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LIQUID-GAS SEPARATOR FOR ZERO GRAVITY ENVIRONMENT

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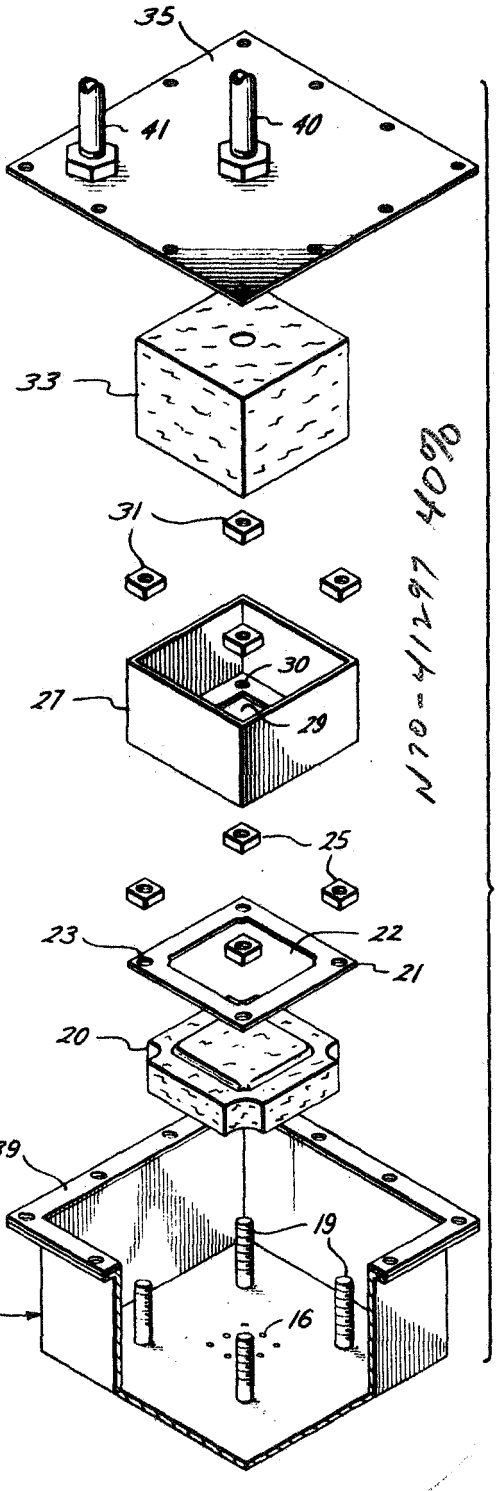

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Fig. 1

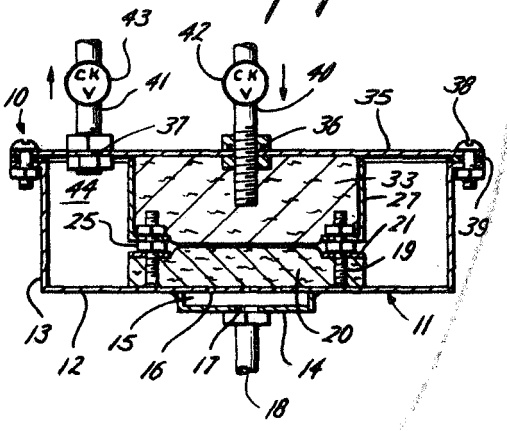

Fig. 2

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LIQUID-GAS SEPARATOR FOR ZERO GRAVITY ENVIRONMENT

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7 Claims. (Cl. 55—35)

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

This invention relates to an apparatus for separating the gas from a liquid-gas stream while operating at either gravity or zero-gravity conditions.

In all manned spacecraft, an environmental control system must be provided to insure a proper environment for the operators thereof. In addition to pressurizing the cabin of the vehicle, a special suit is normally provided for each operator which can be pressurized in the event that the cabin pressure fails. Due to the air-tight construction of such a suit, there must be some means for cooling the interior of the suit in order to alleviate severe discomfort to the wearer. The present most commonly used cooling means consists of merely passing cool gas such as oxygen through the suit and over the body of the wearer. However, since this gas picks up and retains moisture from the wearer's body, the cooling system must include means capable of separating this moisture from the gas in order that the gas can be continuously recirculated through the suit. A typical example of such a means is the water separator disclosed in U.S. Patent No. 3,131,040 issued April 28, 1964. This separator absorbs the moisture from the stream in a sponge member while allowing the gas to pass therethrough. However, it has been found that when the sponge of this separator is compressed to force the liquid therefrom into a storage tank, a certain amount of gas which is present in the sponge is forced along with the liquid into the storage tank. Normally, this small amount of gas would create no problem but in a zero-gravity environment such that as that commonly encountered by a spacecraft, this gas collects in the storage tank and severely limits the storage volume available for liquid. The separating unit of the present invention not only solves this problem but also provides a device capable of separating the gas from a liquid-gas stream in other environments from that illustrated.

The present invention comprises a housing having two layers of a highly absorptive material in an abutting relationship. Although these two layers may be of the same material, each has a separate and distinct density. The density of the first or absorptive layer is relatively loose and will accordingly allow both the gas and the liquid of a liquid-gas stream to pass therethrough. The gas passes directly through this layer meeting substantially no resistance to flow, while the liquid, on the other hand, is absorbed by this layer material and flows across said layer under the influence of the pressure of the incoming stream.

The second or wicking layer which is in direct abutment with said first layer, is compressed to such a density that no gas can pass through the wicking layer at any time during the operation of the unit. However, since this wicking layer is comprised of a highly absorptive material, the liquid absorbed in the first layer will pass into the second layer upon saturation of the first layer and will flow across said wicking layer as long as a sufficient pressure differential exists thereacross.

A gas outlet is provided adjacent the interface of the two layers so that the gas can exit from the unit after it has passed through the first layer. However, when the unit is operating at zero-gravity conditions, a check valve is provided on the gas outlet so that a portion of the gas can be trapped in the housing to create and maintain an initial positive pressure in said first layer. Since the pressure below the second layer is substantially less than the initial pressure in said first layer, a pressure differential will be established across the second layer. As long as this differential is great enough liquid will be pushed from the first layer into and through the wicking layer into a storage tank. As the liquid is transferred from the first layer to the wicking layer the gas trapped within said first layer expands into the space previously occupied by the liquid, thereby continuously reducing the initial pressure to a value below that which is necessary for liquid flow across the wicking layer. The opening pressure of the check valve should be so set that the initial pressure will be great enough to push all of the liquid from the first layer into the second layer before the initial pressure drops below the desired value. When the initial pressure so decreases, operation will cease until another surge of the liquid-gas stream is injected into the unit. The liquid which is collected at the lower end of the wicking layer is substantially free of gas and can easily be stored in a zero-gravity environment.

The invention will be better understood by referring to the drawings in which like numerals identify like parts in the different figures and in which:

FIG. 1 is a vertical section of the separating unit in an assembled position.

FIG. 2 is an exploded view of the components of the unit.

The separating unit **10** is comprised of housing **11** having a bottom **12** and side walls **13** extending upward therefrom. A box-like member **14** is secured with its opened end up to the outer side of bottom **12** by means of welding, or the like, to form a liquid collection chamber **15** therein. A plurality of holes **16** are provided through bottom **13** to establish communication between the interior of the housing and chamber **15**. Chamber **15** has an outlet port **17** at the lower end thereof which is connected to a storage tank (not shown) by conduit **18**.

On the inside of the housing extending upward from bottom **13** and attached thereto are a plurality of studs **19** spaced from and about holes **16**. A highly compressed layer of absorptive material **20** (hereinafter referred to as the wicking layer) is placed between the studs and over holes **16**. This highly absorptive material is preferably one which is comprised essentially of pure silica such as "Refrasil." Compression plate **21** having a large central opening **22** therethrough is positioned onto studs **19** by means of stud holes **23** and is tightened downward onto wicking layer **20** by means of nuts **25**. This plate not only holds wicking layer **20** in place and further compresses same to increase the density thereof, but more importantly insures a sealing engagement between layer **20** and holes **16**.

A box-like container **27** having a large central opening **29** through the bottom thereof, is positioned onto studs **19** by means of stud holes **30** in the bottom of the container and is secured in place by nuts **31**. Another layer of absorptive material **33** (hereinafter referred to as the absorption layer) is loosely packed into container **27** after which lid **35** is secured on the housing by means of screws **38**, or the like. This absorption layer is preferably of the same material as that of the wicking layer but of a much lesser density. A gasket **39** is provided between the lid and the housing to insure an air-tight seal therebetween.

Lid 35 has two openings 36, 37 therethrough. A liquid-gas inlet conduit 40 is connected to opening 36 and extends through the lid into layer 33. A gas outlet conduit 41 is connected to the opening 37. Check valves 42 and 43 are coupled into conduits 40 and 41, respectively. The length and width of container 27, plate 21, and layer 20 is less than those of housing 11 so that when the parts are assembled as shown in FIG. 1, a chamber 44 is formed in said housing.

Before actual operation of the unit is begun, the highly compressed wicking layer 20 should be completely saturated with a liquid the same as that to be separated. This can be done by saturating layer 20 before it is assembled into unit 10 or it can be saturated after assembly by injecting liquid up through conduit 18, chamber 15, and holes 16. This prior saturation acts to insure that no gas will pass through layer 20 before it has become fully saturated by liquid from the stream. After layer 20 is saturated, the operation of unit 10 is as follows.

A liquid-gas stream is admitted in surges through check valve 42 in conduit 40 and directly into the loosely packed absorption layer 33 in container 27. This stream enters the housing at a relatively large pressure and the bulk of the gas immediately passes through layer 33 whereupon it contacts the highly compressed wicking layer 20. It can be seen from FIG. 1 that plate 21 and container 27 are spaced from each other by nuts 25 so the gas, upon contacting wicking layer 20, will seek the path of least resistance and will pass out of layer 33, between plate 21 and container 27, and into chamber 44 in the housing. Since check valve 43 on outlet conduit 41 is set to open at a relatively low pressure, most of the gas will be exhausted therethrough and will be removed from the unit. However, when the pressure of the gas drops below the opening pressure of valve 43, the valve will close and the remaining gas will be trapped in both chamber 44 and adsorption layer 33 to maintain a desired pressure therein. Since the pressure below wicking layer 20 is substantially less than this trapped pressure, a pressure differential will exist across the layer 20. This pressure differential will act on the liquid which has been readily absorbed in said absorption layer to drive said liquid out of layer 33 into and across wicking layer 20. As the liquid from layer 33 contacts layer 20, the affinity between the material of wicking layer 20 and the liquid will prevent the liquid from flowing into chamber 44. As the liquid is driven out of layer 33 and across wicking layer 20, the volume available for the gas in layer 33 increases, which will accordingly decrease the pressure in layer 33 until the pressure differential drops below the value needed for liquid flow across layer 20. When this occurs, operation of the unit ceases until another surge of the liquid-gas stream is injected into the unit. The liquid which has been passed through layer 20 is collected in collection chamber 15 from which it is transferred to a storage tank through conduit 18. This liquid is substantially free of all gas which allows the entire volume of the tank to be utilized for storing liquid.

From the foregoing description it should be obvious that this invention provides a compact separating unit which will separate substantially all the gas from a mixed liquid-gas stream. It should also be obvious that the pressure differential across wicking layer 20 could be provided from an external force; e.g. compressed air injected directly into either chamber 44 or absorption layer 33. Also, if the incoming stream is to be at a steady rate, no external pressure such as the trapped gas would be necessary, since the pressure of the stream would be sufficient to provide the necessary pressure differential across layer 20.

While a particular embodiment of this separating unit has been illustrated and described, it will be obvious that changes and modifications can be made without departing from the spirit of the invention and the scope of the appended claims.

What is claimed and desired to be secured by Letters Patent is:

1. A liquid-gas separating unit capable of operating in a zero gravity environment comprising:
   - a housing having a bottom and side walls attached to and extending upward therefrom;
   - a lid having an opening therethrough sealingly connected to the upper ends of said side walls to form a closed chamber inside said housing;
   - inlet means connected to said opening adapted to convey a liquid-gas stream to said closed chamber, said bottom having a liquid outlet means therethrough;
   - an absorption layer of highly absorptive material having a relatively loose density in said housing and positioned in direct contact with said inlet means, said absorption layer following the gas in the stream to pass therethrough while absorbing the liquid therein ;
   - a wicking layer of highly compressed absorptive material of a density greater than said absorption layer, being in sealing engagement with said liquid outlet means within said housing and in juxtaposition with said absorption layer, said wicking layer preventing the gas from passing therethrough while allowing the liquid which is absorbed by said absorption layer to pass theretthrough;
   - gas outlet means in said housing in fluid communication with said absorption layer whereby the gas can be remove from the unit after it is separated from the liquid; and
   - means connected to said gas outlet means to allow only a portion of the gas to exit through said gas outlet means whereby a positive pressure can be maintained within said absorption layer.

2. A liquid-gas separating unit comprising a housing having an inlet port and a liquid outlet port;
   - a conduit connected to said inlet port adapted to supply a liquid-gas stream to said housing;
   - a first layer of absorptive material in said housing position in fluid communication with said inlet port;
   - a second layer of absorptive material positioned within said housing in sealing engagement with said liquid outlet port and in juxtaposition with said first layer;
   - said first layer being of such a density so as to absorb the liquid from the liquid-gas stream while allowing the gas therein to pass therethrough, said second layer being of a greater density than said first layer so as to prevent gas from passing therethrough while allowing the liquid absorbed by the first layer to pass therethrough; and
   - a gas outlet means in said housing in fluid communication with said first layer to provide an outlet for the gas after it has been separated.

3. A liquid-gas separating unit as set forth in claim 2, including means connected to said gas outlet means to trap part of said gas in said housing to provide a constant presure in said first layer.

4. A liquid-gas separating unit as set forth in claim 2 wherein the material of said first and second layer is comprised of essentially pure silica.

5. A liquid-gas separating unit comprising a housing having a liquid-gas stream inlet means and a liquid outlet means;
   - a first absorptive means permeable to both the liquid and the gas in a liquid-gas stream positioned in said housing and in direct contact with said inlet means;
   - a second absorptive means permeable to the liquid and impermeable to the gas positioned in said housing and in juxtaposition with said first means, and said second means also positioned directly over said liquid outlet means; and
   - gas outlet means in said housing in fluid communication with said first permeable means to provide an out-

let for the gas after it passes through said first permeable means.

6. A liquid-gas separating unit as set forth in claim 5 including a means connected to said gas outlet means to trap a portion of said gas in said housing to provide a constant pressure in said first permeable means.

7. A method of separating a gas from a liquid-gas stream comprising the steps of injecting a liquid-gas stream into a first layer of absorptive material which will absorb the liquid while allowing the gas to pass therethrough, removing the gas from said first layer after it has passed therethrough, passing the liquid which is absorbed by said first layer through a second layer of absorptive material which is impermeable to gas, and collecting said liquid after it has passed through said second layer.

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