Suction drainage apparatus for use in conjunction with vacuum sources of the type that may fail in either an "open" or a "closed" state. The system includes a trap chamber having an inlet adapted to be connected to a catheter for receipt in a body cavity and an outlet connected to a pressure regulation device which, in turn, is connected to the vacuum source. To preclude pressure buildup within the body cavity of the patient in the event of vacuum failure in the "closed" state, a pressure release path from the trap chamber is provided. To prevent backflow of ambient air into the body cavity of the patient in the event the vacuum source fails in an "open" state, a backflow precluding device in the vacuum flow path is provided.

16 Claims, 5 Drawing Figures
SUCTION DRAINAGE APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to suction drainage apparatus of the type used to drain gases and body fluids from a body cavity as, for example, the pleural cavity.

Injuries to the lungs and/or various surgical procedures will often result in the accumulation of air and/or fluid between the lung and the chest wall, in the pleural space, which will interfere with respiratory mechanics. Such interference may be fatal and often invites other complications. Thus, in such instances, the need for chest drainage has long been recognized and practiced by the medical profession.

Initial chest drainage techniques employed drainage apparatus comprised of a single-seal bottle and a chest drainage catheter. The catheter was connected to a glass tube which led through a stopper in the bottle to a point beneath the surface of water in the bottom of the bottle. A second opening in the bottle stopper permitted escape to the atmosphere of air evacuated from the chest cavity during the respiratory process. The water in the bottle served to preclude backflow of ambient air into the chest cavity of the patient. The principal drawback of the single-bottle drainage system was that the same could not be used for evacuation of body fluids from the chest cavity. If so used, the ultimate result would be a fluid level rise in the bottle which, correspondingly, increased the depth to which the glass tube was submerged, thereby increasing the head of back pressure which resulted in a progressive elevation in resistance to drainage.

Accordingly, the prior art interposed a trap bottle in the system between the patient's chest cavity and the seal bottle creating a "two-bottle" system. This system operated satisfactorily so long as there was no need to operate the same by forces greater than that of gravity and the patient's respiratory mechanics.

Thereafter, the medical profession determined that in many instances, evacuation of air and fluid from the chest cavity is enhanced and could be effected safely by the addition of negative pressure from an external source with the result that the "three-bottle" suction drainage system evolved. In one form or another, the three-bottle system is almost universally employed today where suction is required, is desirable, and/or is available.

In all forms, the three-bottle system consists of a trap bottle, a seal bottle and a pressure-regulating or suction control bottle. The suction control bottle can be linked to the seal bottle or to the trap bottle with the result that two schools of practice evolved. Each arrangement has its respective advantages, and, under certain operating conditions, hazards.

The most common arrangement of the three-bottle system may be termed a "series" arrangement wherein the pressure-regulating bottle is linked to the seal bottle, which, in turn, is linked to the trap bottle. This arrangement may also be practiced with but two chambers by appropriately locating the sealing elements and pressure-regulating elements in a single chamber. The advantage of a series system is that the seal bottle acts as a backflow-preventing valve when the pressure-regulating bottle is not connected to a vacuum source, as, for example, during transport of a patient from the operating room to the recovery room or when a vacuum source fails in an "open" state. An additional advantage of the series system is that an air leak from the lung will be displayed by air bubbling through the seal bottle, and its magnitude and variation can be visually assessed.

The hazard of the arrangement emerges when the suction port of the pressure-regulating bottle becomes obstructed (as when a vacuum source fails in a "closed" state) for then the system becomes closed and lethal intrapleural pressures may be generated. When such occurs, the only possible escape for the patient hinges on his ability to withstand the pressures necessary to drive the water in the pressure-regulating bottle through the conventional submerged tube therein and out of the bottle.

An alternate commonly used system to the series arrangement of the bottles may be termed the "in parallel" system, wherein both the pressure-regulating bottle and the seal bottle are separately connected to the trap bottle. The advantage of this system is that the seal bottle functions as an escape valve even when the suction port of the pressure-regulating bottle is obstructed. The disadvantage is that when the system is not connected to suction, as in the transport of the patient or when a vacuum source fails in an "open" state, a connection between the trap bottle and pressure-regulating bottle must be occluded to prevent ambient air from backflowing through the open suction port to the patient's chest cavity causing respiratory embarrassment due to collapse of the lung. Moreover, with this system, the seal does not provide an indicator of air leakage from the lung.

Thus, there is a need for a suction drainage apparatus that not only precludes possible lethal pressure buildup from an air leak from the lung, but prevents the possibility of backflow of ambient air into the patient's pleural cavity as well, and provides suitable visual indications of air leaks from the lung.

SUMMARY OF THE INVENTION

It is the principal object of the invention to provide a new and improved suction drainage apparatus. More specifically, it is an object of the invention to provide a suction drainage apparatus that prevents lethal pressure buildup in a patient's chest cavity from a pulmonary air leak and precludes collapse of the lung from backflow of ambient air through the drainage system, and which further can provide visual indications of air leakage from the lung.

The exemplary embodiment of the invention achieves the foregoing objects by means of a construction employing four chambers. A first one of the chambers serves as a trap chamber for collection of drainage and has an inlet connected to a catheter which is located in the patient's body cavity to be drained. A second chamber has an inlet which is submerged below liquid in said chamber and is connected to the trap chamber. Said second chamber also has an outlet connected to atmosphere. A third chamber also includes an inlet which is submerged below liquid and is connected to the trap chamber. The third chamber has an outlet which is connected to an inlet of the fourth chamber above a desired liquid level therein. An outlet is provided in the fourth chamber for connection to a source of vacuum. A second inlet in the fourth chamber leads from the atmosphere to a variable depth below the level of the liquid in the fourth chamber.
As mentioned previously, the second chamber provides a pressure-release path to dissipate pressures as when the outlet of the fourth chamber is closed while the third chamber serves to preclude backflow of ambient air into the patient's chest when the outlet of the fourth chamber is open.

It is contemplated that the chambers may be defined by separate bottles or, preferably, in a single, integral disposable unit.

The invention further contemplates the provision of a selectively operable liquid communication path between the second and third chambers which may be open when liquid is introduced into the same so that the user of the device need not fill both chambers separately.

As will be seen, the invention does away with the disadvantages of prior systems in that there is no need to concern oneself with the opening or closing of ports during patient transportation nor need there be concern for vacuum source failure which could result in either a closed-system condition or an open-system condition.

Other objects and advantages will become apparent from the following specification taken in conjunction with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of the one-bottle system of the prior art;

FIG. 2 is a schematic illustration of the two-bottle system of the prior art;

FIG. 3 is a schematic illustration of the series three-bottle system of the prior art;

FIG. 4 is a schematic illustration of the parallel three-bottle system of the prior art; and

FIG. 5 is a schematic illustration of a suction drainage system made according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

An early form of drainage apparatus for body cavities is illustrated in FIG. 1 and is seen to include a single container 10 having a stopper 12 and containing a liquid 14 such as water. A tube 16 extends through the stopper 12 to vent the space above the liquid level to the atmosphere while a second tube 18 extends through the stopper 12 to a point just below the liquid level. The upper end of the tube 18 is connected via a conduit 20 to a catheter located in a body cavity as, for example, the pleural cavity. This system may be used successfully to vent air from the pleural cavity and operates as a result of respiratory mechanics of the patient. Air existing in the pleural cavity, between the lining of the chest and the lung, upon exhalation by the patient, is compressed and forced through the conduit 20, the tube 18, the liquid 14, the container 10 and out the vent 16 to atmosphere. The liquid 14 covering the lower end of the tube 18 serves as a seal to preclude backflow of ambient air into the pleural cavity when the patient inhales.

The single-bottle system is not suitable for drainage when both air and body fluids must be drained from the cavity. More particularly, if body fluids are passed into the conduit 20, gradually, the level of the liquid 14 within the container will build up. As a result, there will be a back pressure-head generated corresponding to the height of the liquid level above the lower end of the tube 18. The resistance of the pressure-head to the escape of air from the pleural cavity can become sufficiently great as to seriously interfere with the patient's breathing mechanics.

In order to accommodate both body fluid and air drainage, the prior art resorted to the configuration illustrated in FIG. 2. The same includes a bottle 10 which is identical to the bottle 10 illustrated in FIG. 1 and will hereinafter be referred to as a "seal bottle" by reason of the fact that the same serves to prevent backflow. In addition, the system illustrated in FIG. 2 includes a second container 32 to serve as a trap for body fluids 34. The trap container 32 includes a stopper 36 through which tubes 38 and 40 extend to terminate well above the contemplated level of the body fluids 34 within the container 32. The tube 40 is connected in a conduit 42 to the long tube 18 which has its one end submerged below the level of the liquid 14 in the seal bottle 10 while the tube 38 is connected via a conduit 44 to a catheter in the pleural cavity of the patient. The tube 16 vents the seal bottle to atmosphere. As a result, when the "two-bottle system" illustrated in FIG. 2 is employed, drained body fluids 34 are isolated from the seal bottle 10 so that they can be drained without any accompanying back pressure buildup that could be detrimental to the patient.

It is self-evident that the function of the foregoing two-bottle system is dependent upon gravity and the forces of the patient's respiratory mechanics.

The next step in the evolution of a chest drainage apparatus was to add an external source of controlled negative pressure to enhance drainage. This was achieved by the development of three-bottle drainage systems, and, more particularly, two types of three-bottle systems, hereinafter termed the "in series" system and the "in parallel" system.

FIG. 3 illustrates the three-bottle "in series" system which is the most common in use today. The same consists of a trap bottle 32 in all respects identical to that shown in FIG. 1; a seal bottle 10 identical to that illustrated in FIG. 1 and a pressure-regulating bottle 50. The pressure-regulating bottle 50 includes a stopper 52 through which tubes 54, 56 and 58 extend. The pressure-regulating bottle 50 is further adapted to receive a liquid 60 such as water. The tube 54 is connected via a conduit 62 to the vent tube 16 of the seal bottle 10 while a conduit 64 connects the tube 58 to a source of vacuum such as a pump 66. Both of the tubes 54 and 58 terminate well above the level of the liquid 60 within the pressure regulating bottle 50.

The tube 56 is in communication with the atmosphere externally of the bottle 50 and has its lower end located below the level of the liquid 60 within the bottle 50 to some predetermined distance. The same operates as follows. The height of the level of the liquid 60 above the lower end of the tube 56 determines essentially the negative pressure differential from atmospheric pressure to be ultimately applied to the pleural cavity for draining the same. Should the pump 66 attempt to draw a greater vacuum than that needed or desired for drainage, atmospheric air will flow in through the tube 56 into the bottle 50 to maintain the negative pressure at the desired level.

This system works well for its intended purpose as long as there is no failure of the pump 66. As is well known, vacuum pumps typically alternate between conditions wherein their vacuum port is in communica-
tion with the atmosphere or is cut off from communication with the atmosphere. Hereinafter, such conditions will be termed "open" and "closed" states, respectively. Should the pump 66 fail in an open state, the system illustrated in FIG. 3 is perfectly adequate in that it may then function much the same way as the two-bottle system illustrated in FIG. 2 with a proper seal against backflow being maintained by the seal bottle 10. However, should the pump 66 fail in the closed state, as air and body fluids are forced into the system at the trap bottle 32, the pressure-regulating valve will ultimately be conveyed to the pressure-regulating bottle 50 from which it cannot escape except through the tube 56. As mentioned previously, the liquid level within the bottle 50 to accomplish the pressure-regulating function, must be well above the lower end of the tube 56 so that there can be no relief of the pressure buildup except by forcing the liquid 60 up the entire height of the column defined by the tube 56 until such time as the liquid level has been decreased by evacuation to the lower end of the tube 56. Thus, the three-bottle system illustrated in FIG. 3 can be extremely dangerous should the pump 66 fail in the closed condition. It is also obvious in view of the foregoing that this hazard is not always dependent on total pump failure. For, the same circumstance will occur if the volume of air leaked from the lung exceeds the capacity of the suction source.

While not shown herein, there is a variation of the series three-bottle system illustrated in FIG. 3 which only requires two separate vessels. According to this variation, the pressure-regulating bottle 50 also serves as the seal bottle 10 and the arrangement is constructed by substituting the tube 18 of the seal bottle 10 for the tube 54 of the pressure-regulating bottle 50. Of course, in so doing, it is necessary that the lower end of the tube 18 be just below the liquid level of the liquid 60 in the bottle 50. It is to be understood that reference herein to a three-bottle system is expressly intended to include this variation thereof, for the principle is the same.

Another type of three-bottle system, the "in parallel" system, is illustrated in FIG. 4 and is seen to include a trap bottle 32 in all respects identical to that illustrated in FIG. 2 with the exception that its stopper is provided with an additional outlet tube 70 well above the contemplated level of body fluids 34 therein. The seal bottle 10 has a stopper 12 through which tube 18 extends to a point below the surface level of the liquid 14 therein. The tube 18 is connected into trap bottle 32 by means of tubes 42 and 40. Seal bottle 10 is vented to the atmosphere by means of tube 16 extending through the stopper 12. Pressure-regulating bottle 50 has a stopper 52 with tubes 54, 56, and 58 passing therethrough. Tube 56 extends from atmosphere to a point below the surface level of liquid 60 in the bottle. Vacuum pump 66 is connected into bottle 50 by means of tube 64 connecting to tube 58 which tube terminates in the bottle above the liquid level. Tube 54 is connected by tube 72 to the outlet tube 70 in the trap bottle 32.

Malfunction of the in parallel three-bottle system may occur if failure of the pump 66 occurs. When the pump 66 fails in the closed mode, though external suction is lost, pressure buildup is prevented through the seal bottle 10 which is vented by tube 16 to atmosphere. However, should the pump 66 fail in the open state, it will be appreciated that a path of direct communication from the atmosphere to the pleural cavity of the patient exists which will result in backflow of ambient air causing collapse of the lung.

Thus, the suction drainage systems heretofore known are subject to disadvantages under certain operating circumstances and certain conditions of suction system failure.

The invention overcomes all of the foregoing disadvantages. An exemplary embodiment of a suction drainage apparatus made according to the invention is illustrated in FIG. 5. And while the same is illustrated as being comprised of a plurality of separate containers interconnected by conduits or tubing, it is to be understood that the following description is but an exemplification of the principles and it is contemplated that the invention may be implemented by the use of separate vessels and connectors as illustrated or by a unitized construction of a disposable nature according to techniques well known in the art.

The exemplary embodiment of the invention includes a trap bottle 32 having a stopper 36 through which tubes 38, 70 and 40 extend. All of the tubes 38, 70, 40 have their lower ends well above any contemplated level of body fluid drainage 34 within the trap bottle 32.

The tube 38 is connected via a conduit 44 to any suitable form of catheter 94 which is positioned in a body cavity for drainage while the tube 40 is connected via a conduit 42 to a tube 18 extending through the stopper 12 of a first seal bottle 10. The tube 18 has its lower end just below the level of a liquid 14, such as water, therein. The first seal bottle 10 is closed by a stopper 12 having a short tube 16 extending therethrough to establish communication between the atmosphere and the interior of the bottle 10 above the liquid 14. The tube 70 in the trap bottle 32 passes through stopper 36 and is connected into a second seal bottle 102 via conduit 72 and tube 98. Tube 98 in the second seal bottle 102 is similar to the tube 18 in the first seal bottle 10. Again, the lower end of the tube 98 is located just below the level of a liquid 104 within the seal bottle 102.

Returning to the second seal bottle 102, the same also includes a short tube 118 similar to the tube 16 extending through its stopper 100. However, the tube 118 is connected via a conduit 120 to a tube 54 extending through stopper 52 in the pressure-regulating bottle 50 which may be identical to the pressure-regulating bottles 50 of FIGS. 3 and 5. Tube 56 extends from atmosphere through stopper 52 to a point below the liquid level in bottle 60. A vacuum pump 66 is also connected to the pressure-regulating bottle 50 by means of a conduit 64 and tube 58 as illustrated.

In normal operation, the tube 18 in the first seal bottle 10 serves as a manometer reflecting the negative pressure in the drainage system. However, should the pump 66 fail in a closed state, it will be recognized that pressure release will obtain via the first seal bottle 10 without a detrimental buildup of pressure by reason of the fact that the tube 16 establishes communication of the interior of the bottle 10 to the atmosphere while the lower end of the tube 18, in communication with the trap bottle 32 is just below the level of liquid 14 in bottle 10.

On the other hand, should the pump 66 fail in the "open" state, it will be appreciated that the location of
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the lower end of the tube 98 of the second seal bottle 102 just below the level of the liquid 104 therein will preclude any backflow of air into the pleural cavity of the patient. Thus, the system is adaptable for use with suction and eliminates any possibility of harm to the patient due to pump failure. Moreover, it will be appreciated that the same can be employed without suction in the same way as the two-bottle system illustrated in FIG. 2. And, as with the “in series” three-bottle system, air leaks in the lungs may be visually assessed by observation of the bubbling in the second seal bottle 102.

The invention also contemplates the provision of a liquid flow path between the first and second seal bottles 10 and 102, respectively. As illustrated, a conduit 128 extends therebetween and includes a manually operable valve 130. The purpose of this construction is simplification of filling of the seal bottles 10 and 102 with a liquid such as water, particularly when the invention is embodied in a unitized structure. When such is the case, only one of the bottles need be filled with the valve 130 open to result in the other of the bottles being filled to the same level. After filling, the valve 130 may be closed, the entire operation not requiring separate filling of each bottle.

It will also be appreciated that the invention does not require four distinct chambers to practice. For example, the structure of the seal bottle 102 may be incorporated in the pressure-regulating bottle 50 as described above in conjunction with the description of the variation of the “in series” three-bottle system of FIG. 3.

Finally, it should be recognized that vacuum source failure referred to herein is not limited to failure of a vacuum pump itself. Source failure of the “open” type can occur due to large-scale leaks in a vacuum line while “closed” state failure may result from the closing of a valve in a vacuum line.

1 claim:

1. Suction drainage apparatus comprising: first means defining a trap chamber having an inlet adapted to be connected to a catheter to be received in a body cavity to drain fluids therefrom, and an outlet, said chamber being adapted to serve as a trap for body fluids drained from the body cavity; second means defining at least one additional chamber to receive liquid and having a first inlet connected to said first chamber outlet, a second inlet, and an outlet adapted to be connected to a vacuum source; said additional chamber first inlet extending thereinto a distance sufficient to be just immersed in a liquid received in said additional chamber; second inlet establishing communication from the interior of said additional chamber to the exterior thereof and extending thereinto to be immersed in liquid received in said additional chamber a distance sufficient to establish a desired negative pressure; and means in said apparatus for preventing reverse flow through said first chamber inlet while precluding pressure buildup in said first chamber.

2. The suction drainage system of claim 1 wherein said additional chamber is comprised of two components each adapted to receive a liquid, a first of said compartments including said first inlet and the second of said compartments including said second inlet and said outlet, and means establishing a path of gas flow between said compartments.

3. The suction drainage apparatus of claim 2 wherein said preventing means comprises a third chamber adapted to receive a liquid, said third chamber includ-
13. The suction drainage apparatus of claim 12 further including selectively operable valve means in said liquid flow path.

14. The suction drainage apparatus of claim 10 further including means establishing a liquid flow path between said seal chambers.

15. The suction drainage apparatus of claim 14 further including selectively operable valve means in said liquid flow path.

16. The suction drainage apparatus of claim 10 further including a catheter connected to said trap chamber inlet and a vacuum pump connected to said pressure regulating chamber outlet.

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