June 6, 1967 G. FRANCIS 3,323,544

METHOD AND APPARATUS FOR DRAINING LIQUID FROM CONTAINERS

Filed March 24, 1965 3 Sheets-Sheet 1

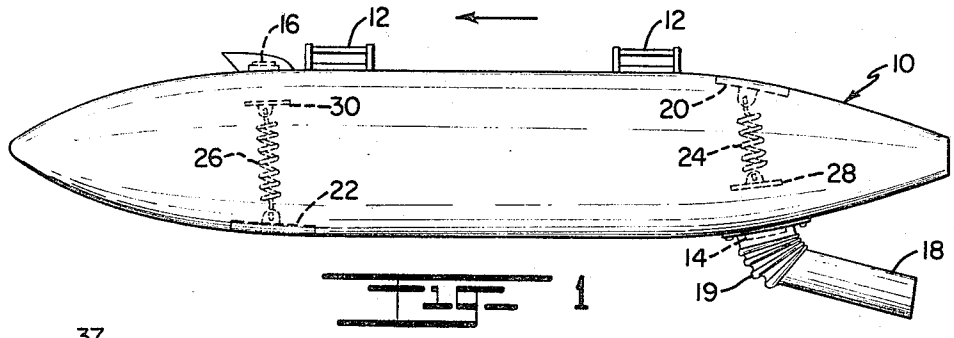



FIG. 1

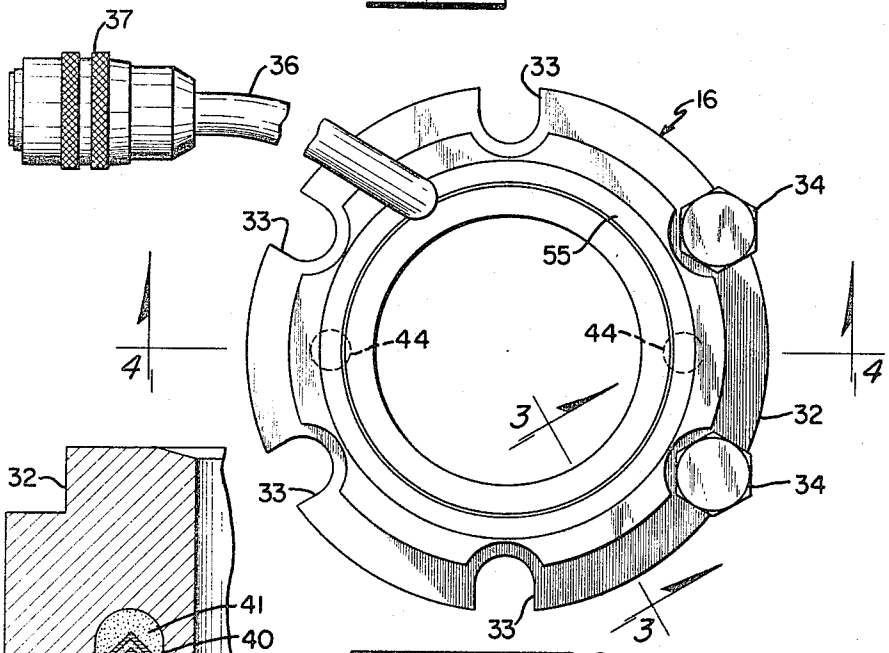



FIG. 2




FIG. 3

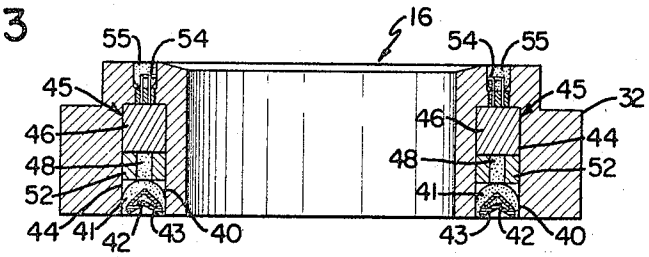



FIG. 4

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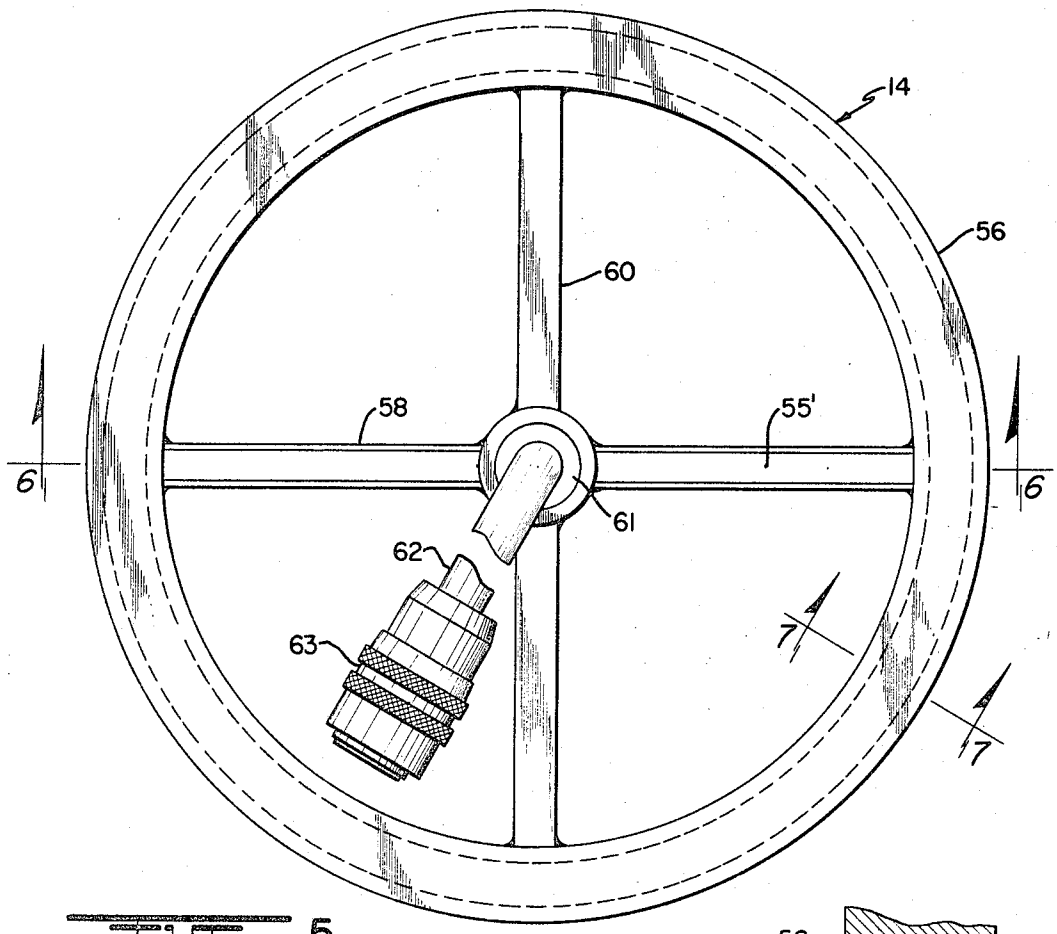



FIG 5

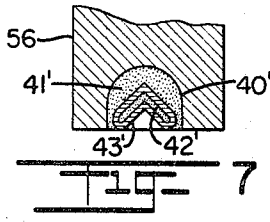



FIG 7




FIG 6

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METHOD AND APPARATUS FOR DRAINING LIQUID FROM CONTAINERS

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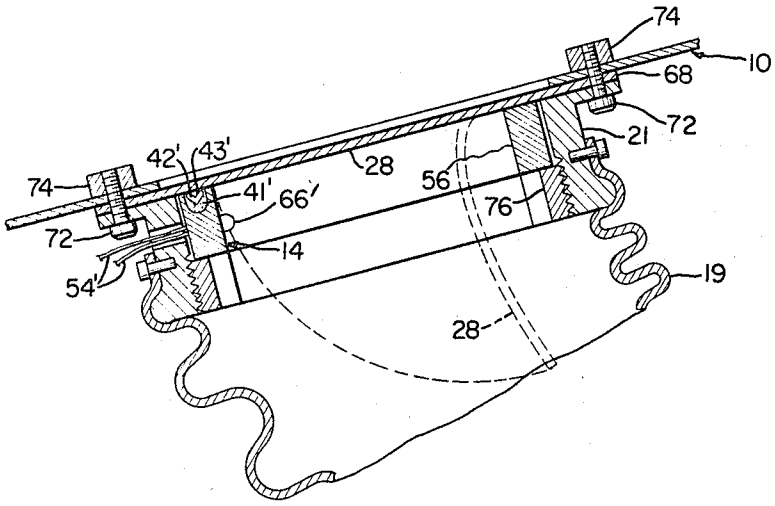



FIG. 8

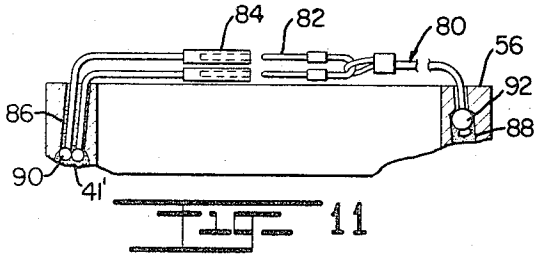



FIG. 11

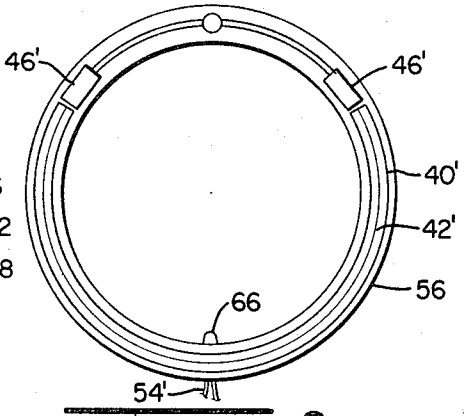



FIG. 9

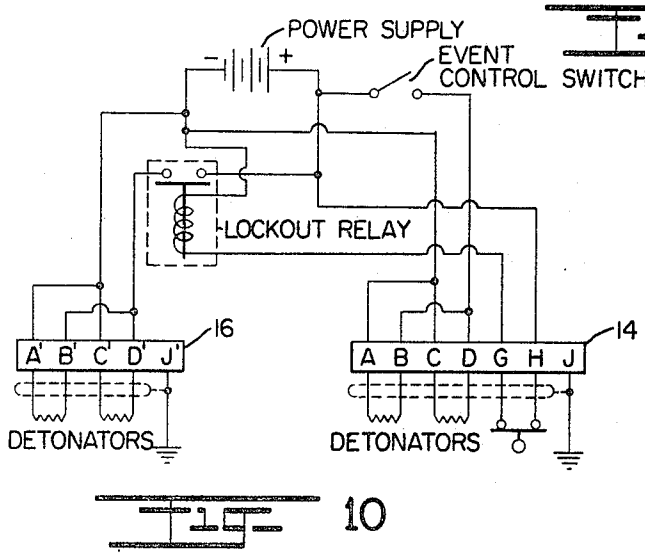



FIG. 10

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United States Patent Office 3,323,544 Patented June 6, 1967



3,323,544

# METHOD AND APPARATUS FOR DRAINING LIQUID FROM CONTAINERS

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13 Claims. (Cl. 137—587)

## ABSTRACT OF THE DISCLOSURE

The invention relates to apparatus for draining fluid tanks, such as, wing tanks for aircraft, by sequentially cutting first a drain hole and second an air breathing hole in the tank by means of circular explosive cutters located at different areas on the tank, and comprises means for insuring that the holes are cut in the proper sequence, such means being an actuating device for the explosive cutter of the air-breathing hole which is operative only upon movement of the cut-out portion for the drain hole.

This invention relates to a method and apparatus for draining liquids from containers, more particularly, it relates to a method and apparatus for sequentially cutting a liquid outlet hole and an inlet hole in a container by means of explosively actuated cutters.

The invention is specifically directed to apparatus for draining liquids from a tank or container carried underneath an aircraft wing; however, it is by no means limited to this application as it can be used for cutting holes in various type containers, flat work, and other material.

Various occasions arise where it is necessary to discharge liquids from tanks carried beneath the wings of aircraft. For example, in the use of aircraft in fighting fires or in crop dusting it may be desirable to release liquid fire retardant material or insecticides from tanks carried under the wings of the aircraft. Certain military applications now require the release of liquids from tanks carried beneath the wings of military aircraft.

The rapid and effective discharge of liquids from a suspended tank requires that an air hole be cut in the tank as well as a liquid outlet hole in order to provide for effective flow of fluid from the outlet hole. It is well known that in order for liquid to flow rapidly from the outlet of a container without "breathing" an air inlet hole must be provided so that air can fill the space occupied by the liquid being discharged from the container. Accordingly, any method and apparatus providing for the effective release or discharge of liquids from a suspended tank must provide for the cutting of both an air inlet hole and a liquid outlet hole in the tank or container.

If the tank from which the liquid is to be discharged is carried on an aircraft, the air inlet hole on the top of the container must be cut after the liquid outlet hole is cut in the bottom of the container. The reason for this is that if the air inlet hole on top is cut first and poisonous or corrosive liquids are being carried in the tank, these liquids will be discharged over the wings and other parts of the aircraft with resultant damage thereto, and the pilot and other personnel in the aircraft may suffer serious injury. Accordingly, it is necessary that the holes be cut sequentially, that is, that the liquid outlet hole in the bottom of the tank be cut before the air inlet hole in the top of the tank is cut so that all of the liquid being discharged from the tank will pass out of the liquid outlet hole in the bottom of the tank.

The apparatus for cutting the holes in the tank must be one which provides instantaneous and reliable cutting of the holes upon actuation of the cutting mechanism by the pilot. It has been found that the most effective means for cutting the holes is the use of an explosive cutting



mechanism. Such mechanisms generate large forces. It is important that the cutter back up mechanism which is positioned on the outside of the tank not be shattered by the force of the explosion which effects cutting of the holes as shattering with consequent production of numerous fragments of metal, plastic and other material will result in serious damage to the aircraft.

Accordingly, it is an object of this invention to provide a method and apparatus for discharging liquids from containers.

It is another object of this invention to provide an apparatus for cutting holes in metallic and other rigid material.

It is another object of this invention to provide apparatus for sequentially cutting holes in containers and other objects.

It is a further object of this invention to provide explosively actuated cutters for cutting holes in containers and other objects which are not subject to fragmentation and shattering by the explosive which performs the cutting operation.

The invention in its broadest sense as applied to cutting holes in a container comprises two explosively actuated cutters adapted to be placed one on the bottom of the tank for cutting the liquid outlet hole and one on the top of the tank for cutting the air inlet hole, in combination with switching means which operates to actuate the cutter for the air inlet hole only after the liquid outlet hole has been cut. The sequential switching means is actuated by movement of the section of the tank cut out to form the liquid outlet hole. The explosive cutter itself forms an essential part of the invention and comprises a heavy metal annulus having an arch shaped, annular groove in its bottom edge facing outwardly with an annular concave explosive charge positioned in and conforming to the groove with its concave surface facing outwardly and having a metal lining on its concave surface, and a detonation train for detonating the explosive charge.

In the preferred modification, a buffer layer of non-explosive material is positioned between the explosive charge and the bottom of the groove in the annulus, the surface of the explosive is in the form of a V and two detonators 180 degrees apart are used for redundancy in detonating the explosive cutting charge.

The invention will now be described in conjunction with the accompanying drawings where like parts are represented by like numerals and in which,

FIG. 1 is a schematic showing of a liquid tank or container provided with explosive cutters on its top and bottom;

FIG. 2 is a top plan view of the explosive cutter used on the top of the tank for cutting an air inlet hole;

FIG. 3 is a vertical cross section of the back-up annulus of the explosive cutter taken on the line 3—3 of FIG. 2;

FIG. 4 is a section taken on the line 4—4 of FIG. 2 looking in the direction of the arrows;

FIG. 5 is a top plan view of the explosive cutter used on the bottom of the tank for cutting the liquid outlet hole;

FIG. 6 is a section taken on the line 6—6 of FIG. 5 looking in the direction of the arrows;

FIG. 7 is a section taken on the line 7—7 of FIG. 5;

FIG. 8 is a cross sectional view of a modification of the explosive cutter of FIGS. 5 and 6 mounted on the bottom of a tank;

FIG. 9 is a bottom view of the modification of FIG. 8;

FIG. 10 is a simplified schematic diagram of the circuitry for actuating the detonation trains of the explosive cutters, and

FIG. 11 is a cross sectional view of the liquid outlet cutter annulus showing a modification of the means for

actuating the circuit for the air inlet cutter by outward movement of the cut out plate for the liquid outlet.

Referring now to FIG. 1, there is shown a tank **10** for suspension from the underneath side of the wing of an aircraft by suspension lugs **12**. The tank is for carrying liquids to be discharged while the aircraft is in flight. The liquids, of course, may be poisonous, corrosive or otherwise deleterious. Lower and upper exposive cutters **14** and **16**, respectively, are schematically shown mounted for cutting liquid outlet and air inlet holes, respectively. A nozzle device **18** is connected by means of a flexible elbow **19** to a mounting adapter **21** which is attached over a portion of the tank which is to be cut out to form the liquid outlet hole. The purpose of the nozzle, of course, is to control the stream of liquid leaving the tank.

One modification of the invention will now be described. Anchoring members **20** and **22** are secured to the internal walls of the tank opposite the area of the openings for the purpose of anchoring springs **24** and **26**, respectively, which are attached to portions **28** and **30**, respectively, of the tank to be cut out to form the liquid outlet opening and the air inlet opening. The purpose of this arrangement is to remove the cut out portions **28** and **30** from the area of the openings to permit free passage of fluid therethrough. It has been found that the cut out portions move outwardly rather than inwardly after being cut out and the springs **24** and **26** are necessary to draw them inside the tank.

Referring to FIG. 2, the upper cutter **16** for cutting the air inlet hole is constructed in the form of an annulus **32** provided with holes **33** and mating screws or bolts **34** for attachment to tank **10**. A conduit **36** and plug **37** are provided for electrical lead wires leading to the detonation train of the cutter **16** as will be more fully explained later. The annulus **32** must be made of heavy metal, such as high strength steel in order to provide a sufficiently heavy backup fo rthe explosive cutting charge to prevent shattering when the explosive charge is detonated.

Referring to FIGS. 3 and 4 it will be seen that the annulus **32** is of solid cross section and is constructed with an annular groove **40** facing outwardly toward the bottom of the annulus. The groove **40** extends entirely around the annulus in this modification. The groove is arch shaped and has no square corners. This shape provides the greatest strength for the surrounding metal and presents no points of weakness to promote shattering, such as corners which would result from a groove of rectangular shape. An annular layer **41** of resin such as epoxy resin, referred to hereinafter as a buffer element or layer, is potted into the bottom of the groove **40**. The buffer layer **41** may be of suitable non-metallic material, such as nylon, Teflon or other suitable plastic. The upper surface of the buffer layer **41** is V-shaped and V-shaped explosive cutting charge **42** inside metal casing **43** is seated in the V of buffer layer **41**. The explosive cutting charge **42** is in the shape of an annulus and is positioned in the groove with its concave surface facing outwardly.

The explosive cutting charge in the preferred modification is V shaped and has over its concave surface an annular metal liner which is the front of casing **43**. As is well known, the effect of the V shaped cavity is to concentrate the force of the explosion and localize its effect. When the V shaped cavity is lined or covered with a layer of metal the explosion acts to transmit jets of molten metal together with jets of gas from the explosion of the charge so that the object to be cut is subjected to jets of both metal and gas. The explosive used may be TNT, Amatol, RDX and similar explosive. The metal used for the metal casing **43** over the explosive charge **42** is preferably lead as it can be readily formed into an annulus.

The cutting charge of V shaped annulus of explosive covered with the metal sheath or casing **43** is made by filling a lead cylinder with explosive, sealing it at both ends and rolling the filled cylinder on a V shaped die progressively until the desired shape is attained and until the required amount of explosive per length is obtained. This is conventional practice.

The buffer element **41** plays an important part in this invention as it insures reliability in the operation of the device and aids materially in controlling the detonation of the explosive cutting charge **42**. It serves to buffer the force of the explosion of the explosive cutting charge and prevent shuttering of the back-up annulus.

Seated in wells **44** of the groove **40**, 180° apart are the detonation trains **45** comprised of detonator **46** of lower order explosive and lead in explosive charge **48** of a higher order explosive. The explosive of the detonator may be lead azide or similar explosive and that of the lead in charge **48** may be PETN, RDX, or other type higher order explosive. The purpose of the detonation train is, of course, to build up a detonation wave to detonate the explosive cutting charge. The lead in explosive charge **48** may be dispensed with if desired and the detonator **46** used alone. The explosive charge **48** is seated in metal sleeve **52**.

Lead wires **54** are potted in the annulus **32** with plastic **55** as shown to conduct an electrical charge to the detonator **46**.

Referring now to FIGS. 5, 6 and 7 there is shown one modification of the lower cutter **14** comprised of heavy steel annulus **56** and crossbars **58** and **60** supporting a switch mechanism **61**, conduit **62** and plug **63**. The conduit **62** carries the electrical wires for the switch and associated circuit to be described later. Crossbar **58** in this modification has a groove on its top which carries electrical connections from conduit **62** to the detonators in the annulus. A single crossbar can be used or, if desired, other means can be used for supporting the switch and conduit **62**. The main purpose of the crossbars **58** and **60** is to stop the cut out portion as it moves outwardly after explosion of the explosive cutter so it can be retracted by the spring **24**.

In FIG. 6 the construction of the annulus **56** of the lower cutter **14** and its associated elements is seen to be similar to that of annulus **32** of the upper cutter **16**. Like numerals with primes are used to indicate like parts. The annulus **56** has an annular groove **40'** in its lower edge passing completely around the annulus. Like the annular groove **40** of the upper cutter **16**, it is V shaped in cross section and it is an important feature of the invention that these grooves are V shaped or in the shape of an arch rather than rectangular in shape. As stated above, the arch shaped cross section of the groove in contrast to a rectangular cross section makes the back-up annulus much stronger and helps to prevent shattering thereof because there are no square corners to constitute points of weakness around the groove. The annular buffer element **41'** of plastic or other non-metallic material is seated in the bottom of the groove **40'** and the V shaped explosive cutting charge **42'** with the metal liner **43'** covering its concave facing surface is seated on the plastic buffer element **41'**. The plastic element **41'** is seated in the groove **40'** by molding. The annular explosive cutting charge **42'** may be made as explained above by first constructing an annular lead sheath of the proper V shaped construction and packing the explosive in the sheath. It can also be constructed by molding the annular explosive charge into the required shape and then encasing it in the lead liner.

Wells **44'** are provided in the annulus 180 degrees apart and they contain the explosive train comprising detonator **46'** and the lead in explosive charge **48'** surrounded by metal sleeve **52'**.

A switch **64** and associated circuitry is supported at the intersection of the crossbars **58** and **60**. As shown in FIG. 10, the operation of the circuit to provide sequential explosion of the explosive cutters is as follows: The circuit is shown in the safe condition with outwardly biased button **66** (FIG. 6) in the inward position. So long as the current flows through the switch of the liquid outlet cutter the lock-out relay will be deactivated to cut off the

firing circuit to the air inlet cutter. When the event control switch is closed to admit current to the detonators of the outlet cutter and actuate the explosive cutter, switch **64** will be actuated by the outward movement of the cut out portion **28** to release switch element **66** cutting off current to the relay and thus permitting current to reach the detonators of the air inlet cutter. When the lower cutter **14** is mounted on the tank wall as shown in FIG. 1 the actuating pin **66** is depressed into its retracted or first position by tank wall portion **68** enclosed by the annulus **56**. This construction and operation insures sequential actuation of detonators **46'** and **46** with the resultant sequential cutting of the lower liquid outlet hole in the bottom of the tank and upper air inlet hole in the top of the tank in that order.

The operation of the explosive cutting mechanism utilizing the lower cutter modification of FIGS. 5 and 6 will now be described. The lower and upper cutters **14** and **16**, respectively, are mounted on tank **10** as shown in FIG. 1 in the proper position. The tank filled with corrosive or other type liquid is mounted underneath the wing of an airplane by means of mounting lugs **12**. With the lower cutter **14** mounted on the tank wall the actuating pin **66** will be depressed inwardly by contact with tank portion **28** to be cut out and thus held in a position representing the safe condition of the circuit. Upon actuation of the event control switch the detonation trains comprised of detonators **46'** and lead in explosives **48'** will be actuated to detonate annular V shaped explosive charges **42'** to cut out portion **28** from the tank and form the liquid outlet hole. Upon the movement of cut out portion **28** outwardly the actuating pin **66** will be released to its outward position thus permitting current to flow to the detonators of the air inlet cutter **16** as explained above with the result that the cutter is actuated to cut the air inlet hole. It is thus seen that the construction and operation of the device provides for sequential cutting of first the bottom liquid outlet hole and second the upper air inlet hole. As explained above, this cutting sequence is necessary so that all of the liquid leaving the tank will pass through the liquid outlet hole and none will escape through the air inlet hole to cause damage to adjacent parts of the airplane wing or to personnel in the aircraft.

The sequential actuation of detonators **46** of the upper cutter **16** is of course effected by the movement of cut out portion **28**. In this illustrative modification, the movement of the cut out portion **28** is outwardly thus permitting actuation pin **66** to move to its outwardly biased position. However, if desired the construction of the switch and actuating pin can be such that the pin moves inwardly to a second position.

A preferred modification of the lower explosive cutter for the fluid outlet opening is shown in FIGURES 8, 9 and 11. FIG. 8 shows the preferred method of mounting the cutter on a door covering the fluid outlet hole so that the hole is cut in the door. The tank can be reused merely by supplying a new door after use. This same method of using a door to cover the outlet hole and cutting a hole in the door is the preferred way of using the previously described modification.

A door **68** and circular adapter **21** are mounted over the lower fluid outlet hole by means of studs **72** and nuts **74**. The adapter is of circular configuration and is provided with threads on its upper internal surface. The explosive cutter **14** is inserted inside the adapted and secured therein by means of circular securing ring **76**. In this construction of the lower explosive cutter **14** the switch may be located in the annulus **56** or at any other convenient location. The actuating pin or button **66'** for the switch protrudes inside the annulus **56** as shown. The actuating pin **66'** is spring biased into the outward position representing safe position of the circuit of FIG. 10. When the button **66'** is pressed inwardly by the cut out portion **28** moving outwardly the detonators **46** of the air inlet cutter are activated as explained above.

Referring to FIG. 9 it will be seen that the groove **40'** in the annulus **56** does not extend all the way around the annulus. In this modification the detonators **46'** are located at the end of the grooves so that the explosive cutting charge **42'** in the groove is end initiated. This construction with the explosive cutting charge not extending through 360° results in the cutting of an arc which does not extend through 360° so that the cut out portion **28** takes the form of a lid with a hinge on it when the explosive cutting charge is actuated.

In the operation of this modification, when the event control switch is closed to activate the explosive cutting charge of cutter **14** cut out portion **28** is formed leaving a hinge portion attaching it to door **68**. The path and final position of the edge of cut out portion **28** is indicated by dotted lines in FIG. 8. As the cut out portion **28** moves outwardly after the explosion it presses button **66'** into its inward position thus activating detonators **46** of the upper explosive cutter for the air inlet hole.

This construction provides for sequential actuation of the lower explosive cutter for the fluid outlet hole and the upper explosive cutter for the air inlet hole, respectively. It will be seen that in this modification as in the first modification the firing circuit which actuates the detonation train for the upper explosive cutter for the air inlet hole can only be activated by movement of the cut out portion **28** for the liquid outlet hole after it has been cut out of door **68**. In other words, in both modifications it is impossible for an upper hole to be cut until a lower hole has been cut. The movement of the cut out portion **28** for the liquid outlet hole actuates the circuit for detonation of the explosive charge for the upper air inlet hole in both modifications.

Experimentation has proved that the cut out portion for the holes moves outwardly rather than inwardly after the explosion and explanation for this is as follows. When the explosive of the cutter is detonated a pressure is created at the face of the liquid which forces the cut out portion outwardly since the liquid is incompressible. The same effect is not achieved with the small cutter as by the time it is sequentially initiated some liquid has left the container and the cut out portion will move inwardly.

In FIG. 11 there is shown a modified form of actuating means for activating the detonating circuit for the upper air inlet cutter by outward movement of cut out plate **28**. In this modification a connector **80** is included in the circuit and the detonators of the upper air inlet cutters are activated by severing of the connector **80** by outward movement of the cut out plate **28**. The connector may be in the form of a continuous wire with a weak portion at the breaking point, or a plug **82** and mating prongs **84** may be included in the connector for breaking the circuit by outward movement of cut out plate **28**.

It is important that the connector **80** be properly connected or anchored at its ends in the annulus **56** of the cutter, otherwise loose fragments may be formed by breaking at the edge of the annulus or otherwise, with resultant serious damage to the aircraft or personnel therein. To avoid this the ends of the connector are anchored as shown inside the annulus on opposite sides so that the connector will not be severed by the edges of the annulus. Channels **86** and **88** are formed on opposite sides of the annulus **56** extending from groove **40'** to the upper edge of the annulus. The connector is anchored in channel **86** by one end as at **90** and in channel **88** at the other end by means of anchoring ball **92**. The connector is, of course, anchored in the annulus before buffer material **41'** and the explosive cutting charge **42''** are seated in the groove **40'**.

The invention has been described by its application to a container mounted on an airplane; however, it is not limited to this application as it can be used in any appli-

cation where sequential cutting is required. The invention includes the explosive cutter per se and is not limited to its use in the sequential cutting application. The invention has been illustrated with the use of two detonators but is not limited to such use as one or more detonators may be used, two detonators being preferred for purposes of redundancy. The invention is not restricted to the use of the non-metallic buffer element 41, 41' but the use of this element is preferred and it is an inventive feature of the explosive cutter per se. In the claims when the cutters are referred to as being located on the container or tank this language includes location of the cutters either on the door 68 or on the tank 10 itself. The firing circuit shown in FIG. 10 is, of course, conventional and optional as other conventional firing circuits may be used.

It is therefore to be understood that various modifications and changes may be made in the construction and arrangement of parts of the present invention without departing from the spirit and scope thereof as defined by the appended claims. Various changes and modifications may be made in carrying out the present invention without departing from the spirit and scope thereof. Insofar as these changes and modifications are within the purview of the annexed claims, they are to be considered a part of this invention.

What is claimed is:

1. Apparatus for the sequential cutting of holes in a container comprising: a first explosive cutter to be located at a first position on said container for cutting out a first portion thereof; a second explosive cutter to be located at a second position on said container for cutting out a second portion thereof; and actuating means operative upon movement of said first portion after it has been cut out to activate said second explosive cutter to cut out said second portion.

2. Apparatus of claim 1 in which each of said explosive cutters comprises: a heavy metal annulus having an annular groove in its bottom edge facing outwardly; an annular concave explosive charge positioned in said groove with its concave surface facing outwardly; a concave metal lining on said concave surface conforming thereto; and at least one detonation train for detonating said explosive charge.

3. The apparatus of claim 2 in which an annular back-up layer of non-metallic material is positioned between the bottom of said annular groove and said explosive charge.

4. The apparatus of claim 2 in which said actuating means is a connector extending across said annulus and having both of its ends anchored internally of said annulus.

5. Apparatus for dispensing liquids comprising: in combination, a container to be supported above the ground; a first explosive cutter located on the bottom of said container for cutting out a first portion thereof; a second explosive cutter located on the top of said container for cutting out a second portion thereof; each of said explosive cutters comprising a heavy metal annulus having an annular groove in its edge facing said container; an annular concave explosive charge positioned in said groove with its concave surface facing outwardly; a concave metal lining on said concave surface conforming thereto; an annular back-up layer of plastic material positioned between the bottom of said annular groove and said explosive charge; at least one detonation train in each of said explosive cutters for, respectively, detonating said explosive charges; and actuating means located adjacent said first explosive cutter operable by the movement of said first portion after it has been cut out to activate the detonation train of said second explosive cutter.

6. Apparatus for the sequential opening of holes in a container, comprising: a first door mounted at a first position on said container; a first explosive cutter located on the outside of said first door for cutting out a first portion thereof; a second door located at a second position on said container; a second explosive cutter located on the outside of said second door for cutting out a second portion thereof; and actuating means operative upon movement of said first portion after it has been cut out to activate said second explosive cutter to cut out said second portion.

7. The apparatus of claim 6 including a circular adapter mounted over each of said portions with said explosive cutters being mounted in respective adapters.

8. The apparatus of claim 7 including a circular securing ring for each adapter for securing the explosive cutters in their respective adapters.

9. The apparatus of claim 1 in which said actuating means includes an actuating member held into a first position by said first portion before it is cut out and spring biased toward a second position in which said second explosive cutter is actuated.

10. The apparatus of claim 1 in which said actuating means is normally in a first position and is operable by movement of said first portion after it has been cut out to be moved to a second position for actuating said second explosive cutter.

11. Apparatus for dispensing liquids comprising: in combination, a container for holding liquids having a lower liquid outlet hole; a door over said hole; a first explosive cutter having an annulus mounted on said door for cutting out a first portion of said door; a second explosive cutter located at a second position on said container for cutting out a second portion thereof; actuating means for actuating said second explosive cutter; and an actuating element in the path of travel of said first portion after it has been cut out and operative thereby to actuate said actuating means.

12. The apparatus of claim 1 in which said actuating means is a connector extending across said first explosive cutter and having both of its ends anchored internally of said cutter.

13. Apparatus for the sequential cutting of openings in an element, comprising: a first explosive cutter to be located at a first position on said element for cutting out a first portion thereof; a second explosive cutter to be located at a second position on said element for cutting out a second portion thereof; and actuating means operative upon movement of said first portion after it has been cut out to activate said second explosive cutter to cut out said second portion.

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