June 27, 1967 W. T. BELL 3,327,630

VENTED SHAPED CHARGE CASE

Filed March 8, 1966

Fig. 1

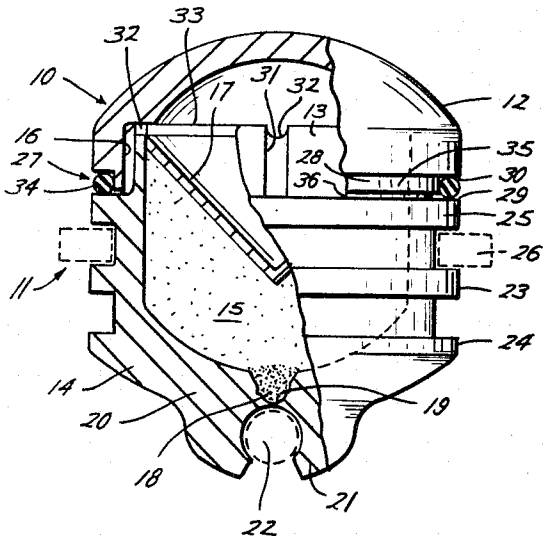


Fig. 2

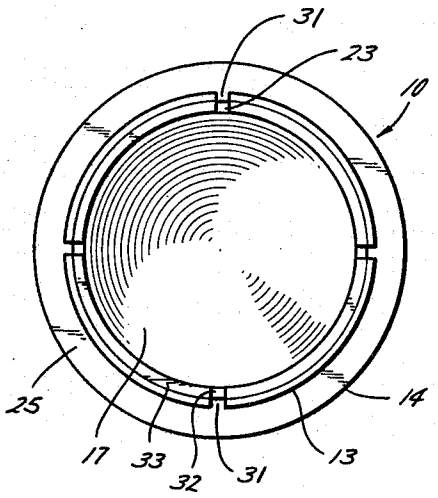


Fig. 3

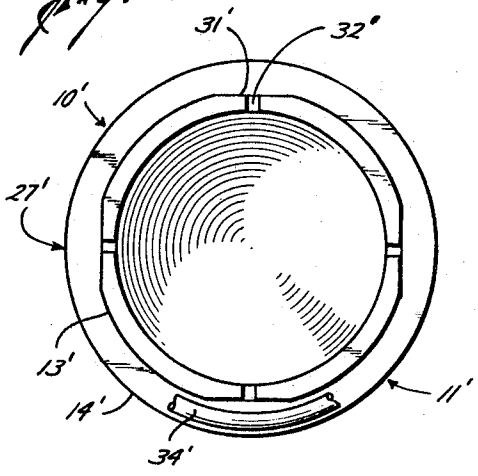
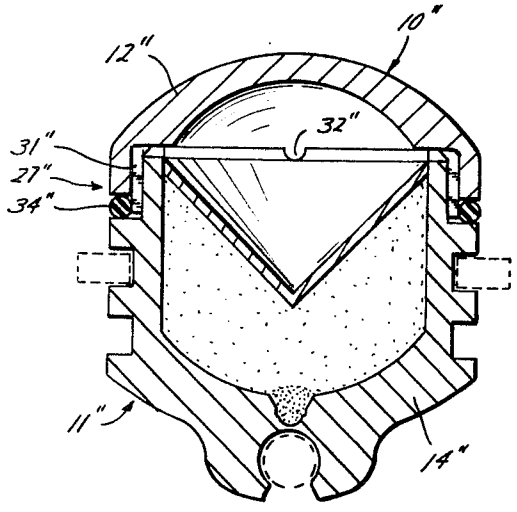


Fig. 4



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VENTED SHAPED CHARGE CASE

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ABSTRACT OF THE DISCLOSURE

This disclosure describes various means by which gases that may have entered a fluidly sealed but gas-pervious shaped charge container can be safely vented therefrom without danger should the shaped charge be returned to the surface without being detonated.

Accordingly, as will subsequently become apparent, this invention relates to shaped charges; and, more particularly, to means for safely relieving hazardous accumulations of gases under pressure from within unfired encapsulated shaped charges as they are being removed from a well bore.

One of the most commonly used perforating devices employed today for perforating wells is the so-called encapsulated shaped charge. Such encapsulated shaped charges are typically comprised of a hollow container in which a shaped explosive and liner are mounted, with a cover fluidly sealing the forward end of the container. The charges are customarily linked together as shown in Patent No. 3,100,443 or mounted either on a so-called strip carrier (such as described in Patent No. 3,048,101) or between a spaced pair of fairly stiff, but somewhat flexible, support members (such as those in Patent No. 3,282,213). Once they are mounted and all connections made, the shaped charges are lowered into a well bore from an electrical cable and positioned adjacent to a particular interval of formations. Then, once they are calculated to be correctly positioned, the shaped charges are detonated to produce the desired perforations through the casing and cement sheath therearound.

Cast aluminum is one of the more popular materials used for fabricating such shaped charge cases since it is easily machined and less expensive than most other materials as well as leaves only minimum amounts of debris in a well upon detonation of the charges. Those skilled in the art do appreciate, however, that most cast aluminum alloys are more or less gas-pervious. Thus, as an aluminum shaped charge case is lowered either into a gas-filled well bore or into one containing liquids with gases in solution, the high well bore pressures will slowly force gases through the walls of the case which, of course, is initially at atmospheric pressure.

This accumulation of gases normally poses no particular problem so long as the shaped charge is detonated in the usual manner. It is not too uncommon, however, for some malfunction, as for example a defect in the detonating system, to prevent detonation of one or more of the shaped charges. It will be appreciated, however, that although the exterior ambient pressure in a well with liquid decreases as the unfired shaped charges are withdrawn from a well bore, the gases filling the interior of the cases will not escape as readily as they entered. Since time does not usually permit the unfired charges to be removed as slowly as they were lowered into a well, the interior of the cases will instead usually remain at a fairly high pressure that may be in the order of several hundreds or even thousands of pounds/square inch as the shaped charges are raised. Thus, as the shaped charges near the surface, it is not at all uncommon for the pressure differential from their interiors to the exterior to become sufficiently high to displace the cover of the cases at least partially, if not entirely, off of the containers.

Where the perforating apparatus must be withdrawn through narrow confines, such as a small tubing string or a seating nipple, one or more covers may have been displaced sufficiently to prevent the further passage of the apparatus. In addition to many other obvious disadvantages, such an occurrence, of course, requires a time-consuming fishing operation which, if unsuccessful, could necessitate the abandonment of a substantial portion of the perforating apparatus in the well bore. This, is, of course, neither desired nor wanted. Similarly, even if the gas-filled shaped charges are eventually recovered with the caps in place, they still present an obvious hazard to those conducting the operation.

Where a perforating operation is conducted in a gas well under pressure, the upper end of the production tubing is typically capped with a so-called "lubricator" assembly which includes an exposed upright pipe having a pressure-sealing gland at its upper end adapted to tightly seal around a suspension cable and suitable valving at its lower end to permit the introduction and removal of cable-suspended tools into and out of the well. Thus, when perforating apparatus is being removed from such a well with "live" charges, the apparatus is first pulled up into the lubricator and the valves therebelow closed.

It is, of course, then necessary to bleed-off the gas pressure in the lubricator before the perforating apparatus can be removed.

In such instances, to save time, the lubricator pressure must be bled-off more rapidly than could possibly be afforded to "decompress" the unfired shaped charges. Thus, the pressure exterior of the unfired shaped charges will be reduced much faster than the accumulated gases can possibly permeate back through the aluminum cases. This rapid depressuring will usually cause one or more of the caps to be displaced as far as the clearance between the shaped charges and internal wall of the lubricator will permit. The obvious hazard of removing a tightly stuck perforator with live charges and detonators from a lubricator needs no description to be fully appreciated.

Accordingly, it is an object of the present invention to provide means for releasing accumulated gases at high pressure from within encapsulated shaped charges as they are being withdrawn from a well bore.

This and other objects of the present invention are obtained by providing a hollow shaped charge case formed of gas-pervious material with means that are selectively operable for venting accumulated gases from within the case whenever the differential between the interior pressure and the ambient pressure exterior of the case is sufficient to actuate the venting means. In one manner of accomplishing this, an otherwise conventional shaped charge case is provided with venting means for releasing accumulated gases from within the case should it be necessary to retrieve the shaped charge from a well bore before detonating it. The venting means include one or more passages through the case and sealing means that fluidly seal the passages against entrance of fluids into the case but which open in response to a higher pressure within the case to release any accumulated gases therefrom.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation together with further objects and advantages thereof, may best be understood by way of illustration and example of certain embodiments when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a partially cross-sectioned view of a shaped charge enclosed within a case of a gas-pervious material and arranged in accordance with the present invention;

FIG. 2 is a plan view of the forward end of the container shown in FIG. 1;

FIG. 3 is a plan view similar to FIG. 2, but showing an alternate embodiment of a container arranged in accordance with the present invention; and

FIG. 4 is a partially cross-sectioned view similar to FIG. 1, but showing still another embodiment of the present invention.

Turning now to FIG. 1, in one embodiment of the present invention, an encapsulated shaped charge **10** is shown comprised of a two-part case **11** of a gas-pervious material, such as aluminum or the like, and having a dished cover **12** snugly fitted over the forward portion **13** of a generally cylindrical hollow container **14** in which a preformed explosive pellet **15** is disposed. To secure the cover **12** and container **14** together, the cover is counterbored, at **16**, for receiving the forward portion **13** of the container. By suitably dimensioning the mating portions to provide, for example, an interference fit, the cover **12** and container **14** will be snugly fitted together.

As is typical, the forward end of the explosive pellet **15** is formed in a generally conical, forwardly diverging, coaxial hollow that receives a complementarily shaped metal liner **17**. A booster explosive **18** is received within a shallow axial recess **19** formed in the internal surface of the rear wall **20** of the container **14**. A spaced pair of rearwardly extending longitudinal lugs **21** are provided for securing a detonating cord **22** against the external surface of the rear wall of the container **14** immediately opposite to the booster explosive **18**. One or more sets of longitudinally spaced lateral lugs **23** and **24** are provided on opposite sides of the container **14** and spaced to the rear of a circumferential flange **25** around the central portion of the container to define grooves for receiving a support **26**.

The case **11**, which is otherwise conventional, is provided with venting means **27** in accordance with the present invention. The venting means **27** include a circumferential groove **28** defined by the forward face **29** of the container flange **25** and the rearward marginal face **30** of the cover **12**. Longitudinal grooves **31** are extended along the exterior surface of the forward container portion **13** from between the forward flange face **29** to transverse notches **32** across the forward face **33** of the forward container portion.

Thus, it will be seen that although the cover **12** is tightly fitted over the forward container portion **13**, direct communicaiton is provided through the passages **31** and **32** between the interior of the case **11** and the circumferential groove **28**. By fitting resilient sealing means, such as an O-ring **34**, into the circumferential groove **28**, it will be appreciated that a greater external fluid pressure will urge the O-ring tightly against the opposed faces **29** and **30** as well as the longitudinal surface therebetween. On the other hand, should there be a greater internal pressure within the case **11** than that outside, such a greater internal pressure will displace the O-ring **34** radially outwardly a sufficient distance to bleed-off any trapped pressure.

If it is preferred, a rearwardly directed circumferential skirt **35** of a reduced external diameter may be provided around the rear marginal face **30** of the cover **12** so as to substantially cover the longitudinal grooves **31** as shown in FIG. 1. It will be recognized, however, that even though the circumferential skirt **35** is over the longitudinal grooves **31**, there will be slight annular clearance, as at **36**, between the rearwardmost edge of the skirt and the forward face **29** of the container flange **25**.

Turning now to FIG. 3, an alternate embodiment is shown of a container **11'** that is otherwise similar to that shown in FIGS. 1 and 2, with the same reference numerals being used but with prime marks to designate equivalent portions. In this alternate embodiment, the longitudinal grooves **31** may be substituted by flats **31'** formed tangentially across the exterior surface of the

forward container portion **13'** and meeting the transverse slots **32'**. These flats **31'**, of course, will provide sufficient clearance between the mating surfaces of the cover (not shown) and container **14'**.

Turning now to FIG. 4, an alternate embodiment is shown of still another shaped charge **10''** that is otherwise similar to that shown in FIGS. 1–3, but with double prime marks denoting equivalent elements. In this alternate embodiment, however, the previously described passages, such as the grooves **31** or flats **31'** along the external surfaces of the forward container portions **13** and **13'**, are replaced by similarly arranged passages, such as flats or longitudinal grooves **31''**, in the internal mating surface of the cover **12''**. The shaped charge **10''** is otherwise the same as that in FIGS. 1–3.

Accordingly, it will be appreciated that whenever one of the shaped charges **10–10''** as shown in FIGS. 1–4 is lowered into a well bore, the O-rings **34–34''** will fluidly seal the passage means (**31–32**, **31'–32'** or **31''–32''**) to prevent entrance of fluids from the well bore into the interior of the shaped charge cases **11–11''**. As previously described, as the shaped charges **10–10''** are lowered into the well bore, gases can and will gradually permeate through the permeable metal of the cases **11–11''** and slowly accumulate therein. The pressure of these gases will, of course, be whatever the ambient fluid pressure is around the shaped charges **10–10''**. Should the shaped charges **10–10''** be detonated in the expected manner, the presence of gases therein will not materially affect the performance of the shaped charge.

Should it be necessary, however, to retrieve one of the shaped charges **10–10''** from a well bore containing liquid without its having been detonated, the exterior ambient pressure around the shaped charge will diminish as it is raised. Inasmuch as accumulated gases within the shaped charge cases **11–11''** cannot readily escape, however, the pressure differential between the interior of the case and their exterior will gradually increase. Then, once this pressure differential has reached an amount sufficient to expand the O-rings **34–34''**, the O-ring will be displaced radially outwardly at least a distance sufficient to uncover the outer end of the passage means (**31–32**, **31'–32'** or **31''–32''**) and release at least a portion of the accumulated gases.

This release may occur several times during the ascent of the shaped charges **10–10''**. Thus, by the time that the shaped charges **10–10''** have reached the surface, a sufficient quantity of these trapped gases will have been vented from the interior of the cases **11–11''** to prevent the displacement of the covers **12–12''** relative to the containers **14–14''**. Similarly, where the well bore is filled with high pressure gases, as the pressure in the aforementioned lubricator is relieved, the venting means **27–27''** will have operated one or more times to release accumulated gases from the cases **11–11''**.

Accordingly, it will be appreciated that the present invention has provided new and improved means for preventing entrapped gases within a shaped charge case from displacing the cover relative to the container before the pressure differential between the interior and exterior of a shaped charge case has reached an excessive magnitude otherwise sufficient to displace the cover relative to the container. In this manner, by venting off any accumulated gases whenever the pressure differential reaches a magnitude less than that necessary to displace the cover, a shaped charge may be safely withdrawn from a well bore with its cover still firmly in position.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects; and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. Shaped charge apparatus comprising: a hollow case having at least a portion of a gas-pervious material; shaped charge means in said case; means sealingly enclosing said shaped charge means within said case; and venting means for releasing accumulated gases from within the enclosed interior of said case whenever the pressure exterior of said case is lower than that in said enclosed intrior.

2. The apparatus of claim 1 wherein said case includes a cover and a container adapted to be joined together and wherein said gas-venting means include resilient sealing means fluidly sealing said cover and container to one another at their junction.

3. The apparatus of claim 2 wherein said gas-venting means further include passage means between the interior of said case and said junction of said cover and container.

4. The apparatus of claim 1 wherein said case includes a container and a cover having complementarily-fitting portions adapted to be joined together along mating surfaces and each defining an opposed marginal surface, and wherein said gas-venting means include resilient sealing means fluidly sealed between said marginal surfaces around said complementarily-fitting portions.

5. The apparatus of claim 4 wherein said gas-venting means further include passage means between the interior of said case and the enclosed space between said resilient sealing means and said complementarily-fitting portions.

6. The apparatus of claim 5 wherein said passage means extend along a mating surface of one of said complementarily-fitting portions.

7. The apparatus of claim 5 wherein said passage means extend along the mating surface of said cover portion.

8. The apparatus of claim 5 wherein said passage means extend along the mating surface of said container portion.

9. Shaped charge apparatus comprising: a hollow case adapted to sealingly enclose an explosive charge and including a cover and a container of a gas-pervious material, said container having a peripheral flange providing a forwardly-directed marginal surface and a cylindrical portion forward of said peripheral flange, said cover having a rearwardly-directed marginal surface defining the entrance of a cylindrical bore therein adapted to receive said forward container portion, said forward container portion and cylindrical bore having complementary mating surfaces adapted for snugly inter-fitting said cover and container to one another; and passage means along one of said mating surfaces adapted for providing communication between the interior of said case and the space between said marginal surfaces when said cover is fitted onto said container.

10. The apparatus of claim 9 wherein said cover and container are of cast aluminum.

11. The apparaus of claim 9 further including shaped charge means in said case; and resilient sealing means in said space and sealingly engaged with each of said opposed surfaces exterior of said passage means.

12. The apparatus of claim 11 wherein said cover and container are of cast aluminum.

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