Jan. 16, 1968 R. E. BIDWELL ETAL 3,363,626

UNDERWATER DRAINAGE APPARATUS

Filed March 17, 1966 3 Sheets-Sheet 1

FIG. 1

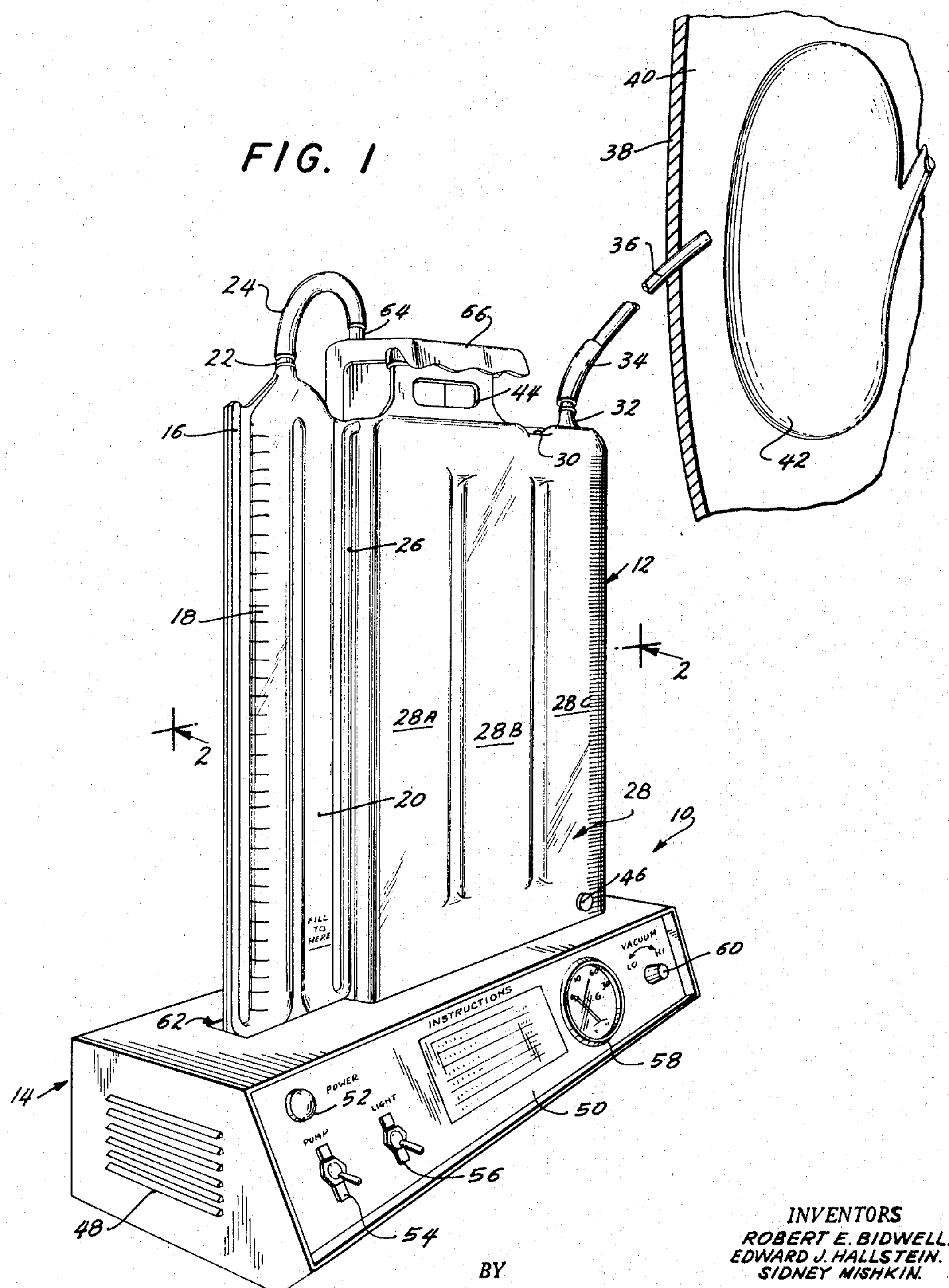

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FIG. 2

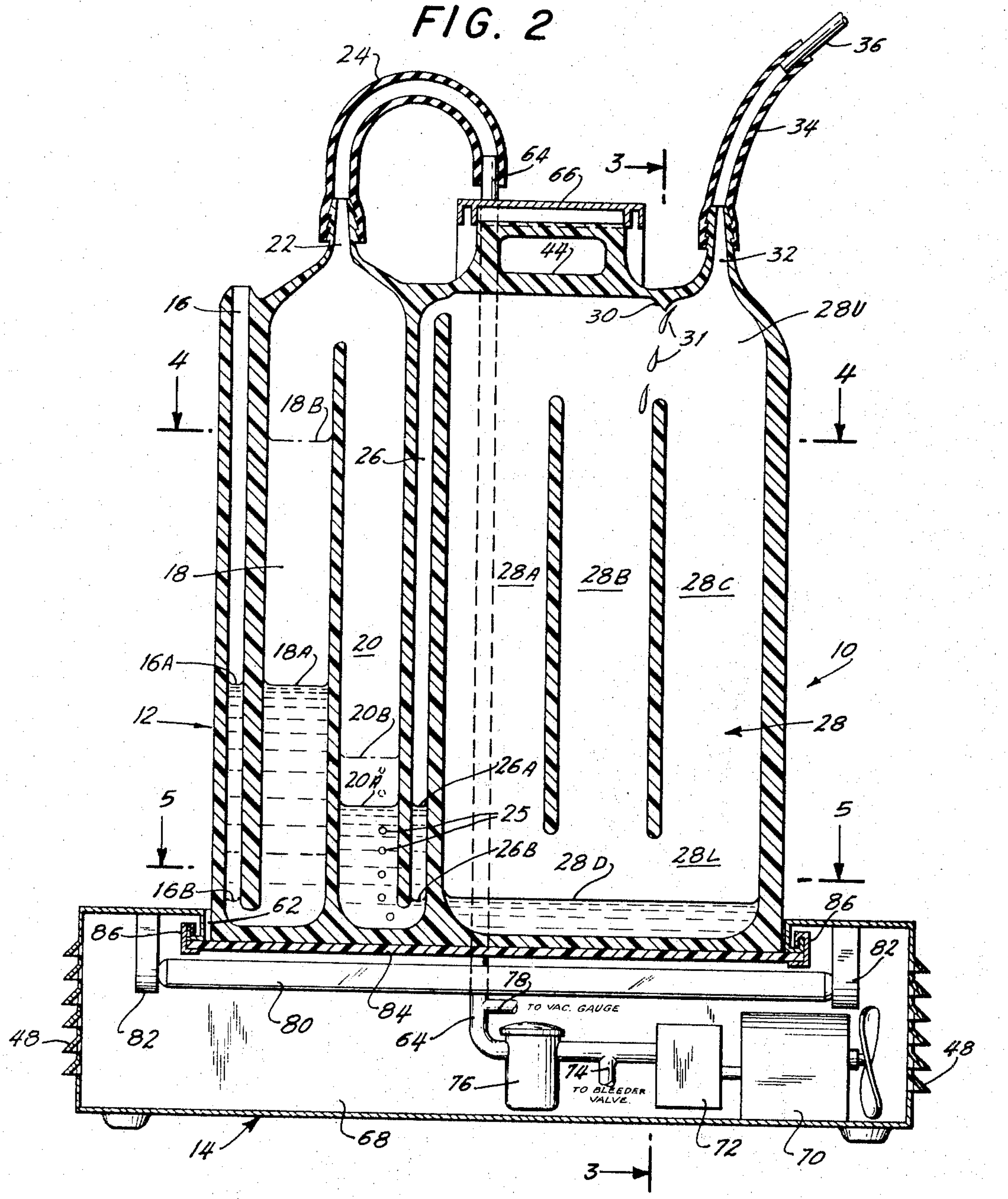

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FIG. 3

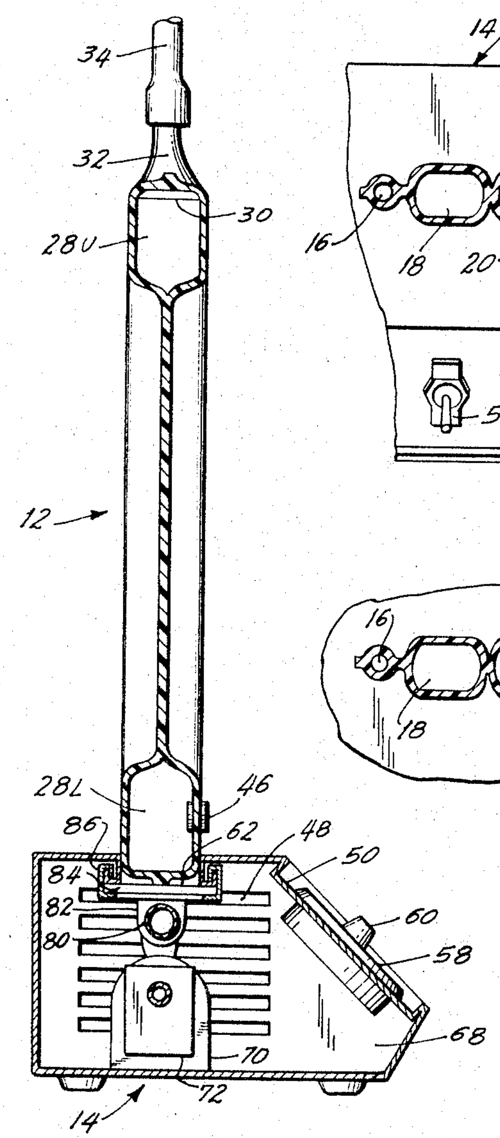
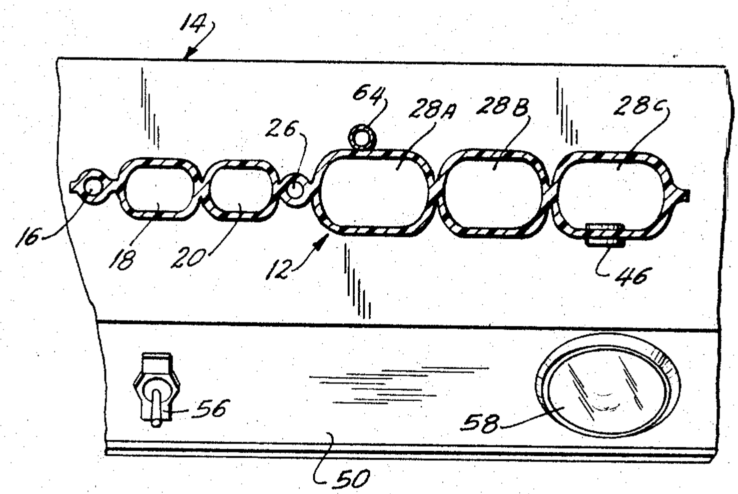


FIG. 4



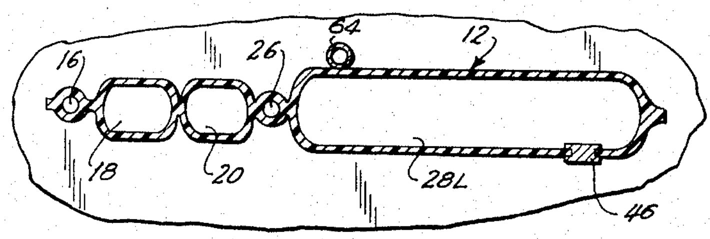


FIG. 5

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UNDERWATER DRAINAGE APPARATUS

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Filed Mar. 17, 1966, Ser. No. 535,178
23 Claims. (Cl. 128—276)

ABSTRACT OF THE DISCLOSURE

A drainage apparatus for evacuating fluids from cavities including a one-piece container having a trap chamber, a seal chamber, and a pressure regulator chamber. The chambers are arranged to include a continuous passage from said trap chamber through said seal chamber to said pressure regulator chamber. The trap chamber has an opening for connection to the cavity and the seal chamber includes an opening for connection to a vacuum source. A stand for holding the container and including a light source, a vacuum source, and controls therefor.

This invention relates to a drainage apparatus, and more particularly, to improved and disposable equipment for safely evacuating a cavity of extraneous fluids.

Current developments in many scientific areas have led to an increasing need for purification techniques of all kinds. In this regard, many related fields have developed a common need to provide clean and antiseptic environments to insure proper control conditions. Thus, these requirements are applicable to many phases of medicine, biological research, space technology, physics, chemistry, etc.

One specific area where this problem has become especially acute is that of medicine, and particularly the aspect of medicine which deals with maintaining clear passages and cavities under operation and post-operative conditions. For example, to treat potentially dangerous conditions of the lung, a prime consideration is the removal of excess fluids (liquids such as water and blood, and gases such as air) from the pleural cavity between a lung and the surrounding rib cage. Circumstances which create these dangerous conditions include any introduction of fluid into the pleural cavity. This could occur following a surgical incision through the rib cage in order to perform surgery on the lung itself, or following stab or bullet wounds which pierce the rib cage, or as a result of pleurisy, etc. It is critical to a patient's survival in such instances to keep the pleural cavity relatively free of fluids in order to allow normal pressure changes in the cavity to restore or at least maintain normal breathing.

To obtain a more complete understanding of this invention, there follows a brief explanation of the lung structure and the manner in which the general "breathing" function is accomplished. During all aspects of breathing, the chest may be considered like a bellows. That is, the chest wall or rib cage and the diaphragm muscles which separate the chest from the abdomen, expand and contract to respectively enlarge and contract the pleural cavity. This alternate expansion and contraction create pressure changes within the cavity which operate on the lung itself to maintain the breathing process. Specifically, as the pleural cavity expands, a relatively negative pressure is created in the cavity tending to expand the lungs and thereby to allow air to be drawn into the lungs. This aspect of breathing is known as inspiration. Similarly, when the rib cage and diaphragm contract, a relatively positive pressure in the pleural cavity forces air out of the lungs. This is known as expiration. It can therefore be seen that the breathing process is essentially passive in nature, being responsive to pressure changes in the pleural cavity.

Breathing problems develop, in general, when the normal steps of inspiration and expiration are interfered with. Thus, should fluid be introduced into any part of the pleural cavity, the normally passive pressure changes within the pleural cavity will be disturbed and normal breathing is thereby hampered. The presence of such extraneous fluid generally leads to greater-than-normal cavity pressure, which seriously impairs both inspiration and expiration, and can ultimately result in death.

The surgical and medical treatment for such pleural cavity imbalance is generally known as "underwater drainage," and involves the removal of fluids from the cavity and the simultaneous prevention of the further introduction of any additional fluids therein. Clearly, unless fluid removal is successfully achieved and normal breathing restored, death of the patient is a strong possibility.

The prior art techniques which was developed to take care of this problem utilizes three basic elements to achieve the desired result: a first container connected to the patient to trap liquids removed from the pleural cavity and to pass therethrough gases similarly evacuated; a liquid seal which permits the evacuated gases to bubble out from the trap container, but which prevents the reverse passage of fluids back into the pleural cavity; and a source of suction to create the necessary negative pressures to draw out the accumulated fluids.

This principle has been embodied in the prior art in a complex interconnected tube and bottle arrangement which is generally denominated as the "three-bottle" system. In such a system, one bottle is utilized to establish the requisite negative pressure (e.g., it is connected to a suction or vacuum pump), a second bottle contains a small amount of water or other suitable liquid to provide the underwater seal, and a third bottle fulfills the trapping function. While the three-bottle system can generally operate in a fairly satisfactory manner if correctly used, innumerable problems have been associated with its application. Initially, there has been a widespread lack of uniformity in the equipment which is manufactured for use in that system. Depending on the manufacturer involved and in some cases on which hospital or laboratory is responsible for the drainage of a patient's pleural cavity, the bottles and their associated interconnecting apparatus have been totally non-uniform. Thus, differences exist in bottle size, tube length and diameter, stopper material, etc. Due in part to this lack of uniformity and to the great expenses involved in the prior art system, many hospitals are now using their own set-ups of bottles, stoppers and tubing. This "amateur" approach has led to many dangerous situations whereby despite alleged precautions taken by supervisory personnel, great confusion has arisen as to the proper manner in which to operate the system. Unfortunately, haphazard set-ups and incorrect interconnections can lead to malfunctions and even an occasional explosion due to the improper accumulation of explosive anaesthesia gases in the system. If the drainage principle were properly applied, of course no such intolerable results would result.

It can be noted that even without such disasters, fundamental errors and an unfortunate lack of antiseptic conditions seem to occur all too often, due to the breakage of system components and to leaks in the system. In addition to the great expense and complexity of the present drainage system, the apparatus currently used must be disassembled and sterilized after each use. Moreover, at least partial disassembling is required merely to withdraw a small sample of the accumulating liquid from the trapping container for medical analysis. In addition, the limited capacity of even the largest bottle which can be used in the system has hampered medical personnel in many cases.

Very little emphasis has been placed on the need for cavity drainage under "emergency" conditions, such as the field of battle, scenes of accidents, etc. Due in large measure to their bulk and complex associated machinery, prior art draining systems have had little or no application to such situations.

It is therefore an object of this invention to furnish an improved underwater drainage system to obviate one or more of the aforesaid difficulties.

It is another object of this invention to provide a disposable underwater drainage unit to safely and efficiently evacuate a body cavity of excess fluids.

It is a further object of this invention to provide a disposable, sterile and one-piece underwater drainage unit which can be installed and labeled to avoid confusion and conditions harmful to health.

In one particular illustrative embodiment of the principles of this invention, a transparent plastic, vacuum-formed underwater drainage unit is contemplated. It is of course understood that any suitable material can be utilized to comprise the apparatus of the present invention, depending upon the particular application involved, and that correspondingly suitable methods of manufacture (e.g., blow molding, pressure forming, injection molding, slush molding, etc.) are possible. The present invention successfully carries out the steps of the underwater drainage principle with a plastic "bottle" of unitary construction with a plurality of internally formed chambers. Included are a trap chamber, an underwater seal chamber, and a liquid manometer, one end of which is open to atmospheric pressure.

There are only three external openings to the one-piece bottle unit, one which attaches to a simple vacuum pump (the prior art system involved a bulky and very expensive floor unit in this regard), a second which is attached to a tube inserted into the patient's pleural cavity and a third which is open to the atmosphere. This contrasts with at least six openings in the prior art. All the necessary interconnections in the system are achieved internally within the formed one-piece unit. The external connection to the pleural cavity is from the trap chamber, while a common internal connection of the liquid manometer and the underwater seal chamber provides an outlet to the vacuum pump. For the purposes of removing a small sample of the gradually accumulating trapped liquid, another problem of the prior art is avoided by the inclusion in the lower end of the trap chamber of a simple self-sealing entry, such as a rubber grommet or the like. Similar entries into the system can be made by furnishing additional grommets wherever desired.

The "activating" equipment to operate this system can be simply housed in a multi-purpose base stand which is adapted to include a drive motor, a vacuum pump, various adjusting equipment and instrumentation as may be desired, and a source of upwardly directed illumination which allows for use of the invention at night or in poorly lighted environments. The one-piece unit can be arranged to rest in a vertical plane in a depression in the base stand, allowing for convenient removal and installation of the bottle. The only connection between the base stand and the bottle is that from the vacuum pump output tube to the previously mentioned aperture common to the manometer and the underwater seal.

The system is made operative merely by setting it up beneath the level of the patient (to insure proper fluid flow) and by making the appropriate connection from the trap chamber to the pleural cavity. When the power and the vacuum pump are activated, appropriate graduations on the main tube of the liquid manometer chamber allow for the establishment of the correct or desired liquid pressure head. This permits variation in exhaust pressure depending upon the situation involved, the condition and age of the patient, etc.

When the drainage commences, liquids and gases which have accumulated in the pleural cavity are drawn initially into the trap chamber, where withdrawn liquid begins to collect; gases which have been evacuated from the pleural cavity pass through the trap chamber and bubble up through the underwater seal until they ultimately reach the source of suction which removes them from the system. This process continues until the normal breathing pressure changes previously described are re-established, at which time the lung will have once again assumed its relatively normal shape proximate to the rib cage.

Termination of cavity drainage is indicated when there is no longer any bubbling through the underwater seal, and when no additional liquid is seen to be dripping into the trap chamber. When it has been determined that drainage has been completed, the two connections from the bottle (to suction and to the pleural cavity) are removed and the entire unit is simply lifted and discarded. Additional drainage can be subsequently accomplished by the installation of a fresh and similarly disposable underwater drainage bottle as described above.

It is therefore a feature of this invention that the drainage of the pleural cavity is achieved by means of a one-piece drainage apparatus which can be discarded after use.

It is a further feature of this invention that an underwater drainage system comprises a disposable bottle of unitary construction which includes a self-contained manometer, an underwater seal and a trap chamber to provide full underwater drainage capacity, all of which are internally formed within said bottle.

It is still another feature of this invention that means are included in an underwater drainage system to rest a one-piece drainage bottle thereon and to also provide all the necessary mechanical and electrical apparatus therein.

Still another feature of this invention is an inexpensive underwater drainage bottle simply constructed in one piece of transparent material, thereby permitting ready observation of the chambers thereof to aid a clinician in determining pressure changes occurring within the pleural cavity.

The above brief description, as well as further objects, features and advantages of the present invention, will be more fully appreciated by reference to the following detailed description of a presently preferred but nonetheless illustrative embodiment demonstrating objects and features of the invention, when taken in conjunction with the accompanying drawing, wherein:

FIG. 1 is a perspective view of one illustrative embodiment of an underwater drainage system in accordance with the principles of this invention, showing a one-piece drainage bottle resting on a support stand with a connection to a pleural cavity;

FIG. 2 is a front sectional view of an underwater drainage system, taken along a vertical plane which includes line **2—2** of FIG. 1, showing the various chambers having different water and fluid levels for different modes of operation of the invention;

FIG. 3 is an end sectional view of an underwater drainage system along the line **3—3** of FIG. 2;

FIG. 4 is a horizontal section, partly broken away for clarity, of an underwater drainage unit taken along the line **4—4** of FIG. 2; and

FIG. 5 is another horizontal section, partly broken away for clarity, of an underwater drainage system taken along the line **5—5** of FIG. 2.

A general underwater drainage system **10** in accordance with the present invention is illustrated in perspective in FIG. 1. The system **10** comprises, generally, an upper one-piece disposable plastic bottle **12**, also referred to as a drainage device or as a container, which rests in a depression **62** in the upper surface of a base housing **14**. The invention contemplates the drainage of excess and extraneous fluids from a cavity in a human body, for example. Such fluids can accumulate to the detriment of a patient in a pleural cavity **40** located between a rib cage or chest wall **38** and a lung **42**. Drainage of the harmful fluids is achieved through tube element **36** inserted in the rib cage **38** and into the pleural cavity **40**, and through interconnecting apparatus **34** into the drainage bottle **12**.

Suction and other suitable instrumentation for the system is controlled from a front panel **50** of the housing **14**, and the suction connection to the bottle **12** occurs from the exhaust tube **64** through interconnecting tube **24**. Supporting canopy **66** provides for stabilization of the supported bottle **12** by virtue of retaining the integrally formed handle **44** of the bottle **12** within the canopy structure.

The underwater drainage bottle **12** is formed with a plurality of internal chambers best described with reference to FIG. 2. A liquid manometer is formed by the relative levels of liquid in chambers **16** and **18**. As will be more fully described below, the equilibrium between liquid levels **16**A and **18**A in chambers **16** and **18** respectively is the "idle" condition of the system; when the system vacuum pump initially applies suction, a liquid pressure head such as that indicated between liquid levels **16**B, **18**B (shown in phantom) is established to measure the relatively negative pressure (or vacuum) created by the applied suction.

An underwater seal chamber **20** is linked at the upper end thereof to the main liquid manometer chamber **18** through a connecting opening, and a first outlet port **22** is formed in the top of the common junction of these chambers. A relatively small amount of liquid, such as water or other suitable density liquid, is placed into the seal chamber **20** to approximately the level indicated at meniscus line **20**A in FIG. 2. Based on well-known principles, the level **26**A of liquid in interconnecting chamber **26** is at the same level as liquid level **20**A during periods of equilibrium in the system.

Internally formed chamber **26** includes a connecting opening for passage of gases evacuated from the pleural cavity **40** and through the trap chamber **28** to the underwater seal chamber **20** from which the gases pass out of the system through the aperture **22**. As previously described, the function of the trap chamber **28** is to collect drained liquids from the pleural cavity **40**. For purposes of convenience, which in no way limits the invention, the trap chamber **28** is illustrated as formed in three general sections, a left section **28**A, a middle section **28**B and a right section **28**C. In actuality, as can be seen by comparing FIGS. 4 and 5, these divisions may exist merely at the central level of trap chamber **28**, with FIGS. 3 and 5 indicating that the chamber **28** is undivided at both the upper and lower portions **28**U and **28**L respectively. This is advantageous with respect to the lower collecting area **28**L where drained liquids can collect at level **28**D in FIG. 2. Since it would be somewhat undesirable for drained liquids to pass along the upper surface of the chamber **28** and through the internal passage **26** into the underwater seal chamber **20**, a simply formed drip ledge **30** is included adjacent to trap chamber sections **28**B and **28**C. The presence of this drip ledge **30** promotes the dripping or flowing of drained liquids **31** directly downward from the drip ledge to where it can collect at level **28**D in trap chamber **28**; the quantity of collected liquid can be readily determined by reference to the graduations on the trap chamber section **28**C (see FIG. 1).

A typical although by no means all-inclusive set of instrumentation and driving means is shown included within base housing unit **14** in FIGS. 1 and 2. For example, cover plate **50**, which can include printed or etched instructions for the simplified operation of the underwater drainage system of the invention, can have apertures through which may be seen in FIG. 1 a power indicator **52**, pump-activating switch **54**, light switch **56**, vacuum gauge **58**, and vacuum-controlling bleeder valve **60**. Vents **48** in the end walls of the housing **14** provide ventillation for the various heat-producing instruments within the chamber **68** enclosed by the housing **14**. The overall system is governed by the driving motor **70**, which energizes a vacuum pump **72** to provide a suction output in tube **64** which ultimately is connected through interconnecting tube **24** to the aperture **22**. The amount of suction provided by vacuum pump **72** can be controlled by the tap **74** from the output pump **72**, the tap being mechanically coupled to the bleeder valve **60**. The suction applied to the system can be read by referring to the vacuum gauge **58** which is connected to the suction tube **64** at tap **78**. Other suitable instrumentation, such as illustrative moisture trap **76**, can be included in the vacuum-producing portion of the system as may be desired and as will be recognized as desirable by those skilled in the art. Advantageously, all electrical devices and connections are appropriately enclosed and rated "explosion-proof."

In order to furnish the capability of providing properly supervised underwater drainage even at night or under poor lighting conditions, an illuminating source such as illustrative fluorescent lamp **80** is enclosed within lamp sockets **82** to provide upwardly directed illumination of the drainage bottle **12** and the liquid levels therein through, for example, frosted glass **84** held by brackets **86**.

To facilitate a complete understanding of the invention, a typical drainage cycle will now be described. Initially, of course, the insertion of tube **36** into the pleural cavity **40** through the rib cage **38** is made; in addition, suitable liquid levels such as **16**A, **18**A, **20**A and **26**A in chambers **16**, **18**, **20** and **26** respectively have been reached. When a source of power (not shown) is energized, the drive motor **70** is activated and the vacuum pump **72** commences operation. Depending upon the adjustment of the bleeder valve **60**, the liquid levels previously mentioned will be varied. Assuming that the patient is an adult male with a significant accumulation of excess fluids in the pleural cavity **40**, it would be desired to establish a relatively high pressure head. Typically, such a head could measure approximately 20 to 30 centimeters of water, and this can be determined by referring to the graduations on the main manometer tube **18**. Thus, for the sake of clarity, it is assumed that the bleeder valve **60** is adjusted to allow sufficient pressure to be established in the system so that the liquid levels **16**B and **18**B are established in manometer tubes **16** and **18** respectively. The differential between these levels represents the established pressure head. In response to this establishment of pressure, the liquid in the underwater seal chamber **20** and the connected interconnecting tube **26** will assume levels **20**B and **26**B (shown in phantom) respectively. (This latter differential head is not critical to the operation of the invention.)

Since it has been assumed that the amount of pressure represented by the differential between the levels **16**B and **18**B is sufficient to commence drainage from the hypothetical adult male patient, some of the excess fluids (gases and liquids together) will begin to pass from the pleural cavity **40** and through the tubes **36**, **34** into the single drainage bottle **12** through the inlet port **32**. The liquid portions of the drained fluid will strike drip ledge **30** and be directed downward in droplets **31** whereby the drained liquids collect at the bottom **28**L of trap chamber **28** at progressively rising level **28**D. The evacuated gases (predominantly air) are drawn by the applied suction from the trap chamber **28** into the internal passage **26** which communicates with underwater seal chamber **20**. By virtue of the negative pressure or suction applied as described above, such gases will "bubble up" as indicated by the symbolic bubbles **25** between the liquid levels **26**B and **20**B. The gases are ultimately exhausted from the system through outlet port **22** as indicated above to the vacuum pump **72**. (In actual operation, the application of suction at aperture **22** may also cause bubbling through the liquid in the manometer tubes **16** and **18**.

That is, outside air will be drawn downward into manometer tube 16 and will bubble up from liquid level 16B through the liquid and out at liquid level 18B. When drainage is complete, the bubbling up of evacuated gases through the underwater seal will stop, although the bubbling up of air through the manometer may continue.)

When the pleural cavity 40 has been fully drained of excess fluids (as indicated by the cessation of bubbling through the underwater seal), the pump 72 can be deactivated by operation of switch 54. The equilibrium liquid levels will now be re-established, whereby manometer tubes 16 and 18 will display equal liquid levels 16A and 18A respectively; similarly, underwater seal chamber 20 and internal passage 26 will have the same levels of liquid (20A and 26A respectively) therein.

After the patient has had the inserted tube 36 removed from his rib cage 38, the disposable aspect of the underwater drainage bottle of the present invention emerges. That is, once the connecting tube 34 is simply removed from the aperture 32 and the tube 24 is removed from the aperture 22, the entire drainage bottle 12 is simply raised from the depression 62 in the housing 14 by disengaging the handle 44 from the canopy fixture 66. The completely disposable unit, including the collected drained liquid at level 28D in the chamber 28, as well as the water in chambers 16, 18, 20 and 26, can be discarded without any need for cleaning, reassembling, or retaining any portions whatsoever. To provide the ultimate in cleanliness and safety, it might be desirable to cap the apertures 22 and 32, although depending upon the manner of discarding, this might be dispensed with.

Subsequent drainage cycles on different patients, or even on the same patient at some other time (it will be appreciated that the drainage bottle can be used repeatedly on the same patient without discarding as long as the trap chamber 28 does not become overly full), can be achieved through the use of freshly installed drainage bottles 12. All that is needed is to attach connecting tubes 24 and 34 through apertures 22 and 32 respectively in the new bottle, the tube 24 connecting into the suction tube 64 and the tube 34 being connected through tube 36 to the pleural cavity 40.

Many possible variations in the embodiments and applications of the present invention are possible. To mention and briefly describe just one such application, it can be noted that an important cause of death in accidents or on the battlefield is not so much the actual penetration caused by a bullet or similar wound (unless the heart or a major blood vessel is pierced), but rather the accumulation of air and/or blood in the pleural cavity. Such accumulations, as previously discussed, can result in a breathing imbalance and subsequent death in many cases. In fact, many of these fatalities occur while the patient is being transported to the nearest hospital facility. The lack of weight and bulkiness of a drainage bottle fashioned in accordance with the principles of the present invention would allow it to be utilized to avoid this type of fatality. For example, the activating elements such as motor 70 and vacuum pump 72 can be operated in response to portable power (not shown) included within enclosed chamber 68 of housing 14. The housing can be carried in a separate relatively small pack, while the drainage bottle 12, connected to the pack to provide suction thereto, has its other aperture 32 connected to the pleural cavity as indicated in FIG. 1. The drainage bottle 12 can conveniently (due to its relatively light weight) be strapped to the patient. Fluid drainage could then proceed as outlined in the above description, and many otherwise hopeless cases could be saved.

Various temporary expedients can be fashioned in accordance with the present invention to prolong life under conditions normally leading to death either on the battlefield or between the battlefield and a local hopsital facility. For example, it would be possible to use a sump or "one bottle" system whereby no externally applied suction is used, and liquid may or may not be added to the

bottle for the underwater seal. (Under drastic emergency conditions where speed is essential, filling the seal tube with water can be dispensed with, even though this could be done quite rapidly.)

The pleural cavity is again entered by the tubes 34 and 36 connected to the aperture 32. "Normal" breathing involves changes in pleural cavity pressure from approximately plus 1 centimeter of water (on expiration) to minus 1 centimeter of water (on inspiration). The presence of any accumulated fluids in the pleural cavity 40 will generally cause abnormally high pleural cavity pressures, greater than the plus 1 centimeter of water which is normally reached during expiration. Such positive pressures will cause much of the accumulated excess fluids in the pleural cavity 40 to be expelled into the drainage bottle 12 without the need for applying suction as above. Specifically, accumulated air in the pleural cavity 40 will be forced out by the positive pressures therein and will either bubble out through the underwater seal previously described (where water is put in the seal chamber) or will be passed to the atmosphere through outlet port 22 or open end manometer chamber 16 where no water is added). The presence of water in the seal chamber 20 positively prevents air from returning back into the pleural cavity 40. (If there is no water in the seal chamber, the relatively positive pleural cavity pressures will prevent most "reverse flow" of air back into the cavity.) This relatively slow bubbling process will continue until the normal breathing pressures in the pleural cavity have been restored. Any drained liquids will again collect in the trap chamber 28 as with the normally operated system. Various modifications of these emergency techniques will be readily apparent to those skilled in the art.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. An underwater drainage device for draining extraneous fluid from a cavity comprising a one-piece unitary container having internally formed therein (a) a manometer open to atmosphere, (b) a seal tube adapted to hold liquid and (c) a trap means adapted to collect liquids drained from said cavity and to pass to said seal tube gases withdrawn from said cavity; said trap means having an inlet port adapted to be connected to said cavity for drainage of fluid and an outlet port for passing gases from the trap means to the seal tube, and said seal tube having at least two connecting openings, a first connecting opening placing the seal tube in fluid communication with the trap means outlet port, and a second connecting opening placing the seal tube in communication with said manometer, the first and second connecting openings of said seal tube being disposed on opposite sides of the liquid seal which is formed when the seal tube contains a sufficient amount of liquid to form said seal, and said device having an outlet port adapted to be connected to a source of suction pressure and formed in the device between the manometer and the liquid seal which is formed when the seal tube contains a sufficient amount of liquid to form the seal.

2. An underwater drainage device for draining extraneous fluid from a cavity comprising a one-piece unitary container having internally formed therein, (a) a manometer open to atmosphere, (b) a seal tube adapted to hold liquid and (c) a trap means adapted to collect liquids drained from said cavity and to pass to said seal tube gases withdrawn from said cavity; said trap means having an inlet port adapted to be connected to said cavity for drainage of fluid and an outlet port for passing gases from the trap means to the seal tube, and said seal tube having at least two connecting openings, a first connecting opening placing the seal tube in fluid communication with the trap means outlet port, and a second connecting opening placing the seal tube in commu-

nication with said manometer, the first and second connecting openings of said seal tube being disposed on opposite sides of the liquid seal which is formed when the seal tube contains a sufficient amount of liquid to form said seal.

3. An underwater drainage device in accordance with claim **1** wherein said device is formed of transparent material and wherein said trap means includes a drip ledge proximate to said inlet port for promoting the accumulation of said liquid in said trap means.

4. An underwater drainage in accordance with claim **1** including in addition a stand having a depression adapted to receive the base of said device, said stand housing pumping means connected to said outlet port for creating a partial vacuum in said seal tube and in said trap means, gauge means for measuring said partial vacuum, means for varying said partial vacuum, driving means for energizing said pumping means, switching means for activating said pumping means and means further responsive to said switching means for illuminating said device.

5. An underwater drainage system for removing gas and liquid from a cavity comprising in combination exhaust means for developing a negative pressure and a drainage container of unitary construction having as internal chambers thereof a manometer connected to said exhaust means for developing a liquid pressure head, a trap chamber connected to said cavity for receiving therein accumulations of said liquid as a seal chamber internally communicating with both said manometer and said trap chamber for transmitting said gas from said trap chamber to said exhaust means through liquid enclosed within said seal tube, and wherein said container is formed with a handle; and including in addition a base for housing said exhaust means, means for driving said exhaust means, means for providing illumination for said container, and means for measuring and controlling the output of said exhaust means, said base having a depression formed in the upper surface thereof for supporting said container.

6. An underwater drainage system in accordance with claim **5** wherein said manometer includes a first graduated tube and a coupled second atmosphere-responsive tube, and wherein an idle condition for said system is defined by the presence of equal liquid levels in said first graduated tube and said second atmosphere-responsive tube, by the presence of a relatively small amount of liquid in said seal tube and by the absence of any fluid flow from said cavity to said trap chamber.

7. An underwater drainage system in accordance with claim **6** wherein said system is rendered operative by the activation of said exhaust means, whereby an operative condition for said system is defined by a differential in liquid levels between said first graduated tube and said second atmosphere-responsive tube, by the presence of said relatively small amount of liquid in said seal tube, and by the presence of fluid flow between said cavity and said trap chamber.

8. An underwater drainage system for draining extraneous fluid from a cavity under emergency conditions comprising a container of unitary one-piece construction having an internally formed collecting chamber with first and second ports formed therein, the first port being adapted to be connected to said cavity and the second port being located at the upper portion of said collecting chamber so that liquids included in the fluid accumulate in the collecting chamber while gases may be eliminated from said collecting chamber through said second port, a seal chamber also formed internally in said container, and said seal chamber having first and second openings, the first opening connected to the second port of the collecting chamber for receiving gases therefrom and the second opening being adapted to be connected to a vacuum source, and a quantity of sealing liquid located in the seal chamber between the said first and second openings thereof and normally located below the level of the first and

second openings when the container is mounted in an operative position, whereby gases passing through the collecting chamber to the seal chamber bubble through the liquid seal and through the said second opening of the seal chamber.

9. A device for draining fluids from a cavity comprising: at least a first chamber, a second chamber and a third chamber, said first chamber including an inlet for receiving gaseous and liquid fluid from the cavity to be drained, and an outlet through which gases may be passed to the second chamber; said second chamber including a first opening for receiving gases from the first chamber, a second opening adapted to be connected to a vacuum source for expelling gases from said second chamber, said second chamber including a means for permitting the establishment of a liquid seal between the said first and second openings, and the third chamber having a first opening connected to the second opening of the second chamber and a second opening which is open to atmosphere; the said three chambers being formed together as a one-piece unitary unit including an integral connecting portion located between and integrally connecting together the said first and second chambers, and another integral connecting portion located between an integrally connecting together the second and third chambers.

10. A drainage device as claimed in claim **9** wherein the said chambers are elongated from an upper end to a lower end and all of the chambers lie in a common plane.

11. A drainage device as claimed in claim **10** wherein the width of the device in a direction perpendicular to said plane is less than six inches.

12. A drainage device as claimed in claim **10** wherein the said openings to the device and between the chambers of the device are located near the upper end.

13. A drainage device as claimed in claim **12** including handle means mounted above and integral with the upper end for grasping and carrying the unitary device with one hand.

14. A drainage device as claimed in claim **9** wherein the said device includes only three external openings for normal operation, one external opening being the said first chamber inlet, one external opening being a connection for expelling gas from said second chamber, the other external opening being an opening from said third chamber to atmosphere.

15. A drainage device as claimed in claim **9** including a means for removing from the first chamber a sample of the liquid trapped therein without interrupting the normal operation of the device.

16. A drainage device as claimed in claim **15** wherein the said means for removing includes an openable, but normally closed, aperture in the wall of the first chamber near the end thereof remote from the said inlet.

17. A drainage device as claimed in claim **9** wherein the interior of said second chamber is generally U-shaped and comprises first and second columns in fluid communication with each other through a lower passageway at the lower portion of the second chamber, the top of the first column forming the said first opening and the top of the second column forming the said second opening, and the lower portion of the U adapted to receive a quantity of liquid to form an underwater seal in said second chamber, whereby when liquid is placed in the said second chamber to form a liquid seal, the second column of the second chamber is connected to a vacuum source, and the inlet of the first chamber is connected to a cavity to be drained, the liquids from said cavity will collect in the first chamber and the gases from the cavity will bubble through the liquid seal and out the second opening of the second chamber to the vacuum source.

18. A drainage device as claimed in claim **17** including an integral connecting portion located between and integrally connecting together the said first and second columns of the second chamber, the said lower passageway being formed in the last said integral connecting portion.

19. A drainage device as claimed in claim **17** wherein the general cross-sectional area of the second column is much greater than the cross-sectional area of the first column.

20. A drainage device for draining fluids from a cavity comprising: at least a first chamber and a second chamber, said first chamber including an inlet for receiving gases and liquid fluid from the cavity to be drained, and an outlet through which gases may be passed to the second chamber; said second chamber including a first opening for receiving gases from the first chamber, a second opening adapted to be connected to a vacuum source for expelling gases to said second chamber, said second chamber including a means for permitting the establishment of a liquid seal between the said first and second openings; the chambers being formed together as a one-piece unitary unit including an integral connecting portion located between and integrally connecting together the said first and second chambers, the last said integral connecting portion having a passageway passing therethrough connecting the said first chamber outlet to the said first opening of the said second chamber, said device further including a third chamber forming a manometer means adapted to receive a liquid for measuring the pressure in the second chamber, said third chamber being formed together with said first and second chambers as a one-piece unitary unit and including an integral connecting portion located between and integrally connecting together the said second and third chambers, the last said integral connecting portion having a passageway located therein and passing therethrough connecting the interior of the third chamber to the second opening of the second chamber, whereby when liquid is placed in the third chamber and the second chamber is connected to a vacuum source, the level of the liquid in the third chamber will indicate the difference between the pressure of the surrounding atmosphere and the pressure in the second chamber.

21. A drainage device as claimed in claim **20** wherein the interior of each one of said second and third chambers is generally U-shaped and comprises a first column and a second column in fluid communication with each other through a lower passageway in the lower portion of the respective chamber, the top of the first column of the second chamber forming the said first opening and the top of the second column of the third chamber open to atmosphere, and the tops of the second column of the second chamber and the first column of the third chamber being in fluid communication with each other to form the said passageway between the second and third chambers, and the lower portions of each of the U-shaped chambers adapted to receive a quantity of liquid, whereby when liquid is placed in the said second chamber to form a liquid seal, the second column of the second chamber is connected to a cavity to be drained, the liquids from said cavity will collect in the first chamber and the gases from the cavity will bubble through the liquid seal and out the second opening of the second chamber to the vacuum source.

22. A drainage device as claimed in claim **21** including an integral connecting portion located between and integrally connecting together the said first and second columns of the second chamber, the said lower passageway of the second chamber being formed in the said second integral connecting portions, and including another integral connecting portion located between and integrally connecting together the first and second columns of the third chamber, the said lower portion of the third chamber being formed in the last said integral connecting portion.

23. A drainage device as claimed in claim **22** wherein the cross-sectional area of the second column of the second chamber is much greater than the cross-sectional area of the first column of the second chamber and wherein the cross-sectional area of the first column of the third chamber is much greater than the cross-sectional area of the second column of the third chamber.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,363,626 January 16, 1968

Robert E. Bidwell et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 9, line 29, "as" should read -- and --. Column 10, line 24, "an" should read -- and --.

Signed and sealed this 25th day of November 1969.

'.)

ietcher, Jr.

, Officer

WILLIAM E. SCHUYLER, JR.

Commissioner of Patents

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,363,626 January 16, 1968

Robert E. Bidwell et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 11, line 15, "to" should read -- from --. Column 12, line 13, after "to", first occurrence, insert -- a vacuum source, and the inlet of the first chamber is connected to --; line 23, "portions" should read -- portion --.

Signed and sealed this 3rd day of February 1970.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents