# United States Patent [19]

**Booth et al.**

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[45] **Jan. 23, 1973**


## [54] ZERO GRAVITY LIQUID MIXER


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[73] Assignee: **The United States of America as represented by the Administrator of the National Aeronautics and Space Administration**



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[52] **U.S. Cl.** ..... **259/4**

[51] **Int. Cl.** ..... **B01f 15/02**

[58] **Field of Search** ..... 259/1, 4, 18, 36, 2, 60



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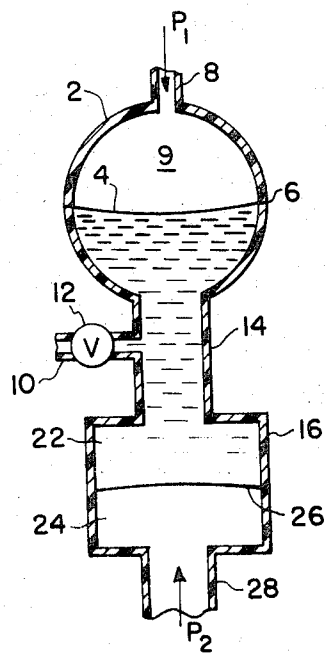
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[57] **ABSTRACT**

Apparatus for mixing liquids under conditions of zero gravity is disclosed. The apparatus is comprised of a closed reservoir for the liquids, having a means for maintaining a positive pressure on the liquids in the reservoir. A valved liquid supply line is connected to the reservoir for supplying the reservoir with the liquids to be mixed in the reservoir. The portion of the reservoir containing the liquids to be mixed is in communication with a pump which alternately causes a portion of the liquids to flow out of the pump and into the reservoir to mix the liquids. In a particular embodiment disclosed, the reservoir comprises a sphere having a flexible diaphragm across the diameter thereof. A fluid pressure is applied to the upper side of the diaphragm and the fluids to be mixed are pumped into a section of the sphere on the opposite side of the diaphragm from the fluid pressure. The fluids in the reservoir are in communication through a conduit with the pump which alternately causes a portion of the fluids to flow out of the pump and into the sphere. The conduit connecting the pump and sphere may contain a nozzle or other jet-forming structure such as a venturi for further mixing the fluids. The reservoir may be completely emptied of liquids stored therein.


**13 Claims, 10 Drawing Figures**



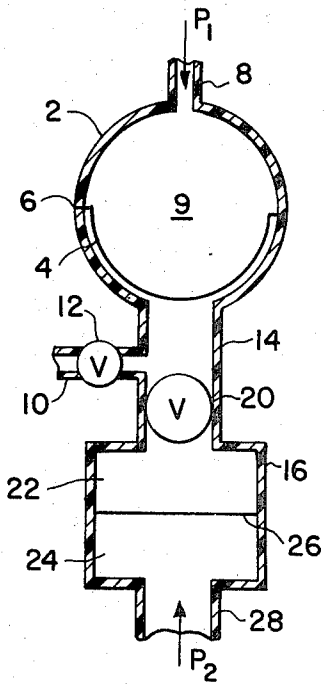



FIG. 1

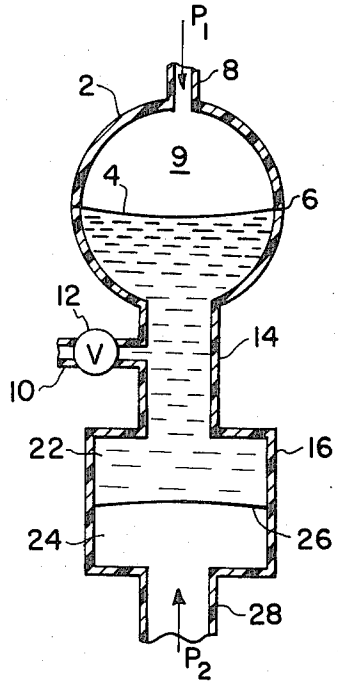



FIG. 2

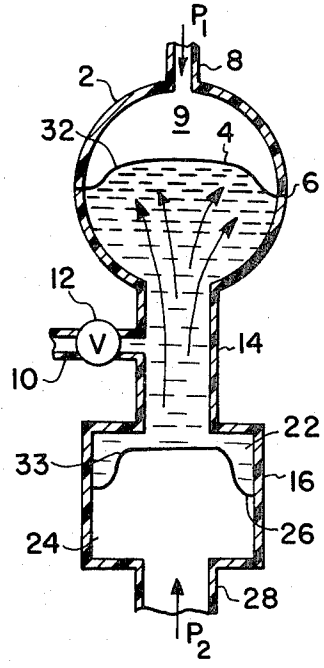
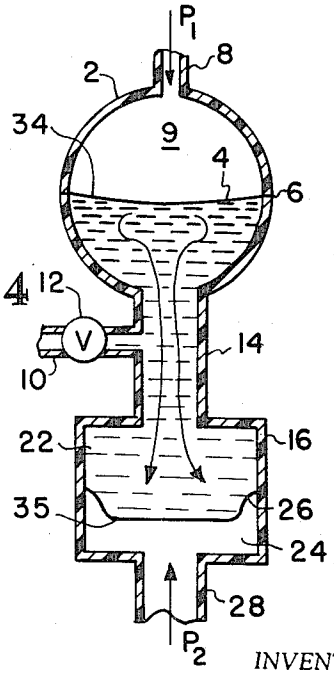



FIG. 3

FIG. 4




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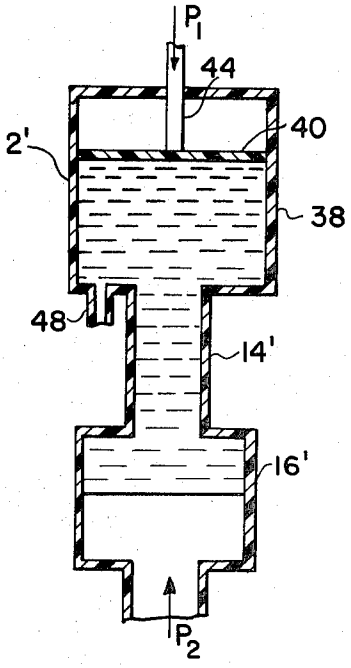



FIG. 5

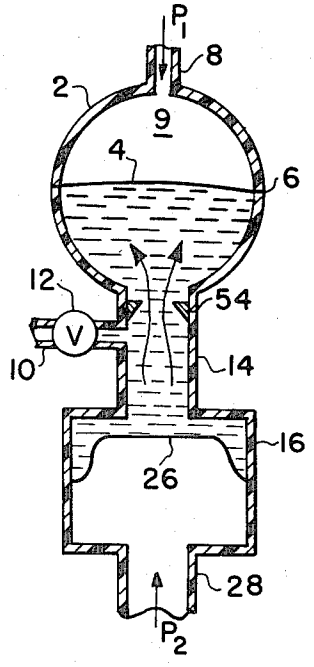



FIG. 6

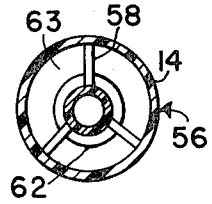



FIG. 8

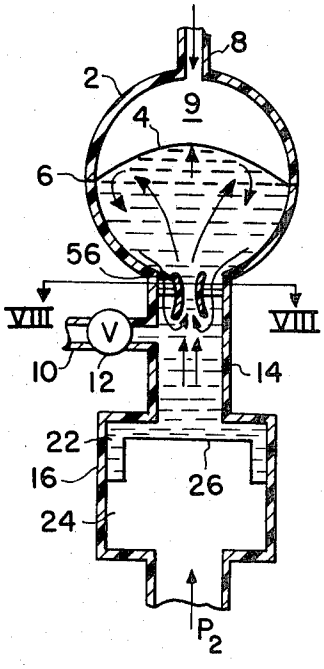



FIG. 7

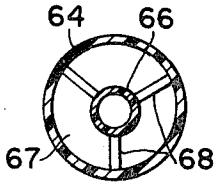



FIG. 10

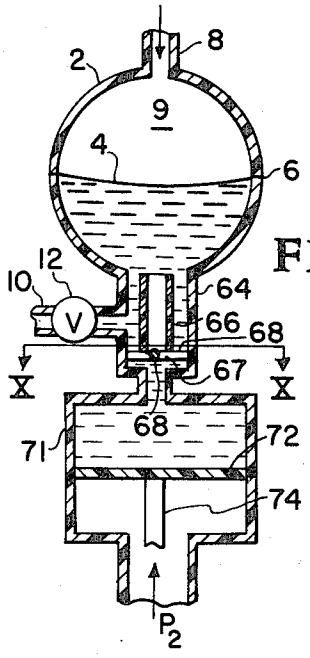



FIG. 9

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# ZERO GRAVITY LIQUID MIXER

## ORIGIN OF THE INVENTION

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

## BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to apparatus for the treatment of liquids in space vehicles. Difficulties have been experienced in mixing liquids in reservoirs in space vehicles because of the zero gravity conditions which exist during flight. Thus, one liquid cannot simply be added to a reservoir tank holding another liquid with the result that the two liquids will mix within a reasonable time. The liquids eventually will mix after an indefinite period of time through molecular action somewhat similar to the mixing phenomenon when two inert gases are added to a vessel. Under zero gravity conditions, there is no stirring action as normally takes place when gravitational forces are active on the density gradients within the liquids. There are many applications where it is impractical or impossible to depend upon the molecular mixing of the liquids, since it is often necessary to thoroughly mix the liquids within a short period of time; for example, to react one liquid with another such as in the case of employing one liquid to "treat" another liquid. For instance, to sterilize urine contained in a holding tank by mixing in a liquid sterilant, it is necessary to mix the liquids within a short period of time.

Experiments that have been conducted in the past show that the diffusion of chromic acid sterilant in urine contained in a holding tank under zero gravity conditions in life support systems takes many days to reach equilibrium. Such time lapse is unacceptably long. In addition, since one liquid which it is desired to treat must be used in later applications, it is not feasible to employ mechanical agitators within the holding tanks or reservoirs because of the impossibility of completely emptying such tanks under zero gravity conditions or in the case of liquids such as liquid oxygen, the presence of agitation devices in a liquid reservoir can constitute an explosion hazard. Therefore, there exists the need for a means of efficiently mixing liquids under zero gravity conditions in a reasonable length of time and storing the mixed liquids in a reservoir which can be completely emptied after the mixing.

## SUMMARY OF THE INVENTION

The present invention is therefore directed to an apparatus for mixing two or more liquids under zero gravity conditions. In the specification, the term "zero gravity" is meant to include gravitational conditions in which the action of gravitational forces on the mixed liquids is zero or substantially negligible. It embraces the conditions normally referred to as the phenomenon of weightlessness experienced in space travel. The present invention comprises an apparatus for mixing liquids under conditions of zero gravity which apparatus is comprised of a closed reservoir for liquids and includes means for maintaining a first positive pressure on liquids contained in the reservoir to facilitate the discharge of the liquids from the reservoir. The liquids are supplied to the reservoir through a valved supply line connected to the reservoir. The reservoir is provided with a conduit connecting the interior portion of the reservoir which holds the liquids that are to be mixed with a pump. The pump is one which is capable of applying a second pressure to the liquids to be mixed. The second pressure is alternately greater than and lesser than the first pressure applied to the liquids in the reservoir. The pump causes a mass of said liquids less than the total mass of the liquids in the reservoir together with the first pressure source alternately to flow between the reservoir and the pump through the conduit, thus mechanically mixing the liquids.



## BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 is a side sectional view of an apparatus according to this invention in which the reservoir is empty.

FIG. 2 is a side sectional view of the reservoir of FIG. 1 which is partially filled with liquids to be mixed.

FIG. 3 is a side sectional view of the reservoir in which the pump means has displaced additional liquid into the reservoir.

FIG. 4 is a side sectional view of the reservoir in which liquids have been partially displaced from the reservoir into the pump means.

FIG. 5 is a side sectional view showing an alternative embodiment of the reservoir.

FIG. 6 is a side sectional view of an additional embodiment of the invention showing a nozzle means in the conduit.

FIG. 7 is a side sectional view of a further embodiment which includes a venturi in the conduit.

FIG. 8 is a sectional view taken along the section line 8—8 of FIG. 7.

FIG. 9 is a side sectional view of a further embodiment including an alternative form of nozzle.

FIG. 10 is a sectional view taken along lines 10—10 of FIG. 9.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention will be further apparent from the following description of illustrative embodiments taken in conjunction with the accompanying drawings.

Referring to FIG. 1, reservoir 2 for the liquids to be mixed is shown in the form of a transparent acrylic plastic sphere or other suitable material. The sphere is provided with a flexible diaphragm 4 which is secured around its periphery to the sphere across the diameter 6 of the sphere and serves upon completion of the mixing process to be described, to discharge substantially the entire amount of liquid from the reservoir 2. An opening 8 is provided on the upper side of the sphere for supplying a fluid pressure $P_1$ from a suitable source, not shown, to the portion 9 of the sphere which is on the side of the flexible diaphragm 4 opposite the side of the diaphragm 4 where the liquids are mixed. The liquids to be mixed in the reservoir are supplied to the reservoir 2 through a supply line 10 having a valve 12 therein and communicating with the reservoir 2 through the conduit 14 at the base of the reservoir 2 on

the side of the flexible diaphragm 4 opposite the opening 8. The other end of the conduit 14 is in communication with a pump 16. In the embodiment shown, the pump 16 comprises an upper chamber 22 on the top side of a second flexible diaphragm 26 and a lower side 24 which is in communication with a source of fluid pressure $P_2$ which pressure can be alternatively varied to a pressure greater than or lesser than pressure $P_1$. Optionally a valve 20 may be provided in conduit 14 for isolating means 16 for repairs if necessary.

When it is desired to mix the two fluids, the valve 12 is opened and the fluids admitted either together or sequentially from the supply line 10 to partially fill the reservoir 2 as shown in FIG. 2, the flexible diaphragm being raised to the position shown at 30. The valve 10 is then closed. In FIG. 3, the flexible diaphragm 4 is positioned at 32 when the pressure $P_2$ is raised to above $P_1$ and the flexible diaphragm 26 is forced to the position 33, displacing the volume of liquid originally contained in the upper section 22 of the pump 16 and forcing it through the conduit 14 up into the reservoir 2 as shown by the heavy arrows in FIG. 3. In FIG. 4 the condition of the apparatus is shown when the pressure $P_2$ has been lowered below that of $P_1$ thus displacing the flexible diaphragm 26 in the pump 16 to the position shown at 35. The pressure $P_1$ then forces the flexible diaphragm 4 down against the liquids to the position shown at 34 and causes the liquids to flow as shown by the arrows into the pump 16.

The alternating of the pressure $P_2$ is repeated a number of times and the liquids are thoroughly mixed within a matter of minutes due to mechanical agitation resulting from the flow of the liquids into and out of the reservoir 2.

FIG. 5 shows an alternative embodiment of this invention wherein a supply line 48 to the reservoir 2' is in direct communication with the reservoir 2'. In addition, the reservoir 2' is in the form of a cylinder 38 and the means for maintaining the pressure $P_1$ on the liquids is by means of the piston 40 connected to a pressure source, not shown, by a connecting rod 44.

In FIG. 6 there is shown an alternative embodiment of the conduit 14. In this embodiment the conduit 14 is provided with a jet-forming restriction 54 to concentrate the flow of liquids displaced from the pump 16 into the center of the conduit 14 as shown by the heavy arrows.

In FIGS. 7 and 8 an additional embodiment is shown wherein a venturi 56 is provided within the conduit 14. The venturi 56 is comprised of walls 62 supported by the arms 58 attached to the walls of the conduit 14 thus providing a space 63 between the exterior of the walls 62 of the venturi 56 and the walls of the conduit 14 in which liquid from the reservoir 2 is drawn down and then into the venturi 56. Liquid is caused to flow upward from the pump 16 into the conduit 14 and the venturi 56 and through the center of the venturi 56, thus forming a stream of the fluid directed into the reservoir 2. The velocity of the fluid stream is such as to cause a further mechanical mixing action to take place within the reservoir 2.

A further modification of the apparatus of this invention is shown in FIG. 9 in which the reservoir 2 is provided with a relatively wider conduit 64 which has a nozzle 66 supported by the arms 68. A flexible membrane 67 covering only the peripheral opening around nozzle 66 is attached to the outer diameter of nozzle 66. This flexible flapper valve closes against arms 68 during a pressure stroke of piston 72 thus forcing the pressurized liquid through nozzle 66 at high velocity. A suction stroke of 72 causes this flexible membrane 67 to bend away from arms 68 thus allowing passage of liquid from the outer diameter of primary storage container 2 back to top of piston 72, thus setting up a circulating pattern within tank 2. The pump 71 in this case comprises a reciprocating piston 72 and rod 74.

The zero gravity operation of the apparatus of this invention can be simulated under positive gravity conditions in the following manner. The reservoir comprised a sphere having a six inch internal diameter and containing a rubber pressurizing diaphragm. The liquid displacement of the pump means mixing diaphragm was about one and three-quarter cubic inches. The variations in pressure $P_2$ were controlled by a three-way solenoid valve which pressurized the pump means to a pressure above $P_1$ and alternately vented the mixing diaphragm to the atmosphere.

The mixing action of the apparatus of this invention is demonstrated in the following manner: The reservoir is filled with a first liquid which is water that is buffered with alcohol to equal the density of a second liquid which is then injected into the reservoir. The second liquid is a similar alcohol and water solution containing a suspension of powdered black rubber to facilitate observation of the mixing of the liquids. Since the density of the two liquids are equal, they will act as though they were in zero gravity since gravity will have no mechanical mixing effect. When the second liquid is added to the reservoir, essentially no noticeable mixing of the liquids takes place. Upon operation of the pump means to alternately cause a portion of the liquids to flow into and out of the reservoir, the liquids become thoroughly mixed within a few moments.

What is claimed is:

1. Apparatus for mixing liquids under conditions of zero gravity, comprising; a closed container for liquids; first pressure means for maintaining a first positive pressure on liquids in said container; a liquid supply line connected to said container for supplying liquids to be mixed to said container; a conduit connecting the interior portion of said container holding said liquids with second pressure means; said second pressure means being applied to the liquids to be mixed, which pressure is alternately greater than and lesser than said first pressure means; said second pressure means displacing a mass of said liquids less than the total mass of said liquids in said container, alternately into and out of said container, thereby mechanically mixing said liquids.

2. Apparatus as claimed in claim 1 wherein said first pressure means for maintaining a first pressure on said liquids includes a first flexible diaphragm, which diaphragm divides said container into a side for said liquids and a side to which a fluid at said first pressure is applied thereby transmitting said pressure throughout said first flexible diaphragm to said liquids.

3. Apparatus as claimed in claim 2 wherein said second pressure means is pump means having a chamber divided into two sections by a second flexible diaphragm, a first section in communication with said conduit and said liquids to be mixed, and a second sec-

tion in communication with a fluid pressure source which alternately applies a pressure to said second flexible diaphragm greater than and lesser than said first pressure.

4. Apparatus as claimed in claim 1 wherein said second pressure means is pump means having a chamber divided into two sections by a flexible diaphragm, a first section in communication with said conduit and said liquids to be mixed, and a second section in communication with a fluid pressure source which alternately applies a pressure to said flexible diaphragm greater than and less than said first pressure.

5. Apparatus as claimed in claim 1 wherein said supply line for said container is in communication with said conduit.

6. Apparatus as claimed in claim 5 wherein said supply line contains valve means for controlling flow to said container.

7. Apparatus as claimed in claim 1 wherein said conduit contains a jet-forming restriction.

8. Apparatus as claimed in claim 1 wherein said conduit contains venturi means at the end of said conduit adjacent said container.

9. Apparatus as claimed in claim 8 wherein valve means is associated with said venturi means to ensure return flow to said second pressure means thereby facilitating circulation of mixing liquids.

10. Apparatus as claimed in claim 8 wherein said valve means is a flexible membrane.

11. Apparatus as claimed in claim 1 wherein said second pressure means is pump means; said pump means being of the type that employs a piston.

12. Apparatus as claimed in claim 1 wherein said first pressure means is designed to discharge liquids from said container to enable mixing of different liquids.

13. Apparatus as claimed in claim 1 wherein said first and second pressure means are designed to purge said apparatus for mixing liquids to enable mixing of different liquids.

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