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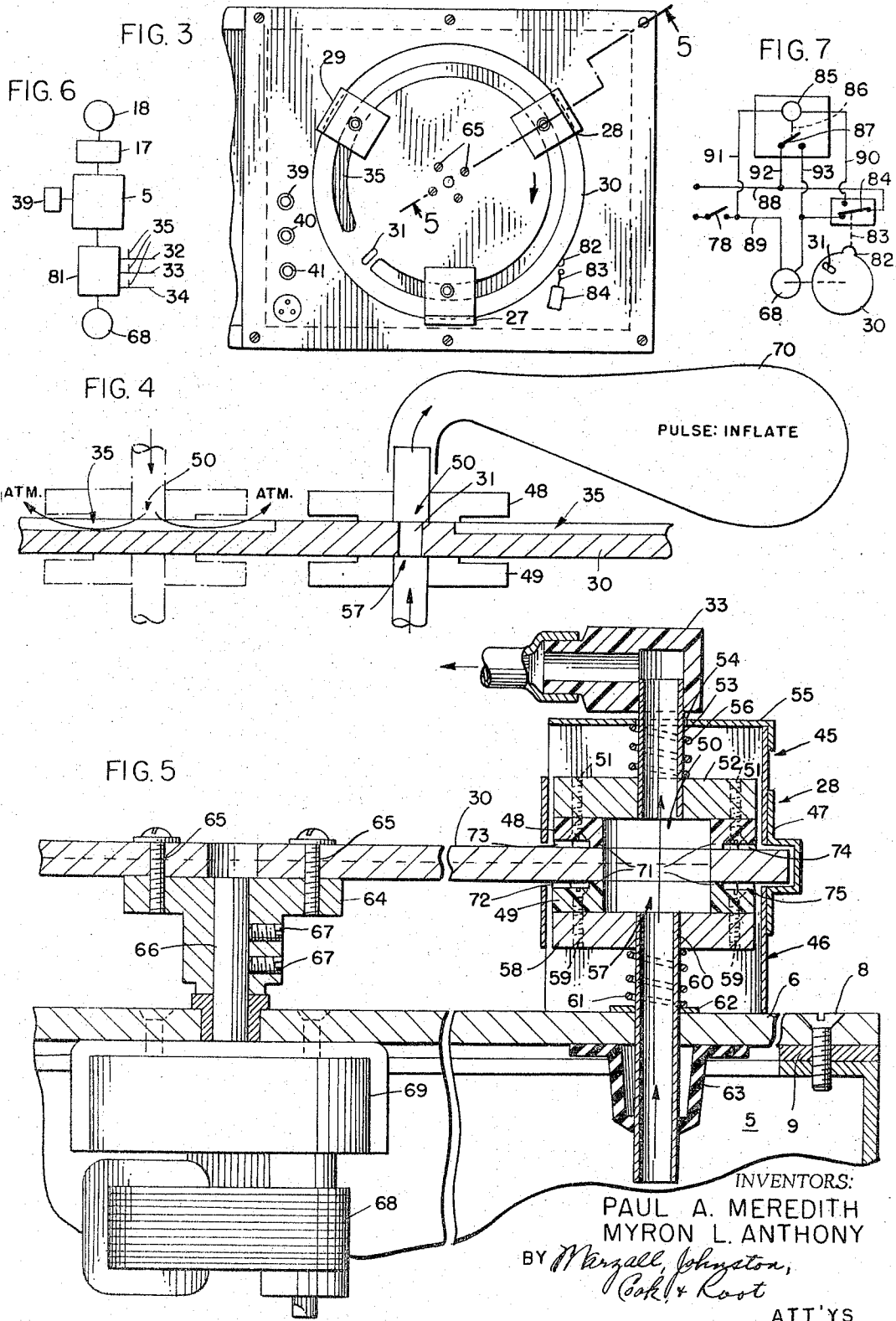
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3,307,533

APPARATUS FOR GENERATING AND CONTROLLING PRESSURE

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3,307,533 APPARATUS FOR GENERATING AND CONTROLLING PRESSURE

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This invention relates to an apparatus for generating and controlling pressure, and more particularly to an apparatus for generating and controlling pressure suitable for application to a body or to portions of the body in rapid pulses followed by a relatively longer period during which no pressure is applied. The invention is especially concerned with an apparatus to be employed in the prevention of phlebothrombosis.

A primary cause of phlebothrombosis is venous stasis, typically resulting from inactivity, as with bed-ridden patients, or chronic circulatory ailments. Phlebothrombosis is a particularly dangerous condition in that the phlebotrombi often break up into emboli which lodge in the lung, as they move toward the central portion of the circulatory system. It is desirable to prevent phlebothrombosis because the consequent risk of pulmonary embolism is substantially reduced.

One of the objects of the invention is to provide a new and improved apparatus which can be used to generate and control pressure in rapid pulses followed by a relatively longer period during which no pressure is applied and which can be employed in conjunction with inflatable bladders that are applied to the extremities and abdomen of the human body, whereby pressure pulses generated in said apparatus and transmitted to said bladders are effectively used in preventing phlebothrombosis and other infirmities of the circulator system.

Another object of the invention is to provide an apparatus of the type described which will generate controlled pressure pulses that will not interfere with normal body circulation.

Still a further object of the invention is to provide a new and improved apparatus of the type described which is compact and simple to operate.

Other objects and advantages of the invention will appear from the following description in conjunction with the accompanying drawings in which:

FIGURE 1 is a perspective view of the exterior of an apparatus embodying the principles of the invention;

FIGURE 2 is an exploded view showing in perspective various components of the apparatus illustrated in FIGURE 1;

FIGURE 3 is a plan view of a portion of the apparatus shown in FIGURE 2 taken along the line 3—3 of FIGURE 2;

FIGURE 4 is a partial sectional view, somewhat diagrammatic, illustrating certain features of the operation of the apparatus; and

FIGURE 5 is a partial vertical sectional view taken along the line 5—5 of FIGURE 3.

FIGURE 6 is a diagrammatic view of the components of the apparatus.

FIGURE 7 is a diagrammatic view including a timer circuit illustrating a preferred embodiment of the invention.

The invention provides an apparatus for generating pressure pulses suitable for application to a body comprising:

(a) A gas plenum,

(b) A source to supply gas under pressure to said plenum,

(c) Means for controlling said pressure in said plenum,

(d) A valve having an inlet connected to said plenum and an outlet adapted to be connected to one or more inflatable bladders to supply a pressure pulse to said bladder or bladders, and

(e) Means to promptly return said outlet to atmospheric pressure following said pressure pulse.

The plenum is a gas-tight chamber which may also be described as an "accumulator plenum." The source of supply of gas under pressure is preferably a pump. The means to control pressure is preferably a valve connected to the plenum chamber. The valve through which pressure pulses are supplied and which can have one or more outlets preferably comprises a moving ported member with one or more stationary ported members. Both the pump and the pressure pulse valve are preferably driven by one or more electric motors. Usually, it is preferable to have a separate motor for each because the power requirements are entirely different.

In the operation of the apparatus it is also preferable to provide a timing control device to cause the valve to dwell a controllable length of time after a given pressure pulse or sequence of pressure pulses. This can be accomplished by using an electrical delay timer which is preferably responsive to movement of one of the valve parts.

The purpose of the plenum is to accumulate and store gas under pressure between outlet pulses. The size of the plenum is determined in part by the pump output capacity. The greater capacity of the pump the smaller the plenum can be. If the pump capacity is great enough the plenum can be entirely eliminated or simply replaced by the output manifold of the pump. A second function of the plenum is to provide an air sump to supply a finite volume of gas to one or more inflatable bladders without a substantial drop in pressure, i.e., the plenum volume is large as compared to the volume of the inflatable bladder with a modest average pump output. However, if the pump capacity is great enough this function is not required. Usually the plenum capacity will be at least ten times the bladder capacity.

The pressure pulse valve is generally adapted to supply air to one or more bladders, usually two or more bladders sequentially in relatively quick succession, and then to dwell for a generally longer period of time which is controlled by a timer before a single pressure pulse or sequence of pressure pulses is repeated.

Referring to FIGURE 1 it will be seen that the apparatus shown comprises a lower housing generally indicated at 1, a front portion generally indicated at 2, and a cover 3 provided with a handhold 4 for ease of removal.

The lower housing 1 contains a chamber or plenum 5 (see FIGURE 5) which is normally gastight and is enclosed in part by the bottom, sides and one end of the lower housing 1, in part by a cover 6, and in part by a partition 7. The cover 6 is secured by means of screws 8 or other suitable fastening means and a gasket 9 is provided to assist in making the chamber 5 gastight.

Two upright members 10 and 11 are provided to receive the cover 3. In one end of the housing 1 a chamber 12 is provided which contains a number of ventilation holes 13 in the side of the housing and additional ventilation holes 14 in the bottom of the housing. This chamber also contains an electrical outlet 15.

Chamber 12 is adapted to receive a compressor unit 16 consisting of a pump 17, a motor 18, a muffler 19, a base 20, an exhaust pipe 21 and an outlet pipe 22. The base 20 of the unit 16 is mounted by means of

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screws or any other suitable manner on a bed plate 23 supported by four shock absorbers or bumpers 24 which in turn are supported by the floor or bottom of housing 1. The compressor unit 16 is also provided with a silencer cover 25 in order to reduce the noise. For similar reasons the inside of chamber 12 is lined with a sound insulating material 26.

The cover 6 of chamber 5 has mounted thereon three upright housing members 27, 28 and 29 each having an upper portion and a lower portion secured together at one side, the lower portion and the upper portion being spaced to receive a rotatable disk 30. The disk 30 has an opening 31 therein which is elongated radially and each of the members 27, 28 and 29 has a passageway therein connected to an outlet in chamber 5 and another passageway in the upper portion thereof connected to fittings 32, 33 and 34 respectively. As the disk 30 is rotated the opening 31 aligns with the passageway in members 27, 28 and 29 thereby permitting gas pressure in chamber 5 to pass through said passageways to outlets 32, 33 and 34, successively. A groove 35 in the top of disk 30 relieves the pressure in fittings 32, 33 and 34 thereby reducing the pressure to atmospheric when opening 31 is not aligned with one of said passageways. Thus, it is possible to produce rapid pulses of superatmospheric pressure followed by a relatively longer period of atmospheric pressure as the disk 30 is rotated.

The fittings 32, 33 and 34 are connected to tubes 36, 37 and 38, respectively, which in turn are connected by hoses to inflatable bladders, not shown, and the latter are secured to the body of a person, usually to the legs, thighs and abdomen and sometimes to the lower and upper arms in order to apply pressure thereto periodically.

The pressure in the chamber 5 is regulated in part by the capacity of the compressor unit 16 and the amount of air used but is controlled more specifically by a relief valve 39 which communicates with chamber 5. This can be any suitable type of valve such as a ball check valve which is capable of relieving the pressure in chamber 5 at any predetermined desired pressure level. Normally, air is used as a source of pressure and the compressed air generated by compressor unit 16 passes through a hose, not shown, which is connected between compressor outlet 22 and an inlet 40 in the top of chamber 5. An outlet 41 also connects chamber 5 by means of a suitable hose, not shown, to an inlet 42 on pressure gauge 43. The pressure in chamber 5 is registered by dial 44 on the face of pressure gauge 43. It will be observed that the front cover 2 of the housing 1 is in reversed position in FIG. 2. This has been shown in this manner to illustrate the appearance of the bottom of the front cover.

The details of the structure for sealing the passageways during the transmission of air from pressure chamber 5 to an outlet duct are illustrated in FIG. 5. As shown, the member 28 (and corresponding members 27 and 29) each comprises a housing having an upper portion 45 and a lower portion 46 secured together at one side by an intermediate portion 47 which is welded or otherwise fastened to the upper portion 45 and the lower portion 46. A pair of plates 48 and 49 (made from a metal such as brass or a suitable polymer, for example, a polymer of formaldehyde such as Delrin or a polymer of tetrafluoroethylene such as Teflon) are mounted in the upper and lower portion of the housing, respectively, and are adapted to move or slide in a vertical path.

The plate 48 is provided with an opening 50 and is mounted by means of screws 51, 51 on a holder 52. Usually four screws are employed one adjacent each corner of the holder 52. The holder 52 is welded or otherwise secured at its lower end to a tube 53 which is slidably mounted in an opening 54 in the top 55

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of housing 45. A coil spring 56 is disposed around tube 53 and contacts at one end against holder 52 and at the opposite end against the inner side of top 55 thereby normally urging the holder 52 and the plate member 48 associated therewith toward disk 30.

Similarly, plate member 49 has an opening or hole therein 57 and is mounted on a holder 58 by means of screws 59 or other suitable fastening means. The holder 58 is secured to the outer side of one end of a tube 60 which is surrounded by a coil spring 61. The upper end of the coil spring 61 abuts against the lower side of holder 58 and the lower end of coil spring 61 abuts against a washer 62 which is seated on the cover 6 of pressure chamber 5. The lower part of tube 60 which extends into pressure chamber 5 is sealed by means of a grommet or seal 63 made of rubber or other suitable material, thereby rendering the connection of tube 60 with chamber 5 gastight. The spring 61 urges the plate 49 in the direction of member 30.

The disk 30 is mounted for rotation by means of a collar 64 fastened to disk 30 by screws 65 or other suitable fastening means and also fastened to shaft 66 by set screws 67 or other suitable means.

The shaft 66 is driven by motor 68 through a suitable gear reducing train 69 thereby causing disk 30 to rotate.

As shown diagrammatically in FIGURE 4 when disk 30 rotates the opening 31 is aligned with openings 50 and 57 in plates 48 and 49, respectively, so that fluid pressure from chamber 5 is transmitted through the passageways in sealing means 28 (and correspondingly in sealing means 27 and 29) to an inflatable bladder 70 (and to other bladders, not shown, which are connected by hoses to outlets 32 and 34). It will be recognized that in FIGURE 4, the illustration is diagrammatic because the bladder will be positioned in most cases at a considerable distance from the pressure generating apparatus and will be connected to one of the outlet tubes 36, 37 and 38 (FIGURE 2) by means of suitable hoses, not shown. The bladder will also be held in position on the body to be treated by means of non-elastic cuffs or in some other suitable manner.

Referring again to FIGURE 4, as the disk 30 continues to rotate the opening 31 passes beyond openings 50 and 57 so that the opening 50 occupies the dotted line position over the groove 35. Since the groove 35 is open to the atmosphere the opening 50 will also be open to the atmosphere and the pressure in the tube connected to the inflatable bladder 60 (and other bladders in a like manner) will be reduced to atmospheric, thereby causing the bladder to deflate or collapse. As the disk 30 continues to rotate the opening 31 will come in contact successively with the openings in sealing means 29 and 27, thereby producing a succession of relatively short pressure pulses which are transmitted to a plurality of bladders causing these bladders to be successively inflated and deflated. The net result is the production of a pulsating pressure characterized by relatively rapid pulses followed by a relatively longer period in which there is an absence of pressure.

It will be noted that the area 71 around openings 50 and 57 is slightly raised or embossed to reduce friction. The four corners of plates 48 and 49 are also raised, as at 72, 73, 74 and 75 to maintain the plates in a level arrangement with respect to disk 30.

While the elements 27, 28 and 29 have been described as sealing means, it will be recognized that the combination of these elements with disk 30 functions like a series of valves in which the plates 48 and 49 are valve seats and the movement of disk 30 opens and closes each valve successively.

Compressor motor 18 is connected to electrical outlet 15 and motor 68 is connected to electrical outlet 76. Both outlets are connected to an electrical source in any suitable manner. Suitable switches 77 and 78 are provided to turn the compressor motor 18 and the motor 68

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off and on. A compartment 79 having a door 80 is provided for storage of hoses which are connected between tubes 36, 37 and 38 and suitable bladders when the apparatus is ready for use.

FIGURE 6 is a diagrammatic representation of the device in which the pump 17 is operated by motor 18 to supply air to plenum 5 in which the pressure is controlled by valve 39. The plenum is connected to the pressure pulse valve 81 which has pressure pulse outlets 32, 33 and 34 and means 35 to promptly return each outlet to atmospheric pressure following each pressure pulse. The valve 81 is driven by motor 68.

FIGURE 7 illustrates a timer circuit in which the disk 30 is provided with a cam lobe 82 which operates through any suitable connecting mechanism 83 to move switch 84 and thereby actuate a reset timer 85. The latter in turn, after a predetermined time interval, through a suitable connecting means 86 closes switch 87 and restarts motor 68 which had been disconnected by the movement of switch 84.

In operation, electric switch 77 is turned to on-position, thereby starting compressor motor 18 which drives air compressor 17. The compressed air is forced through line 22 and inlet 39 into chamber 5 (see FIGURE 5) where a controlled pressure is maintained by relief valve 40. Hoses, not shown, are connected to the outer ends of tubes 36, 37 and 38. The other ends of these hoses are connected to separate inflatable bladders, not shown, the bladders being mounted on the extremities and abdomen of a person in any suitable manner, usually by pressure cuffs or wraps. The manner in which the inflatable bladders are applied to the body does not form a part of this invention.

The electric switch 78 is then turned to on-position thereby causing motor 68 to rotate disk 30. As disk 30 rotates pressure pulses are produced in outlets 32, 33 and 34 and transmitted successively to the inflatable bladders and to the body of the person to whom the bladders have been secured. In preventing phlebothrombosis, it is desirable to use a minimal superatmospheric pressure of at least 5 millimeters of mercury and not more than 30 millimeters of mercury. The duration of each pressure pulse and the time between each pulse will depend upon the speed of rotation of disk 30 and the size of openings 31, 50 and 57. In a typical operation, the pressure would be about 15-20 mm. of mercury, the duration of each pulse would be about 0.5 second and the disk 30 would rotate one revolution per minute. Thus, there would be a period of about 19.5 seconds between pressure pulses in a complete cycle. The present invention is not specifically concerned with the magnitude, duration or timing of the pressure pulses.

Referring to FIGURE 7, at the end of each complete cycle of the disk 30 the cam lobe 82 actuates a suitable mechanism 83 which causes switch 84 to disconnect the direct circuit through lines 88 and 89 and form a new circuit through lines 90 and 91 to reset timer 85. After a predetermined period of time the timer 85 through a suitable actuating mechanism 86 closes switch 87 thereby establishing a circuit through lines 89, 92 and 93 to motor 68 which causes motor 68 to start and turn disk 30 to provide a sequence of pressure pulses in the manner previously described. When motor 68 is stopped by the actuation of switch 84, switch 87 is automatically reset in any suitable manner. In this way, the movement of the pressure pulse valve can be controlled. For example, the disk 30 can make a complete cycle in one minute and remain unactuated for a period of three minutes.

The apparatus is generally useful for supplying pressure for intermittently emptying venous channels underlying pressure cuffs. These veins then refill with fresh blood following the quick pressure pulsations. Applying these same principles at a predetermined cycling over large areas of the body's surface can assure constant venous return to the heart. The apparatus can be used therefore

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to provide a mechanical substitute for a function normally done by muscle activity. This includes application to normally inactive people, bed-ridden people, post operative recovery patients, persons who are in cramped quarters requiring inactivity on prolonged high altitude flights and zero gravity space flight environments. In some cases, it is desirable to use only a single pressure pulse in which case only a single pressure pulse valve outlet is used. Thus, pressure pulses can be applied at intervals through a single valve outlet connected to an inflatable bladder applied to the lower leg.

The invention is hereby claimed as follows:

1. An apparatus for generating pressure pulses suitable for application to a body comprising

- (a) a gas plenum,
- (b) a source to supply gas under pressure to said plenum,
- (c) means for controlling said pressure in said plenum,
- (d) a valve having an inlet connected to said plenum and an outlet adapted to be connected to an inflatable bladder to supply a relatively short pressure pulse to said bladder, said valve comprising a ported member having an opening therethrough movable in alignment with said inlet and said outlet,
- (e) means to promptly return said outlet to atmospheric pressure following said pressure pulse, comprising a groove in the surface of said ported member which does not extend through said ported member and is movable in alignment with said outlet, and
- (f) means for moving said ported member so that the opening therein is aligned with said inlet and said outlet and thereafter the groove therein is aligned with said outlet.

2. An apparatus as claimed in claim 1 in which there are a plurality of said outlets adapted to be connected to inflatable bladders.

3. An apparatus as claimed in claim 1 in which (b) is an air pump.

4. An apparatus as claimed in claim 1 in which the pressure pulse valve (d) comprises a moving single ported member and a plurality of stationary ported members.

5. An apparatus as claimed in claim 4 in which said moving ported member is a rotating disk having an opening therein.

6. An apparatus as claimed in claim 1 which includes a timing control device to cause the pressure pulse valve to dwell a controllable length of time following each actuation.

7. In an apparatus for generating and controlling pressure suitable for application to a body in rapid pulses followed by a relatively longer period during which atmospheric pressure is applied, the combination of:

- (a) a normally gastight chamber,
- (b) means for supplying gas under superatmospheric pressure to said chamber,
- (c) pressure relief means associated with said chamber for controlling the amount of gas pressure therein,
- (d) a plurality of outlets connected to said chamber,
- (e) a substantially flat member having an opening therethrough, said member being mounted for movement so that said opening successively occupies a position in alignment with said outlets in said chamber, the remainder of the area of said member in the path of said movement over said opening being impermeable to gas on the side where said outlets are disposed,
- (f) sealing means engaging opposite sides of said flat member, said sealing means having openings therein adapted to align with said opening in (e),
- (g) means providing a passageway between an opening on one side of said sealing means and an outlet (d) of said chamber,
- (h) means providing a passageway to the opening on the opposite side of said sealing means,

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(i) outlet means connected to said passageway of (h) for transmission of pressure pulses from (a) through (g) and (h) when said opening in (e) is aligned with the openings in (f),

(j) means comprising a groove in the surface of said flat member on the outlet side for relieving pressure in said outlet means (i) when said opening in (e) is no longer aligned with passageways (g) and (h),

(k) means for moving said flat member so that said opening therein is brought into alignment with said passageways of (g) and (h) and thereafter the groove therein is brought into alignment with the passageway of (h).

8. An apparatus as claimed in claim 7 in which said flat member (e) is a circular disk centrally mounted on a shaft driven by a motor at a substantially constant speed.

9. An apparatus as claimed in claim 7 in which said sealing means (f) comprises a pair of plates, each having an aligned opening therein, said plates being resiliently mounted for engagement with opposite sides of said flat member (e) and for alignment with said opening in said member (e).

10. An apparatus as claimed in claim 7 in which said sealing means (f) comprises a housing having an upper portion and a lower portion secured together at one side and spaced to receive member (e), a pair of plates each mounted for vertical movement in said upper and lower

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portions of said housing, respectively, and each having an opening therein adapted to align with the opening in member (e), a holder for each of said plates, a vertical tube connected to each said holder, a sealing gasket connecting the lower tube to an outlet (d) in said chamber in gas-tight relation, a coiled spring around said lower tube between said gasket and said lower holder normally urging said lower plate upwardly in engagement with the bottom of said member (e), a cover on said upper housing having a hole therein adapted to receive said upper tube in slidable relationship, a coiled spring around said upper tube between said upper holder and said cover normally urging said upper plate downwardly in engagement with the top of said member (e), and an outlet fitting mounted on the top of said upper tube and adapted to limit the downward movement of said upper plate when it is not engaged with the upper surface of said member (e).

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