may be separated by an angle E which is approximately 120 degrees. In embodiments (not shown) which have 4 blades, each blade axis may be separated by an angle E which is approximately 90 degrees. In yet further embodiments (not shown) which have 5 blades, each blade axis may be separated by an angle E which is approximately 72 degrees, and so on. In some preferred embodiments, a width D of each blade which extends between lower leading and trailing edges may fall within the range of $3/4$ to 1 times a height H of the impeller, for example, approximately $8/9$ times a height H of the impeller as shown. In some preferred embodiments, a width D of each blade which extends between lower leading and trailing edges may fall within the range of $1/16$ to $5/16$ times a diameter U of the impeller, and more particularly between $1/8$ to $1/4$ times a diameter U; for example, approximately $3/16$ times a diameter U of the impeller as shown.

Figure 18 shows a cutaway view of Figure 17, and illustrates a height H of the impeller shown in Figures 15-17. In some embodiments, each blade may be offset from a bottom

portion of the impeller by a distance of approximately $1/4$ to $1/2$ times height H ; and more particularly 0.3 - 0.4 times height H , such as $1/3$ the height H as shown. In some embodiments, each blade may be offset from a bottom portion of the impeller by a distance of approximately 0.1 to 0.10 times diameter U ; and more particularly 0.6 - 0.9 times diameter U , such as approximately 0.75 the impeller diameter U as shown. Blades may extend from an impeller axis for a distance I , which is exactly half diameter U . In some embodiments, the distance I may be within approximately 2.1 and 2.5 times a height H of the impeller, for instance, approximately 2.3 times the height H . Chamfers K may be added to edges of the central hole for receiving a shaft. In some preferred embodiments, the chamfers K may be angled approximately 30 to 60 degrees, for example, 45 degrees as shown. The inside diameter G of the hub which forms the central hole for receiving a shaft may, in some instances, be between $4/5$ and $6/5$ times height H , for example, approximately the same distance as height H . The inside diameter G of the hub which forms the central hole for receiving a shaft may, in some instances, be between $1/8$ and $5/16$ times diameter U , for example, approximately $7/32$ times diameter U . According to some embodiments, an outer diameter F of the hub may be between $5/4$ and $7/4$ height H , for example, one and a half times height H as shown. Outer diameter F of the hub may also be between $1/4$ and $13/32$ the outer diameter U of the impeller, for example, $21/64$ times diameter U as shown.

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Blade particulars according to some preferred embodiments are shown in Figures 19 and 20. Each blade may be curved (e.g., arched or bowed) and have a transverse radius L . In some embodiments, transverse radius L may be between approximately 1 and 1.5 times a height H of the impeller, and more particularly between 1.2 and 1.3 times a height H of the impeller. For instance, as shown in the figures, radius L may be approximately $5/4$ times height H . In some embodiments, transverse radius L may be between approximately $7/32$ and $11/3$ times a diameter U of the impeller, and more particularly between $1/4$ and $5/16$ times a diameter U of the impeller. For instance, as shown in the figures, radius L may be approximately $11/40$ times diameter U . In some embodiments, a thickness N of each blade may be between $1/25$ and $1/5$ times a height H of the impeller. In some embodiments, a thickness N of each blade may be between $.01$ and $.05$ times an outer diameter U of the impeller. The thickness N may be constant as shown, but may alternatively vary at different portions of a respective blade. For example, thickness N of a blade may be approximately $3/25$ times height H , and/or approximately 0.26 times impeller diameter U as shown. A trough depth M of a blade may be defined between 1) a chord extending between side edges of the blade, and 2)

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an upper concave surface of the blade. Trough depth M may vary depending on radius L and thickness N; however, in some preferred embodiments, trough depth M may be approximately $1/10$ a height of the impeller, and/or approximately 0.024 times the outer diameter U of the impeller as shown.

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Each blade may have a wider root width O which narrows or otherwise tapers to a tip width P. A straight chamfer (as shown) or curvature on a trailing edge of the blade may extend between the root and the tip of each blade, making the upper trailing edge longer than its lower leading edge. A length of tapering S may vary; however, in some preferred embodiments, the length of tapering S formed by the chamfer or curvature may range between approximately $1/2$ and $3/2$ times height H. For example, the length of tapering S may vary between approximately $3/4$ and $5/4$ H. Length of tapering S may, in some preferred embodiments, range between approximately 0.01 and 0.35 times diameter U. For example, the length of tapering S may vary between approximately 0.2 and 0.25 U. In the particular embodiment shown, the length of tapering S is approximately equal to height H and/or approximately equal to 0.22 times diameter U.

Depending on the root O and tip P widths, the length of tapering S may change, as well as an angle R defined therebetween. In some instances, R may range between 10 and 30 degrees, and may be, for example, approximately 20 degrees as shown. In some preferred embodiments, root width O may be between about 0.75 and 1.25 times a height H of the impeller; for example, root width O may be approximately the same height H as shown. In some preferred embodiments, root width O may be between about 0.1 and 0.3 times a diameter U, such as between approximately 0.2 and 0.26 times a diameter U of the impeller. For example, as shown, root width O may be approximately 0.23 times the diameter U. In some preferred embodiments, tip width P may be between about $1/2$ and $3/4$ times a height H of the impeller; for example, tip width P may be approximately $5/8$ times the height H as shown. In some preferred embodiments, tip width P may be between about $3/32$ and $5/32$ times a diameter U of the impeller. For example, tip width P may be between approximately $1/8$ and $9/64$ times the diameter U, such as approximately 0.14 U as shown. Each blade may have an approximate length Q which is between 1 and 2.5 the impeller height H. For example, each blade may have a length between approximately $3/2$ and $7/4$ times height H, such as $33/20$ times height H as shown. In some instances, length Q may be between $5/16$ and $13/32$ times the impeller diameter U. For example, each blade may have a length

between approximately $3/8$ and $11/32$ times diameter U, such as $23/64$ times diameter U as shown.

As shown in Figure 20, a blend cut T may be made to facilitate welding, adhering,
5 fastening, or otherwise joining each blade to the hub of the impeller, or directly to a shaft portion.

While certain present preferred embodiments of a liquid-liquid mixing apparatus, a solvent extraction system and methods of making and using the same have been shown
10 and described above, it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied and practiced within the scope of the following claims.

CLAIMS

1. An auxiliary stirrer tank for a solvent extraction system for receiving an emulsion of liquids from a primary mixer tank comprising:

5 a tank having a tank diameter that is configured to receive the emulsion of immiscible liquids for agitating and facilitating mass transfers therebetween, the immiscible liquids comprising a first liquid and a second liquid; the first liquid being an organic solvent and the second liquid being an aqueous solution.

a shaft positioned within the tank, the shaft being rotatable within the tank;

10 a first set of blades attached to the shaft at a first location on the shaft, blades of the first set of blades being spaced apart from one another about a diameter or periphery of the shaft at the first location of the shaft and extending a first distance outwardly from adjacent the shaft to a first diameter that is between 0.4 and 0.5 times the tank diameter;

a second set of blades attached to the shaft at a second location on the shaft,
15 blades of the second set of blades being spaced apart from one another about a diameter or periphery of the shaft at the second location of the shaft and extending a second distance outwardly from adjacent the shaft to a second diameter that is between 0.4 and 0.5 times the tank diameter;

the pitch of the first set of blades being the same as the pitch of the second set of
20 blades, the pitch being between 30 and 60 degrees and configured to provide an upward pumping force adjacent the shaft and a downward flow adjacent the tank diameter;

wherein the first set of blades and the second set of blades are configured to discourage air entrainment, maintain droplet sizes of the immiscible liquids above 50 μm , maintain a tip speed between 0.5 and 1.5 m/s, and consume less than 0.75 hp per 1000
25 gallons.

2. The auxiliary stirrer tank of claim 1 wherein the first and second diameters are between approximately 0.44 and 0.48 times the tank diameter.

30 3. The auxiliary stirrer tank of claim 2 wherein the first and second diameters are approximately 0.46 times the tank diameter.

4. The auxiliary stirrer tank of claim 1 wherein the pitch of the first set of blades and the second set of blades is approximately 45 degrees.

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5. The auxiliary stirrer tank of claim 1 wherein the mean droplet size of the immiscible liquids is between approximately 250 and 400 μm .
6. The auxiliary stirrer tank of claim 5 wherein the mean droplet size of the immiscible liquids is between approximately 300 and 350 μm .
7. The auxiliary stirrer tank of claim 1 wherein the tip speed of the first set of blades and the second set of blades is maintained between approximately 0.7 m/s and 1 m/s.
8. The auxiliary stirrer tank of claim 7 wherein the tip speed of the first set of blades and the second set of blades is maintained at approximately 0.9 m/s.
9. The auxiliary stirrer tank of claim 1 wherein the tank is configured to run at ambient conditions.
10. The auxiliary stirrer tank of claim 1 wherein the first set of blades and the second set of blades are identical.
11. The auxiliary stirrer tank of claim 1 wherein the first set of blades are blades extending from a hub of a first impeller attached to the shaft at the first location to attach the blades to the shaft; and wherein the second set of blades are blades extending from a hub of a second impeller attached to the shaft at the second location to attach the blades to the shaft.
12. The auxiliary stirrer tank of claim 1 wherein the first set of blades and the second set of blades are configured consume less than approximately 0.5 hp per 1000 gallons.
13. The auxiliary stirrer tank of claim 1 wherein the first set of blades and the second set of blades are configured consume less than approximately 0.25 hp per 1000 gallons.
14. The auxiliary stirrer tank of claim 1 wherein the first set of blades and the second set of blades each comprise more than four blades.
15. The auxiliary stirrer tank of claim 1 wherein the first set of blades and the second set of blades each comprise 6 blades.

16. An auxiliary stirrer tank for a solvent extraction system for receiving an emulsion of liquids from a primary mixer tank comprising:

a tank having a tank diameter that is configured to receive the emulsion of immiscible liquids for agitating and facilitating mass transfers therebetween, the immiscible liquids comprising a first liquid and a second liquid; the first liquid being an organic solvent and the second liquid being an aqueous solution.

a shaft positioned within the tank, the shaft being rotatable within the tank;

a first hydrofoil comprising a plurality of blades attached to the shaft at a first location on the shaft, the blades extending a first distance outwardly from adjacent the shaft to a first diameter that is between 0.4 and 0.5 times the tank diameter;

a second hydrofoil comprising a plurality of blades attached to the shaft at a second location on the shaft, the blades extending a second distance outwardly from adjacent the shaft to a second diameter that is between 0.35 and 0.45 times the tank diameter;

the pitch of the first and second hydrofoils being configured to provide an upward pumping force adjacent the shaft and a downward flow adjacent the tank diameter;

wherein the first and second hydrofoils are configured to discourage air generation, maintain droplet sizes of the immiscible liquids above 50 μm , maintain a tip speed between 1.0 and 2 m/s, and consume less than 0.75 hp per 1000 gallons.

17. The auxiliary stirrer tank of claim 16 wherein the first diameter is between approximately 0.4 and 0.6 times the tank diameter.

18. The auxiliary stirrer tank of claim 16 wherein the first diameter is approximately 0.46 times the tank diameter.

19. The auxiliary stirrer tank of claim 16 wherein the second diameter is between approximately 0.3 and 0.5 times the tank diameter.

20. The auxiliary stirrer tank of claim 19 wherein the second diameter is approximately 0.4 times the tank diameter.

21. The auxiliary stirrer tank of claim 16 wherein both the first and second hydrofoils are constructed from stainless steel.

22. The auxiliary stirrer tank of claim 16 wherein the first and second hydrofoils are constructed with a rake angle between 1 and 10 degrees.

23. The auxiliary stirrer tank of claim 22 wherein the first and second hydrofoils are constructed with a rake angle of approximately 3-6 degrees.

5 24. The auxiliary stirrer tank of claim 16 wherein leading edges of the blades are straight and measure a first length, and wherein trailing edges of the blades are not straight and measure a second length which is longer than said first length.

25. The auxiliary stirrer tank of claim 16 wherein the mean droplet size of the immiscible liquids is between approximately 250 and 400 μm .

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26. The auxiliary stirrer tank of claim 25 wherein the mean droplet size of the immiscible liquids is between approximately 300 and 350 μm .

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27. The auxiliary stirrer tank of claim 16 wherein the tip speed of the first and second hydrofoils is maintained between approximately 1.25 and 1.75 m/s.

28. The auxiliary stirrer tank of claim 16 wherein the tip speed of the first and second hydrofoils is maintained at approximately 1.5 m/s.

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29. The auxiliary stirrer tank of claim 16 wherein the tank is configured to run at ambient conditions.

30. The auxiliary stirrer tank of claim 16 wherein the first location is located approximately 1/3 the tank diameter from a bottom of the auxiliary stirrer tank.

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31. The auxiliary stirrer tank of claim 30 wherein the second location is positioned above the first location by a distance of approximately 60-80% the first diameter.

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32. The auxiliary stirrer tank of claim 31 wherein the second location is positioned above the first location by a distance of approximately 65-75% the first diameter.

33. The auxiliary stirrer tank of claim 16 wherein the second hydrofoil impeller is located above the first hydrofoil impeller relative to a bottom of the auxiliary stirrer tank.

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34. The auxiliary stirrer tank of claim 16 wherein the first set of blades are blades extending from a hub of a first impeller attached to the shaft at the first location to attach

the blades to the shaft; and wherein the second set of blades are blades extending from a hub of a second impeller attached to the shaft at the second location to attach the blades to the shaft.

5 35. The auxiliary stirrer tank of claim 16 wherein the first set of blades and the second set of blades generally uniform in thickness.

36. The auxiliary stirrer tank of claim 16 wherein the first set of blades and the second set of blades generally have a tip-cord angle between approximately 20 and 40 degrees.

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37. The auxiliary stirrer tank of claim 16 wherein the first set of blades and the second set of blades have a curved profile.

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38. The auxiliary stirrer tank of claim 16 wherein roots of the first and second sets of blades are wider than tips of the first and second sets of blades.

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39. An impeller for an auxiliary mixer in a solvent extraction system which receives an emulsion of two immiscible liquids from a primary mixer tank, the impeller being configured to up-pump, discourage air generation, maintain droplet sizes of the two immiscible liquids above 50 μm , maintain a tip speed between 1.0 and 2 m/s, and consume less than 0.75 hp per 1000 gallons; the impeller comprising:

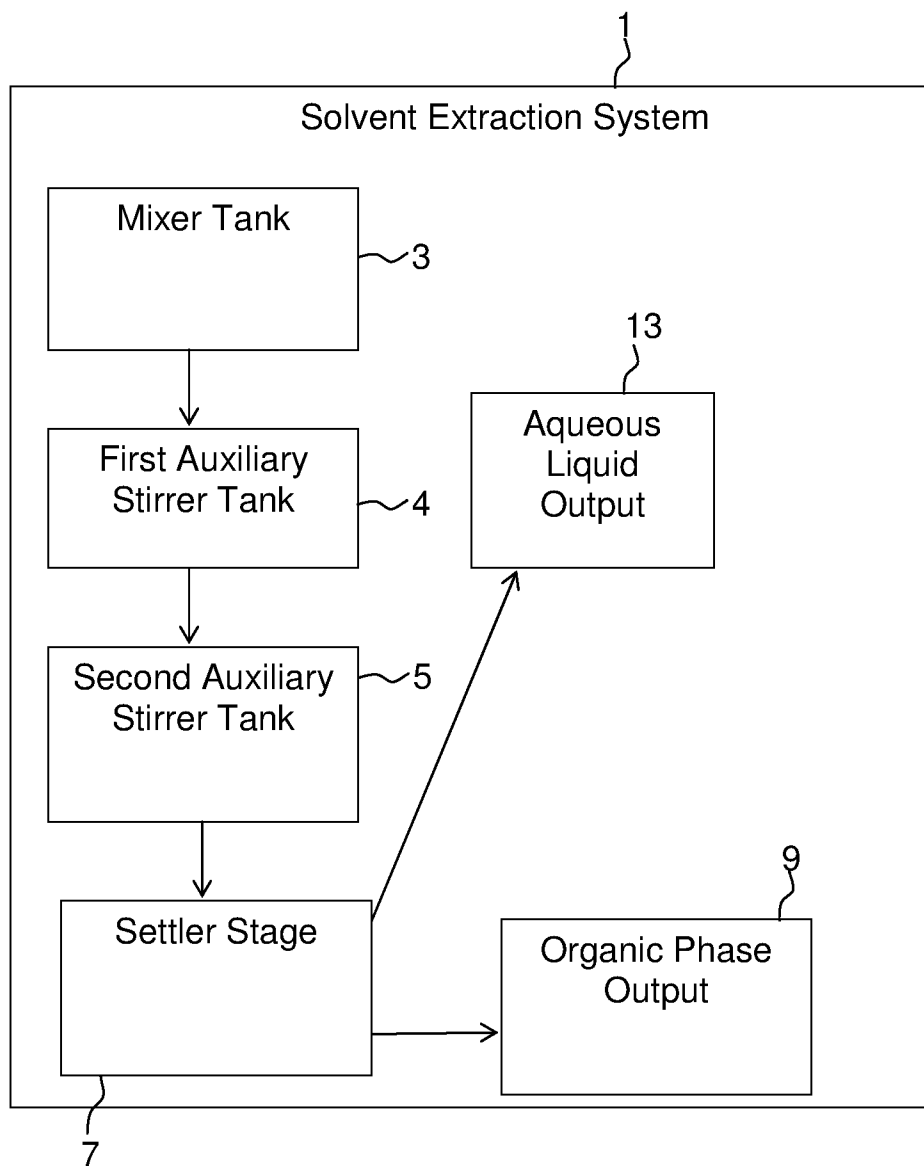
a hub or a shaft portion; and,

at least three blades extending from the hub or shaft portion;

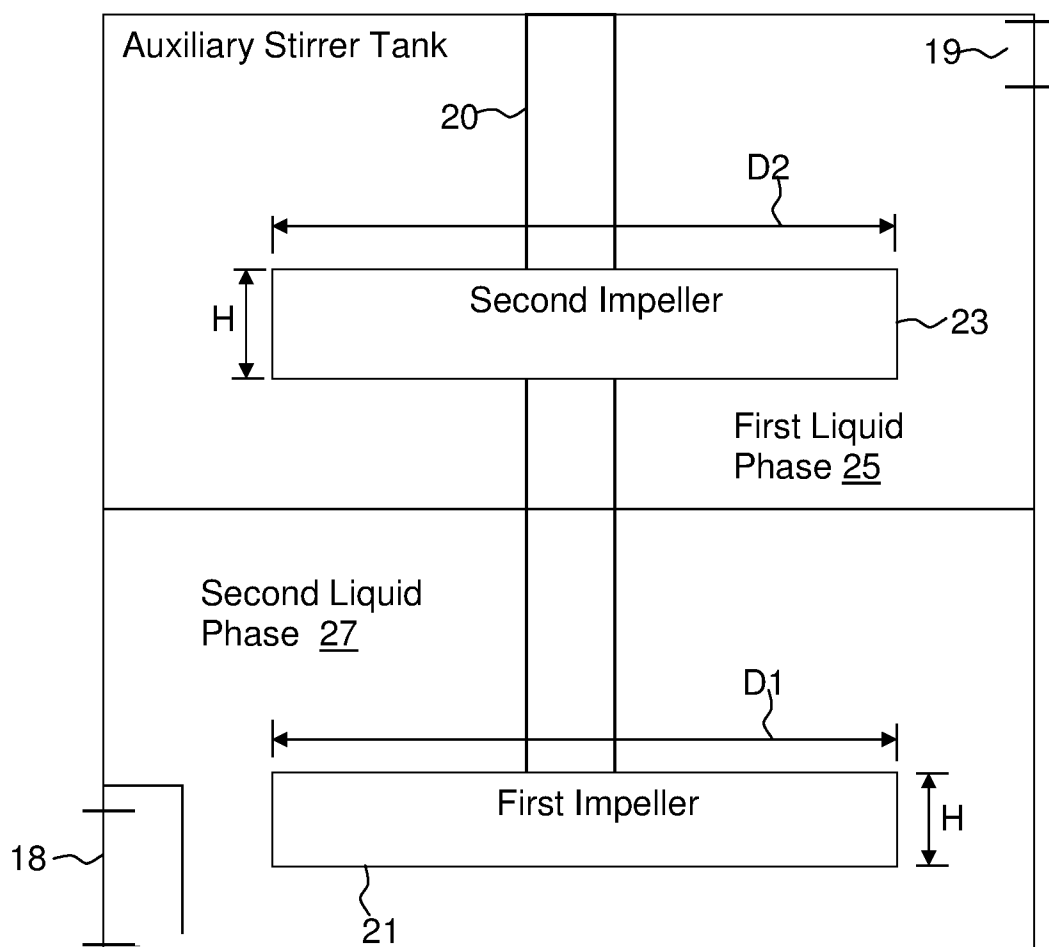
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wherein the at least three blades comprise a rake angle; wherein the at least three blades are curved on an upper side to define a transverse radius; wherein the at least three blades comprise a trailing edge which is longer than a leading edge; and, wherein the two immiscible liquids comprise an organic liquid and an aqueous liquid.

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**FIGURE 1**

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**FIGURE 2**

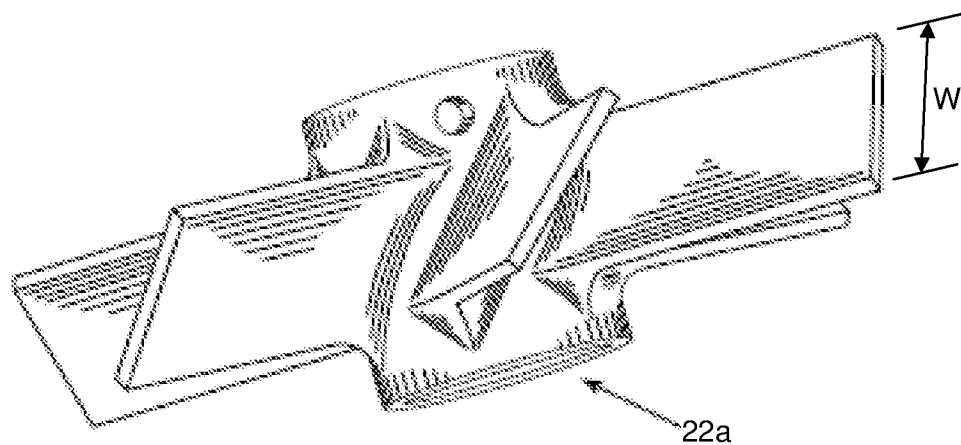


FIGURE 3

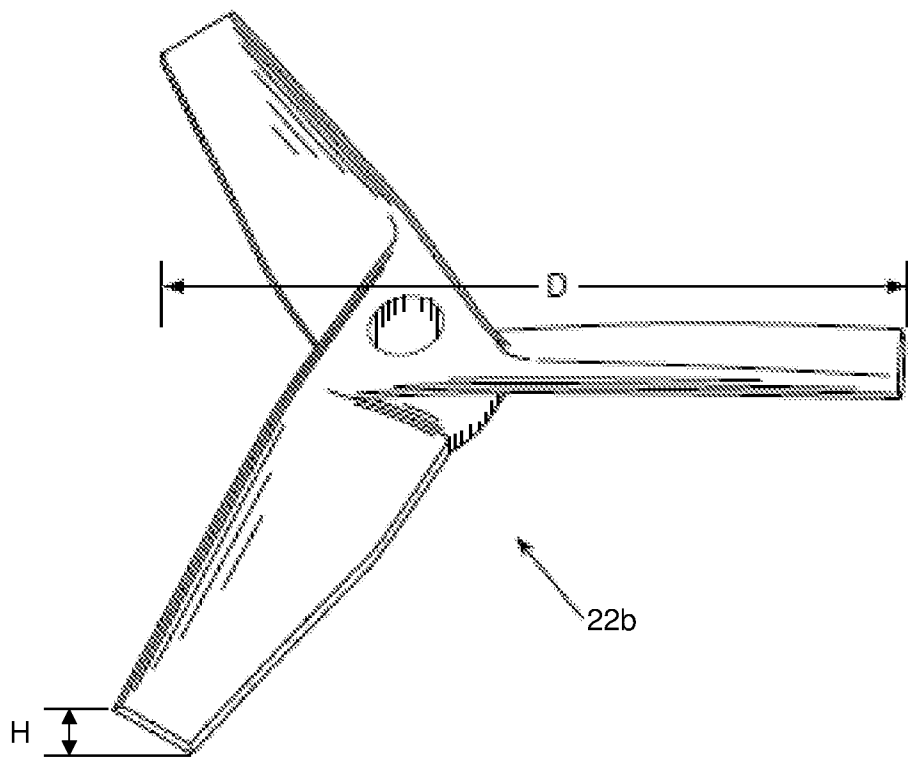
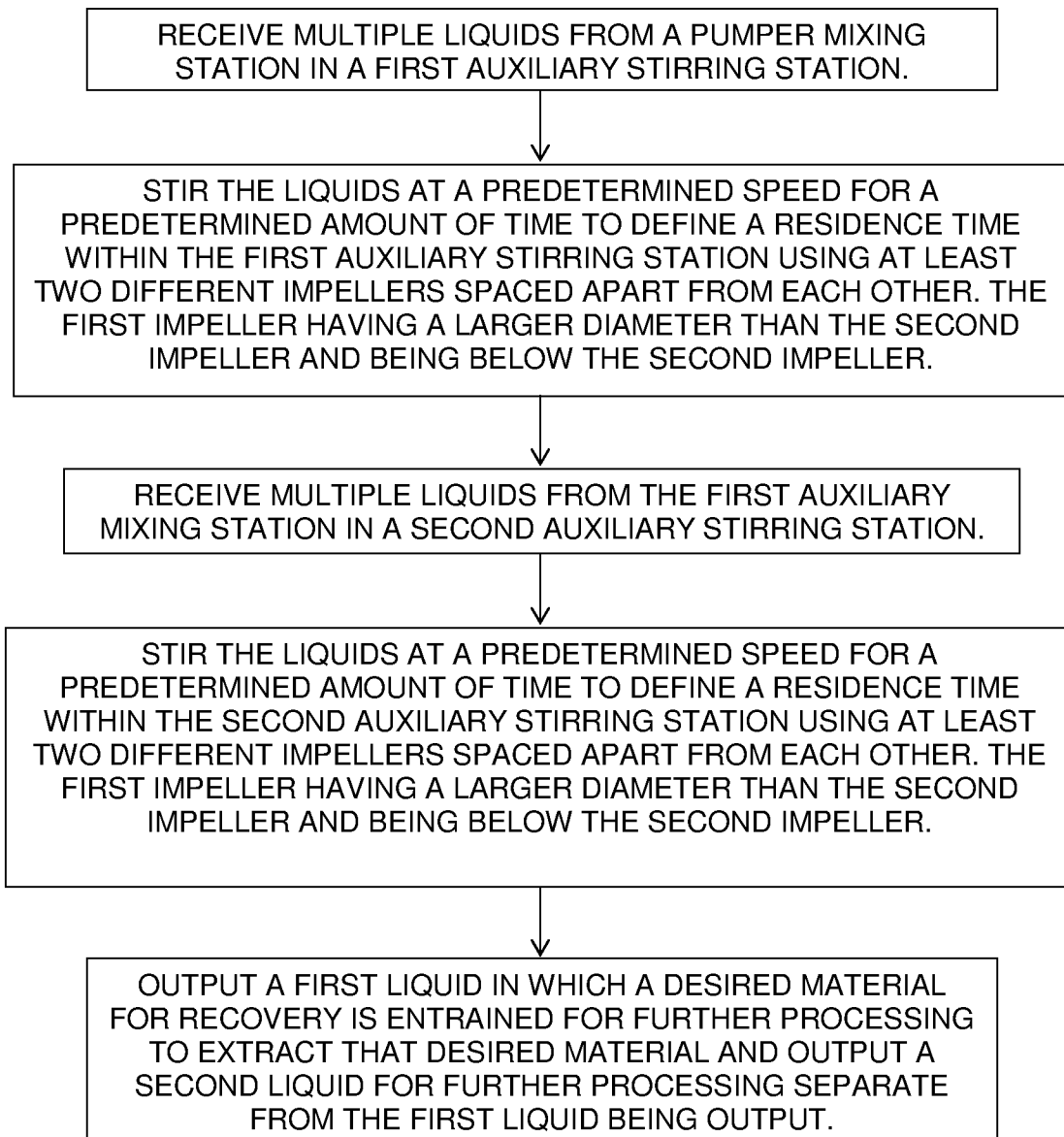


FIGURE 4

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**FIGURE 5**

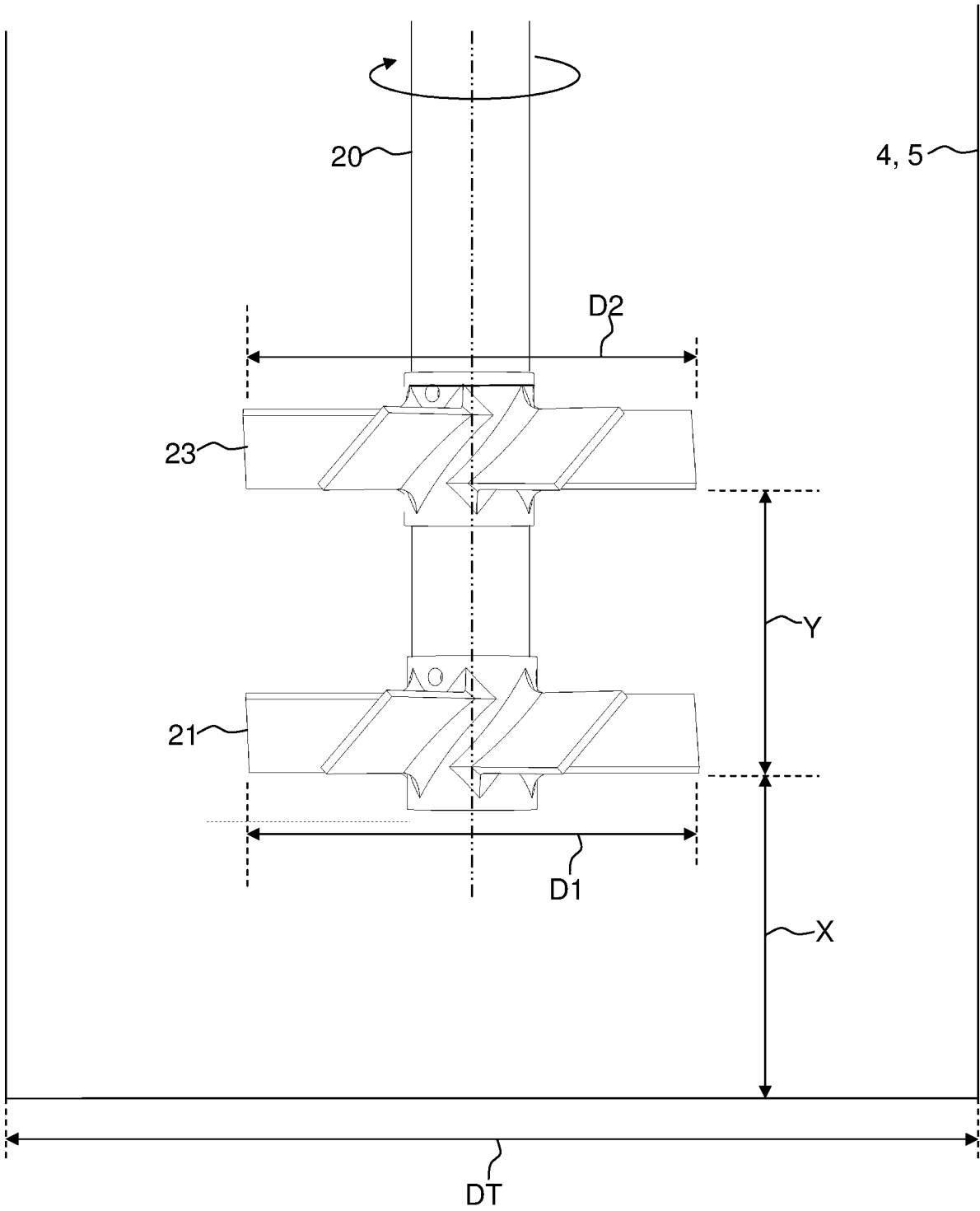
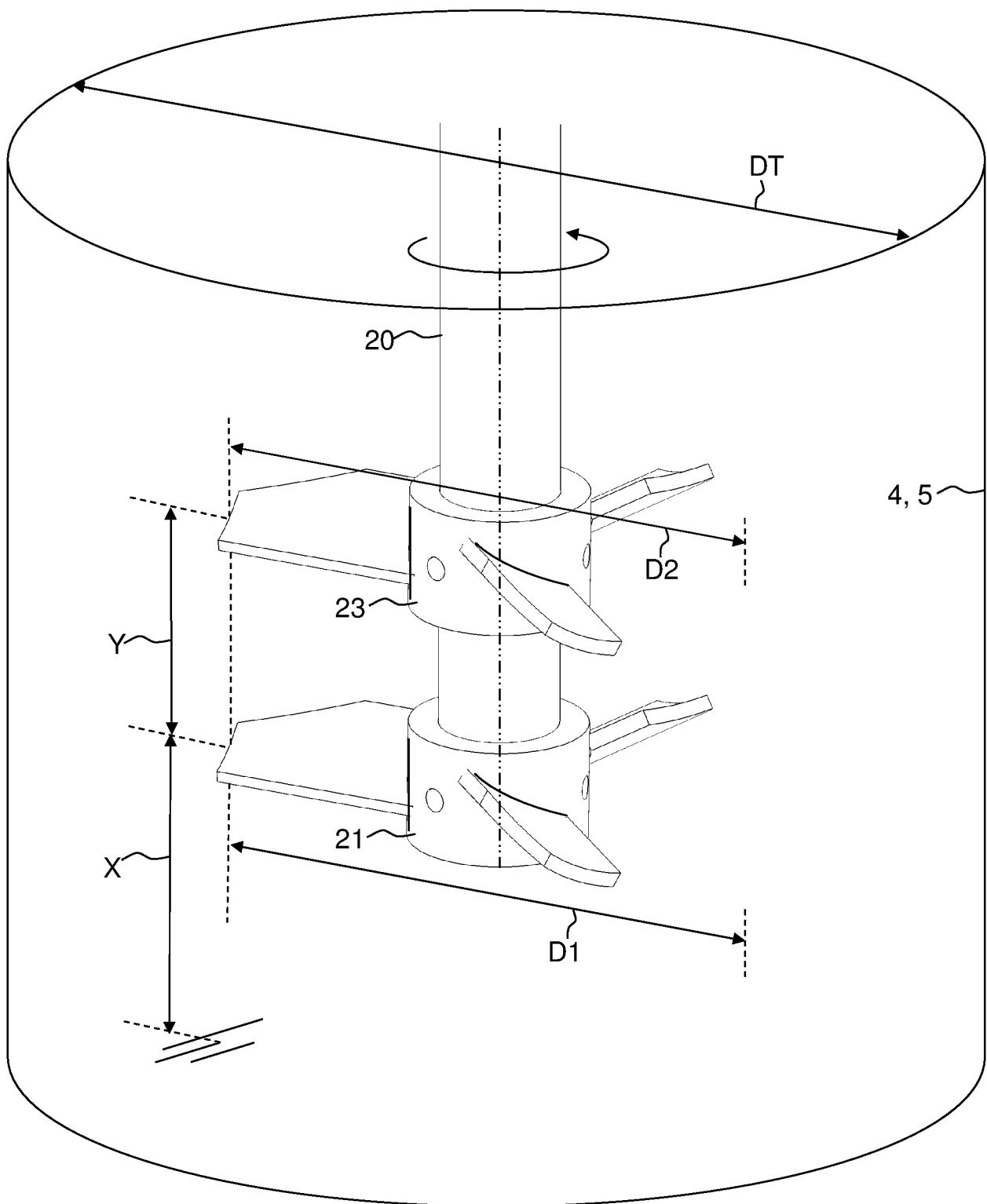


FIGURE 6

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**FIGURE 7**

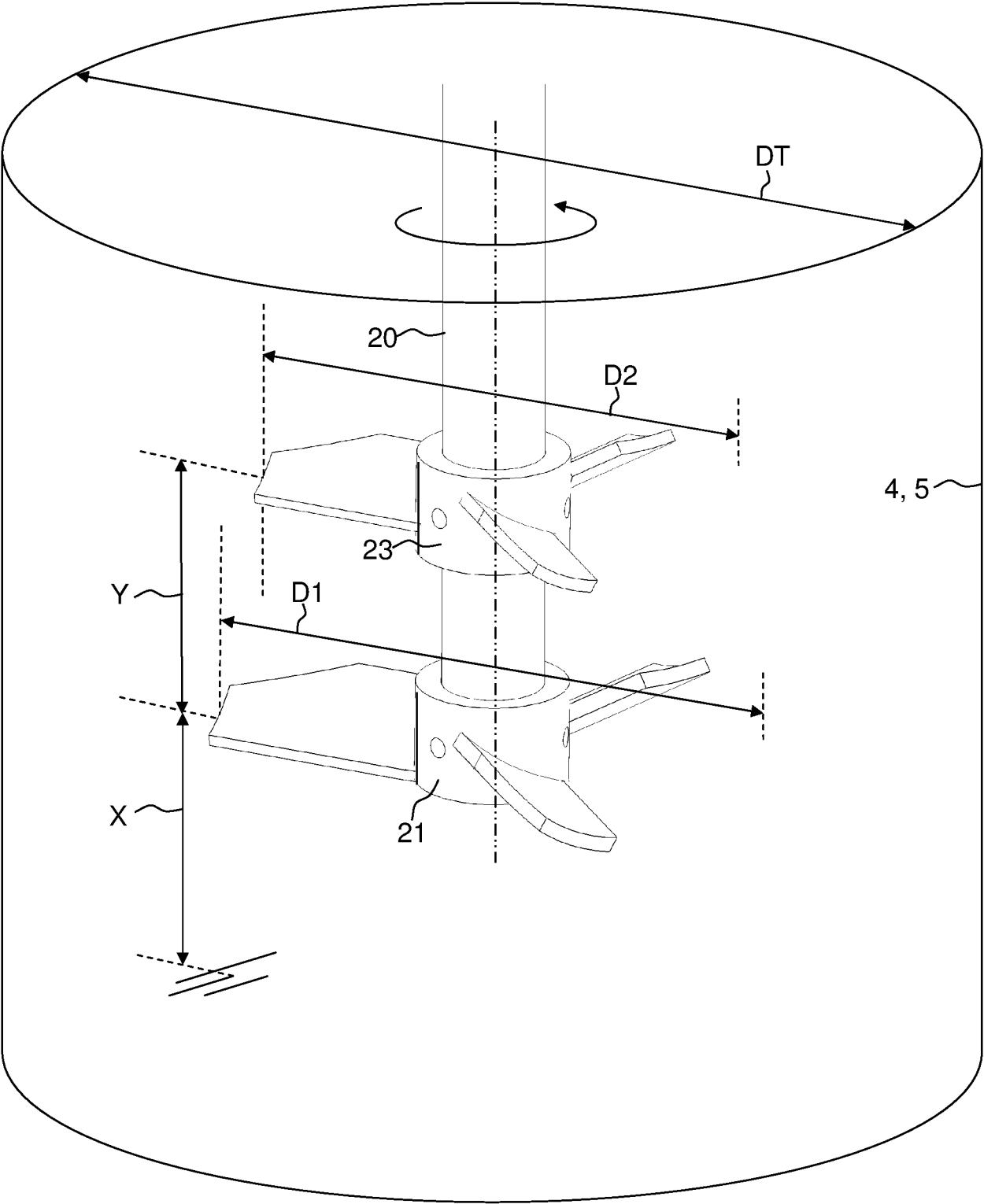
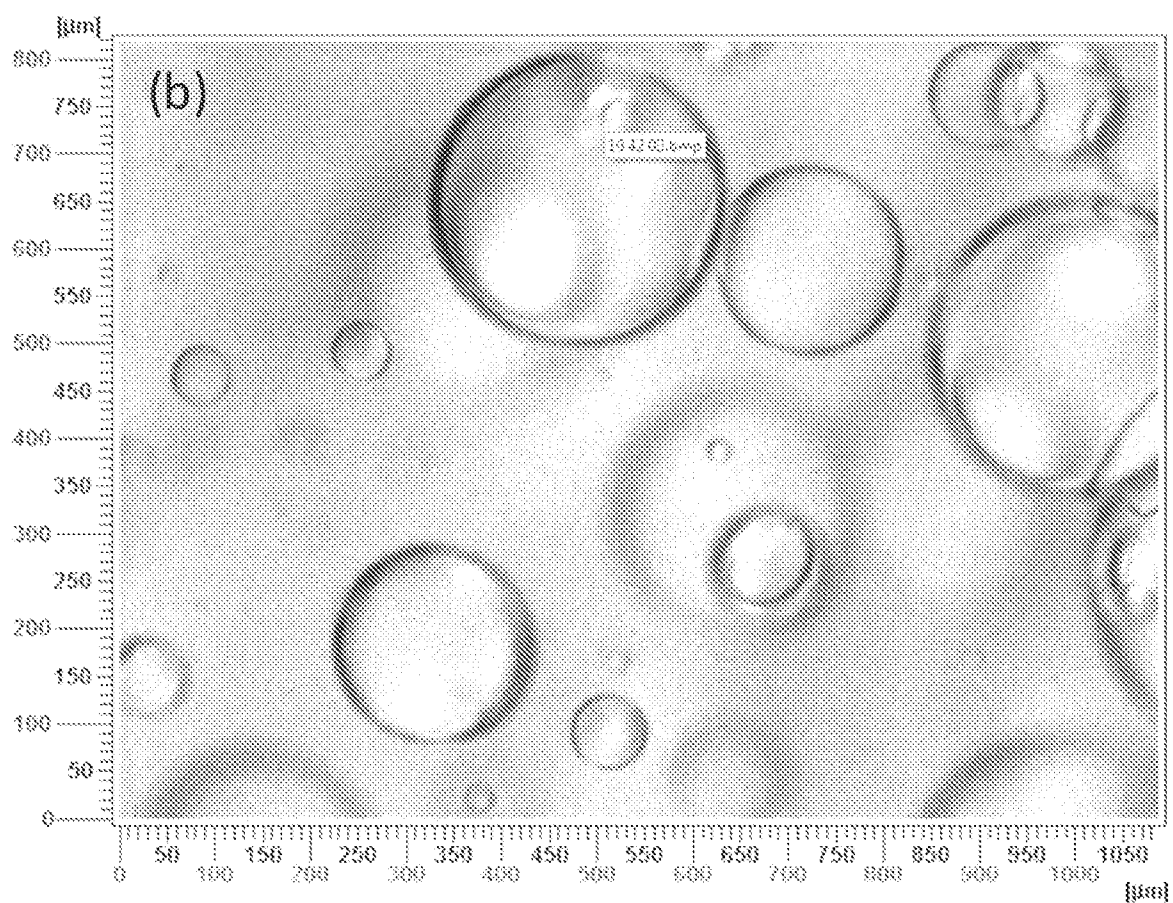


FIGURE 8

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**FIGURE 9**

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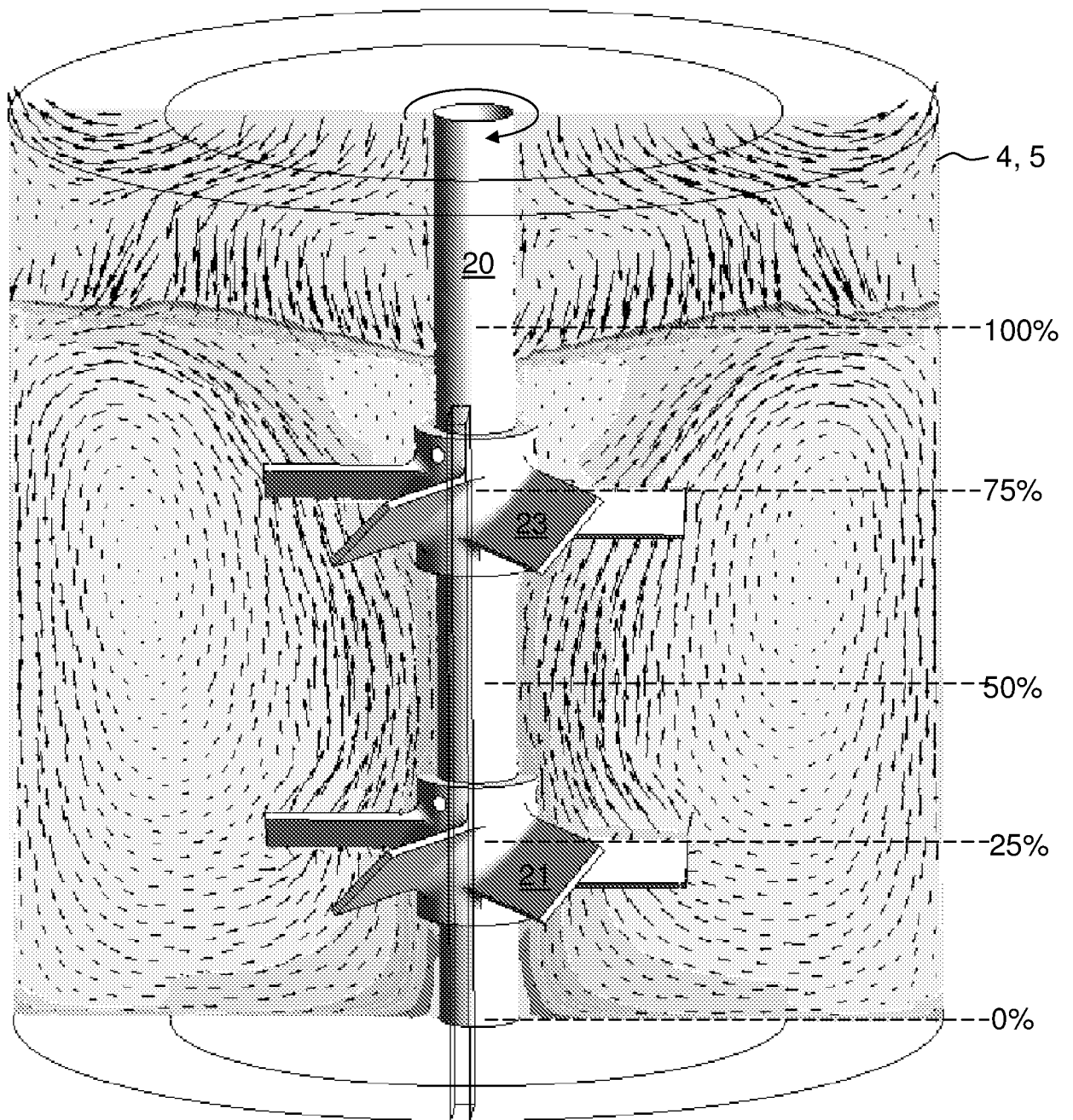


FIGURE 10

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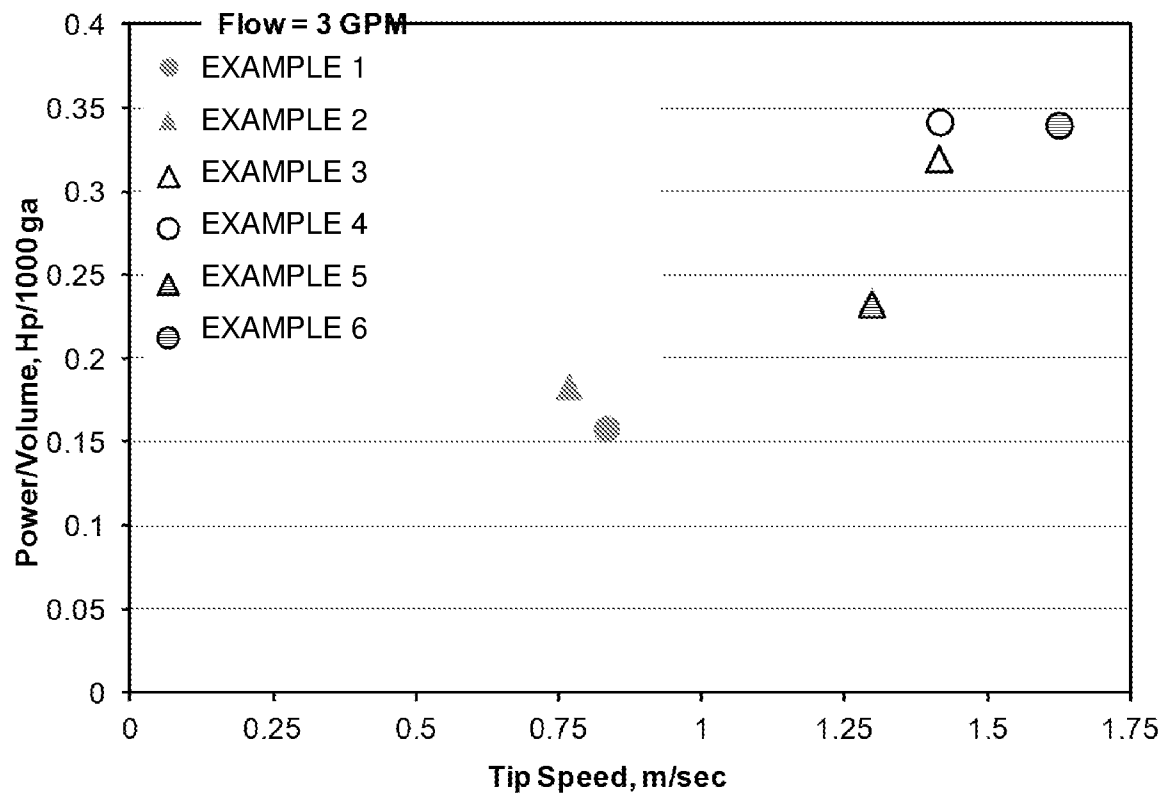


FIGURE 11

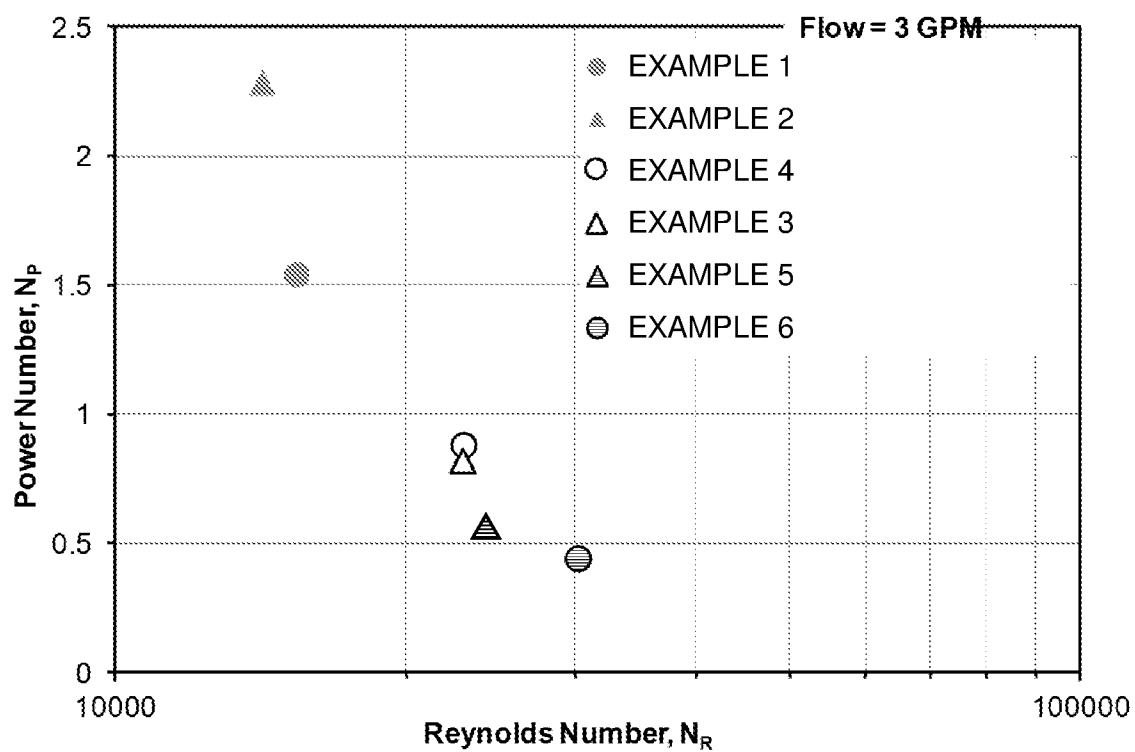


FIGURE 12

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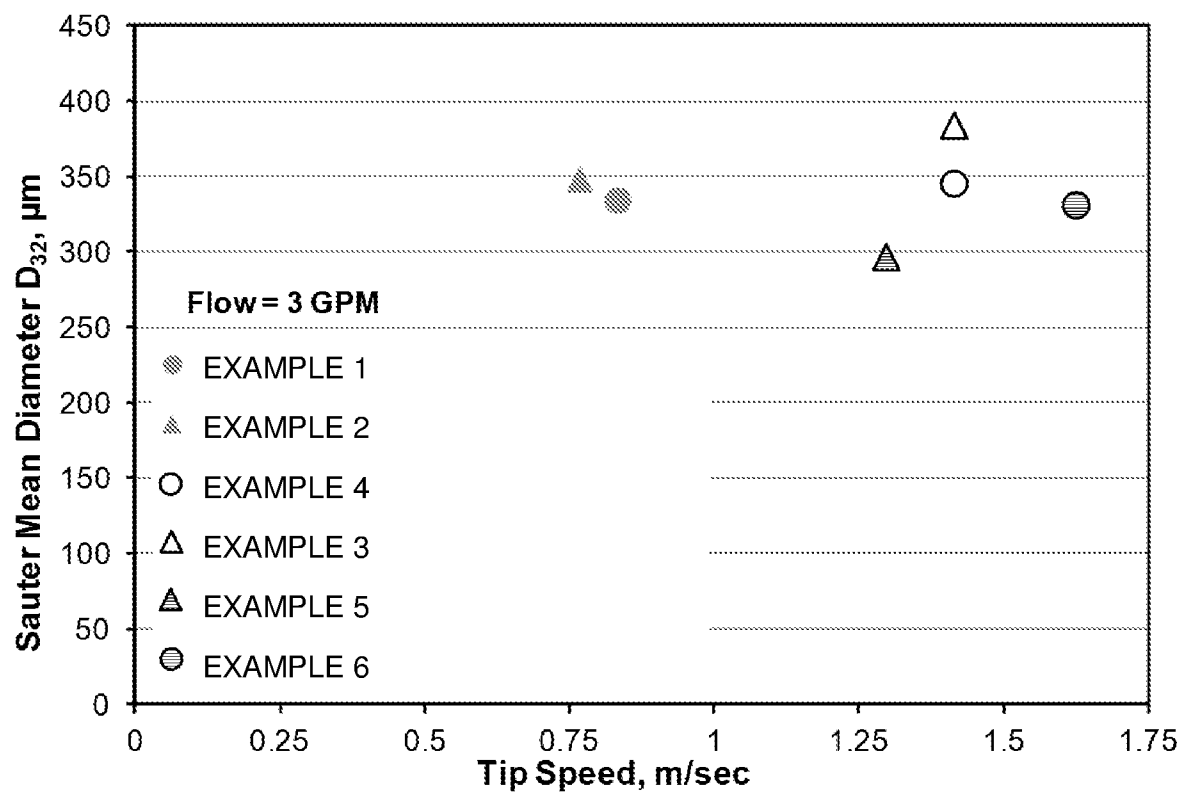


FIGURE 13

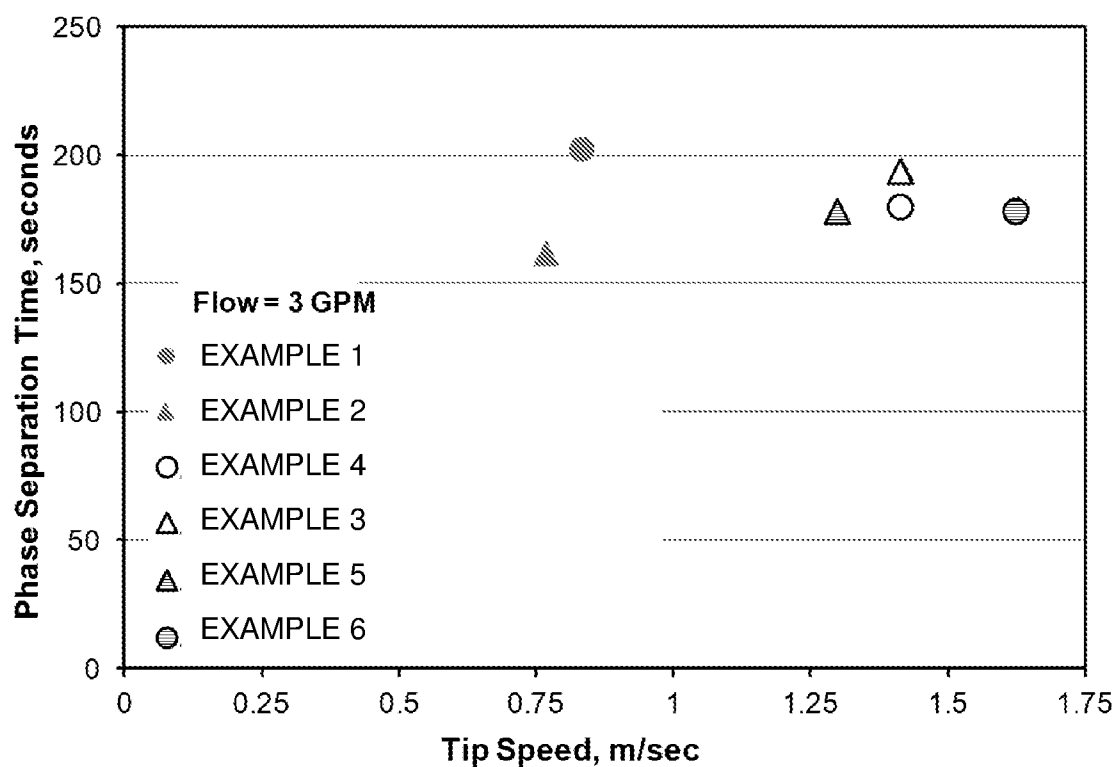
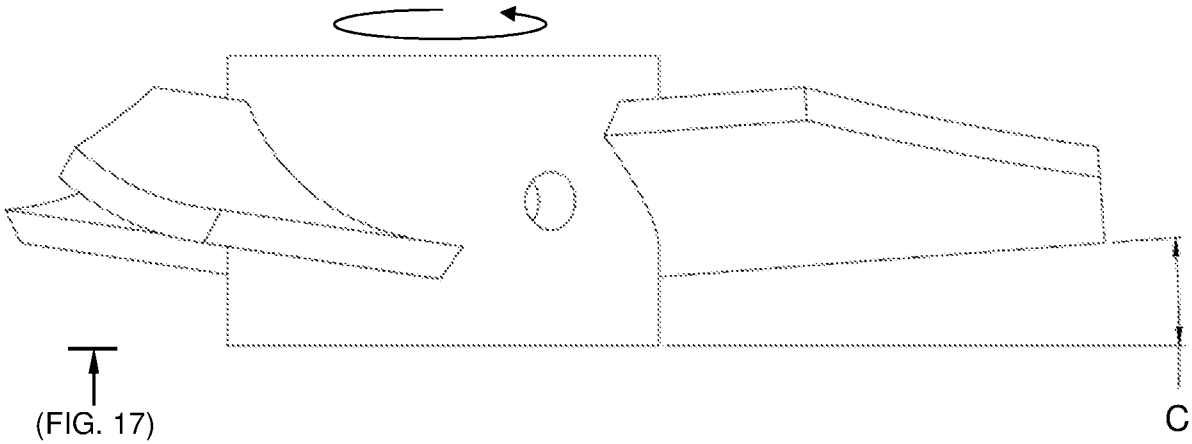
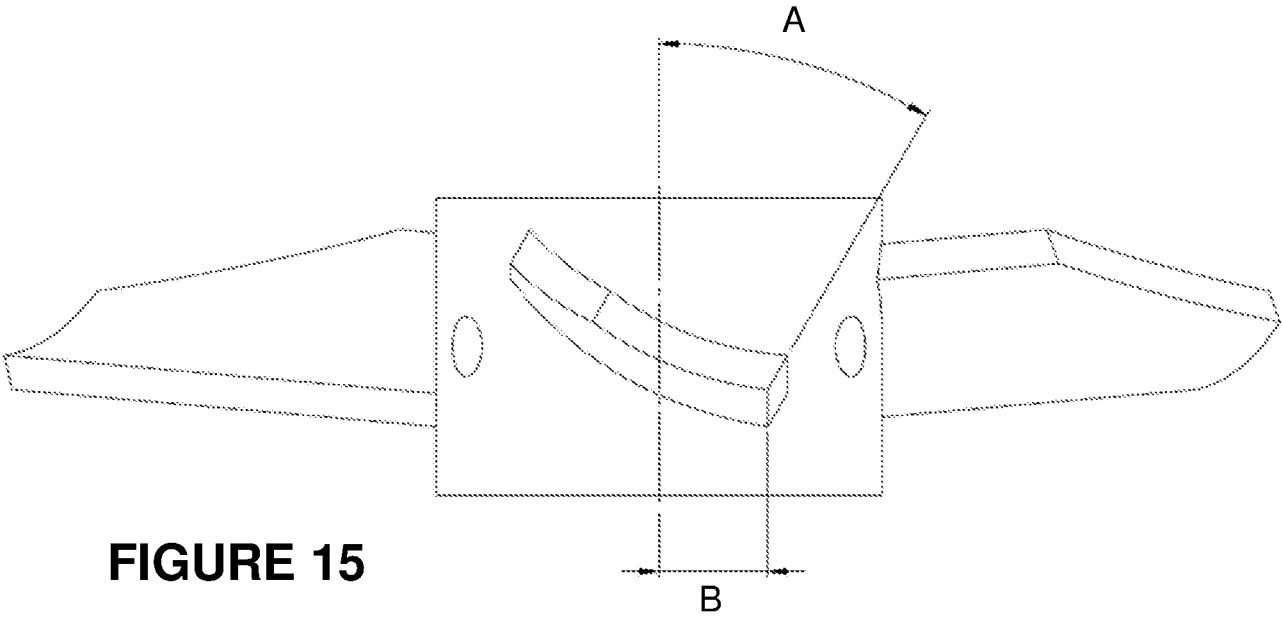


FIGURE 14



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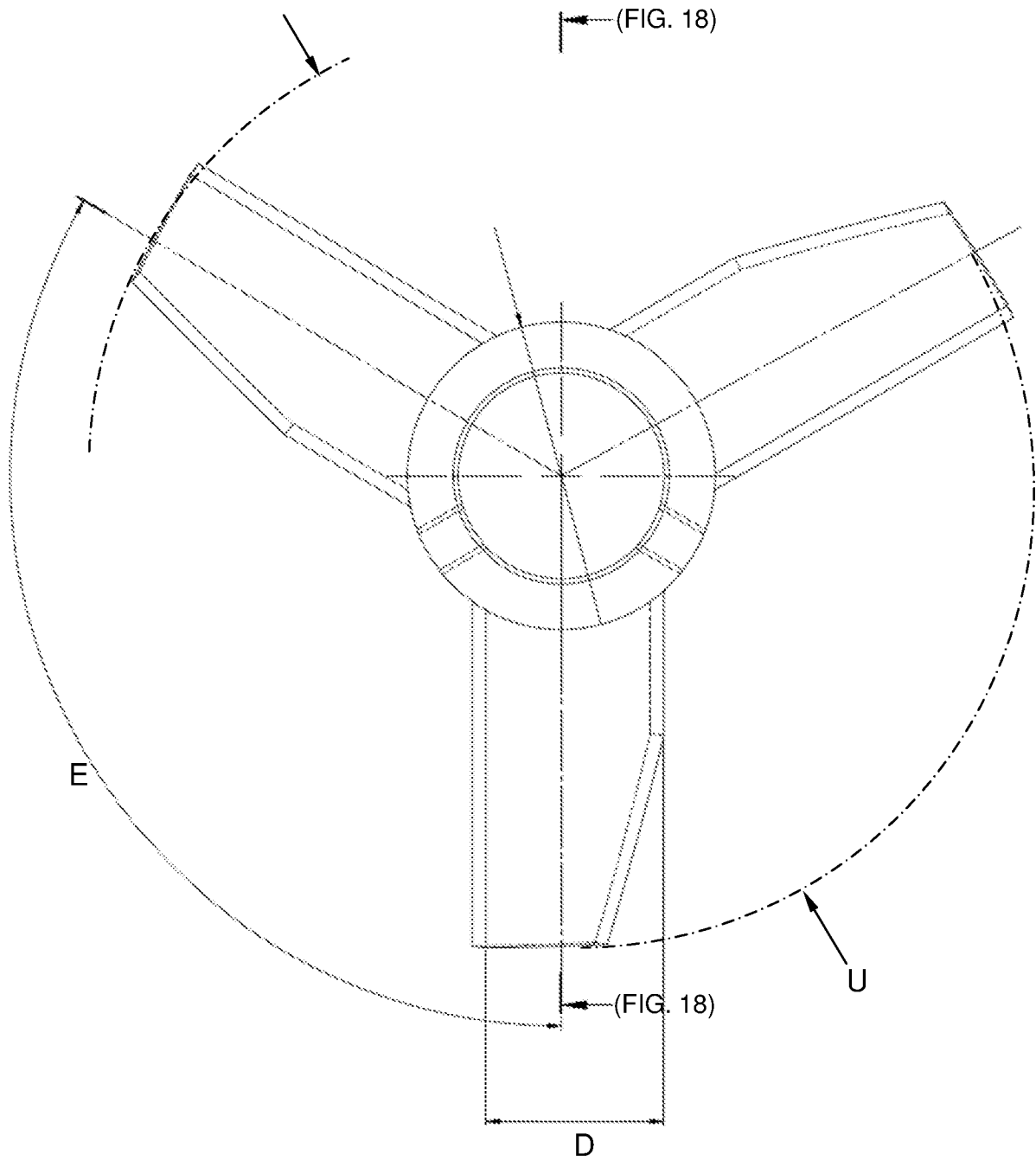


FIGURE 17

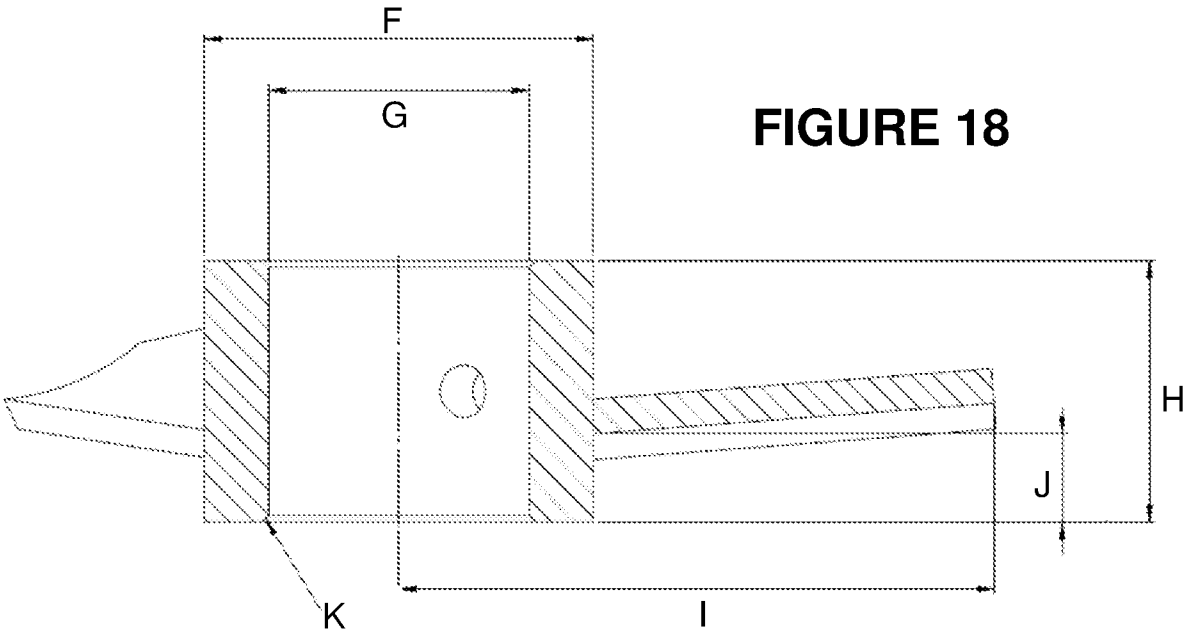


FIGURE 18

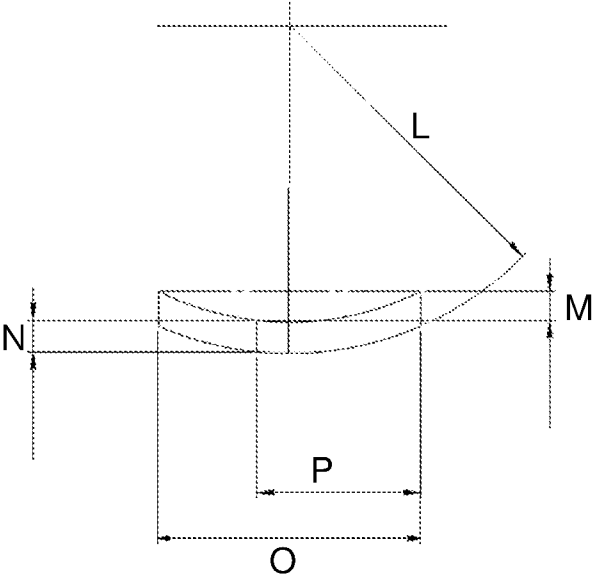


FIGURE 19

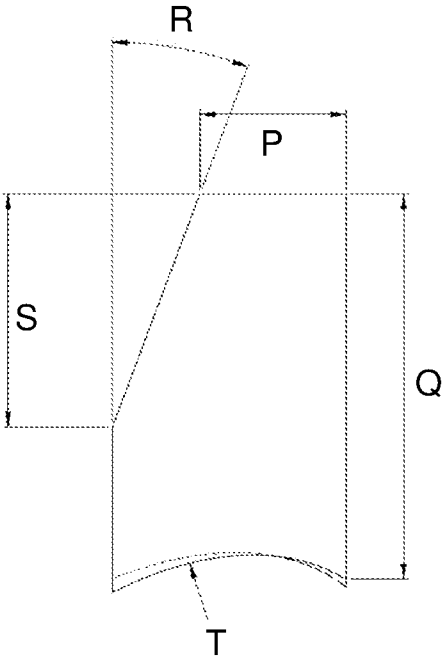


FIGURE 20

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2013/050451

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01D11/04 B01F7/04 B01F7/16 B01F3/08 C22B3/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B01D B01F C22B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/234435 A1 (BICKHAM DAVID ROBERT [GB] ET AL) 25 November 2004 (2004-11-25) paragraph [0054] - paragraph [0055]; figures 1-4	1-15
X	----- EP 0 078 660 A2 (GEN SIGNAL CORP [US]) 11 May 1983 (1983-05-11)	39
A	claims 1-16; figures 1-12	1-38
Y	----- GB 2 117 666 A (UNIV MANCHESTER) 19 October 1983 (1983-10-19) page 4, line 32 - line 38 claim 1; figure 6	1-39
Y	----- EP 1 566 208 A1 (TECN REUNIDAS S A [ES]) 24 August 2005 (2005-08-24) paragraph [0033] figures 1-6; examples 1-4	1-39
	----- -/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

21 February 2014

Date of mailing of the international search report

05/03/2014

Name and mailing address of the ISA/

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Authorized officer

García Alonso, Nuria

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2013/050451

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3 252 689 A (BLOMGREN SR OSCAR C ET AL) 24 May 1966 (1966-05-24) claims 1-25; figures 2,3,10 -----	1-39
A	US 5 762 417 A (ESSEN JOHN VON [US] ET AL) 9 June 1998 (1998-06-09) claims 1-13; figures 1-3 -----	16-39
A	WO 00/16885 A1 (GEN SIGNAL CORP [US]) 30 March 2000 (2000-03-30) claims 1-15; figures 1-3 -----	1-39

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/DK2013/050451

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004234435	A1	25-11-2004	AR 044435 A1 14-09-2005
			AT 411102 T 15-10-2008
			BR PI0411146 A 11-07-2006
			CA 2525898 A1 09-12-2004
			CN 1822900 A 23-08-2006
			EP 1635942 A1 22-03-2006
			ES 2314420 T3 16-03-2009
			KR 20060024380 A 16-03-2006
			MX PA05012598 A 08-02-2006
			MY 135637 A 30-05-2008
			TW I331991 B 21-10-2010
			US 2004234435 A1 25-11-2004
			WO 2004105935 A1 09-12-2004
			ZA 200509228 A 28-03-2007
EP 0078660	A2	11-05-1983	CA 1205459 A1 03-06-1986
			DE 3275817 D1 30-04-1987
			EP 0078660 A2 11-05-1983
			IN 159278 A1 25-04-1987
			US 4468130 A 28-08-1984
GB 2117666	A	19-10-1983	NONE
EP 1566208	A1	24-08-2005	AU 2002358814 A1 18-06-2004
			BR 0215956 A 13-09-2005
			CN 1694751 A 09-11-2005
			EP 1566208 A1 24-08-2005
			ES 2266612 T3 01-03-2007
			MX PA05005650 A 26-07-2005
			US 2005218072 A1 06-10-2005
			WO 2004047946 A1 10-06-2004
US 3252689	A	24-05-1966	NONE
US 5762417	A	09-06-1998	NONE
WO 0016885	A1	30-03-2000	AU 6052799 A 10-04-2000
			CA 2345039 A1 30-03-2000
			CN 1321109 A 07-11-2001
			EP 1123153 A1 16-08-2001
			US 6158722 A 12-12-2000
			WO 0016885 A1 30-03-2000