May 10, 1955 W. H. LINDSAY, JR., ET AL 2,707,917

WELL CASING PERFORATOR

Filed July 25, 1949 2 Sheets-Sheet 1

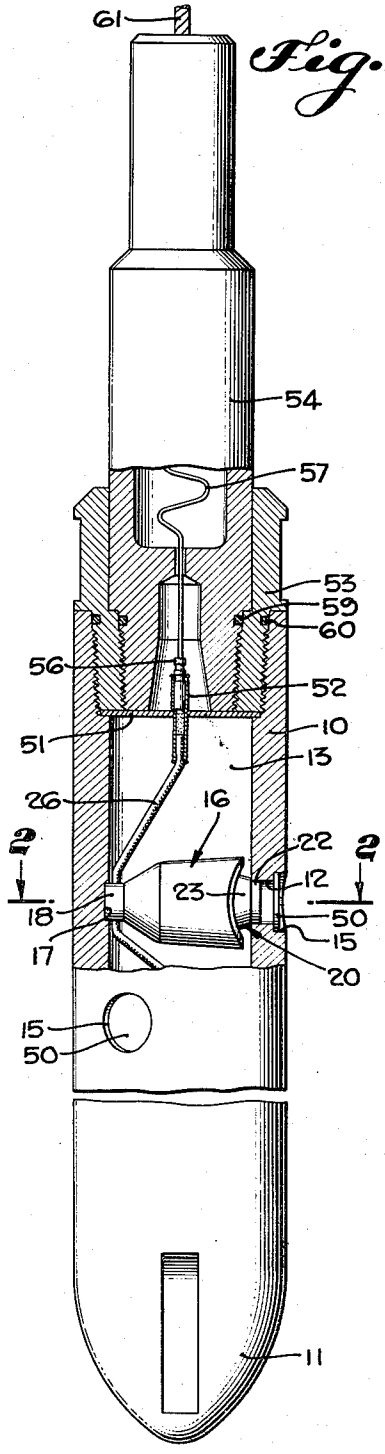


Fig. 1.

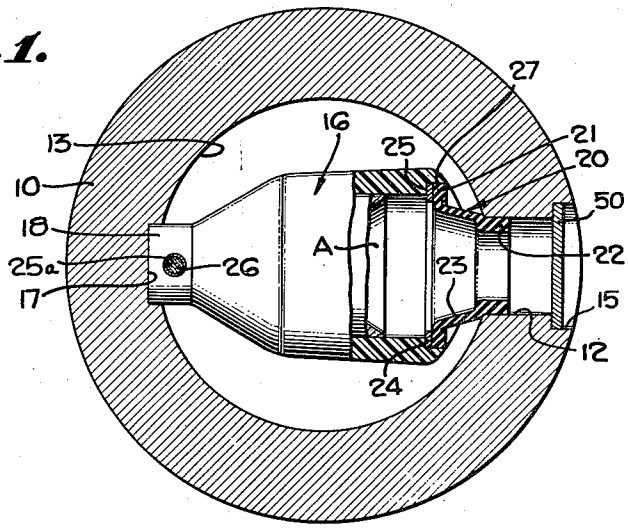


Fig. 2.

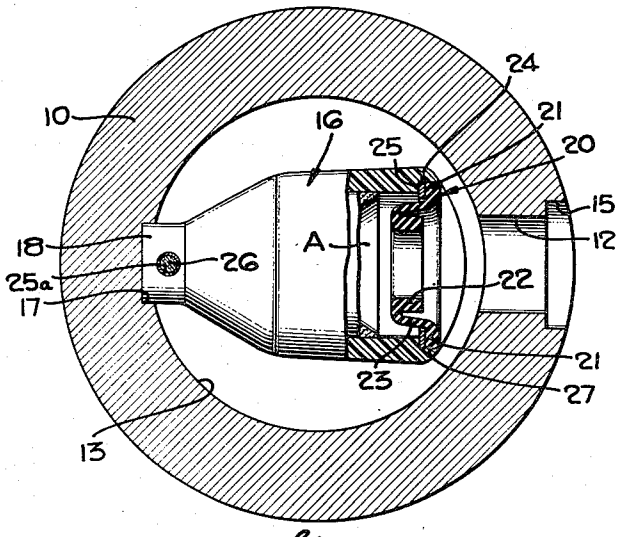


Fig. 3.

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WELL CASING PERFORATOR

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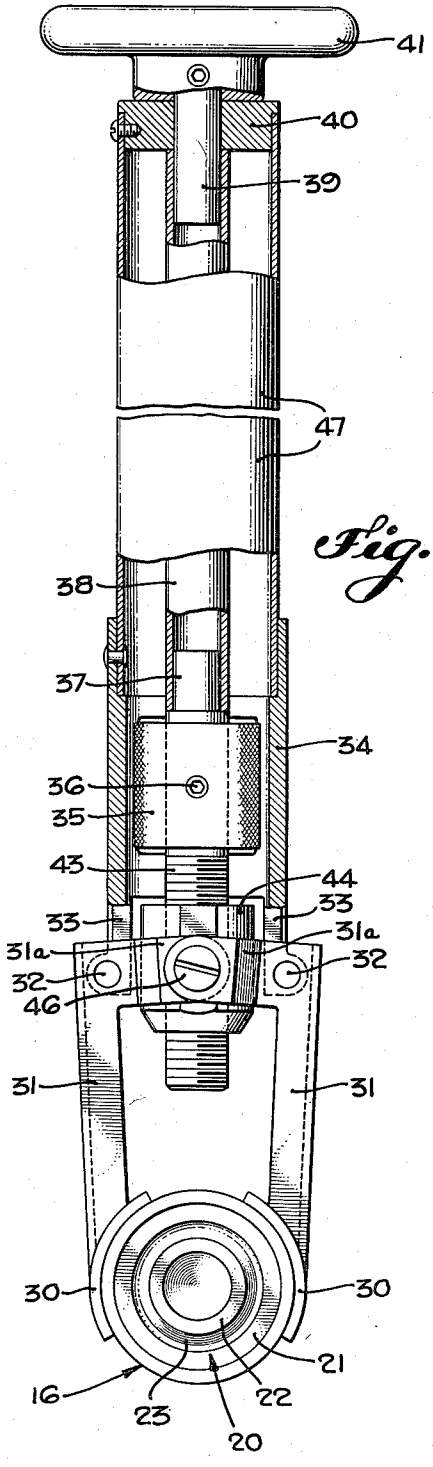


Fig. 5.

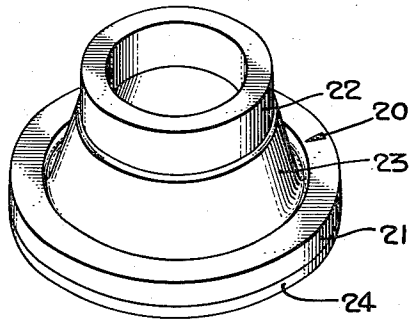


Fig. 4.

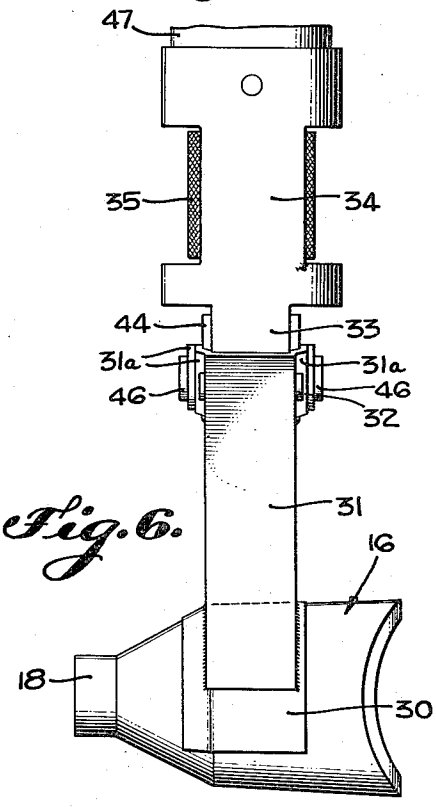


Fig. 6.

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WELL CASING PERFORATOR

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Application July 25, 1949, Serial No. 106,567

6 Claims. (Cl. 102—20)

This invention relates to perforators adapted to be lowered into boreholes, particularly oil and gas wells, for the purpose of piercing or perforating the casing therein or surrounding formations or both, at one or more points. More particularly it pertains to perforators of the aforesaid type, adapted and intended to use detonating explosives of high velocity and of the general character and form known as "shaped charges" as, for example, the type disclosed in U. S. Patent No. 2,399,211 to C. O. Davis et al. issued April 30, 1946. This invention involves improvements on and further developments of the inventions set forth in the copending application of George F. Turechek and Will H. Lindsay, Jr., Serial No. 106,568 filed July 25, 1949, now Patent No. 2,662,474.

Heretofore perforators employing either one shaped charge, as in the beforementioned patent, or a number of such shaped charges were constructed of frangible materials, such structures being entirely destroyed when fired and usually with only the firing line or supporting conductor cable being recovered from the borehole. Such perforators adapted to hold shaped charges were constructed of various materials such as sheet metal, cement or suitable plastics. Expendable perforator devices such as these having expendable structures had a number of disadvantages among them being high cost, the leaving of debris in the borehole, the subjecting of the surrounding casing to high stresses and also the inability to selectively fire less than all of the shaped charge units contained in them simultaneously lest the unfired charges be destroyed by those previously fired.

It was recognized after some experience with perforator devices of the hereinbefore mentioned type, that the aforesaid disadvantages could be obviated and other advantages gained by employing retrievable perforator devices for containing the shaped charges, which would not be destroyed and which could be reloaded repeatedly and if desired be constructed in separate units capable of being separately fired.

In subsequent attempts to develop a retrievable perforator device which could be repeatedly reloaded and reused, the body thereof was formed of a relatively thick walled steel tube having a plurality of longitudinally spaced laterally directed ports and the shaped charge units were mounted in relatively light expendable cylindrical liner assemblies of fibre, plastic or other suitable frangible material and such assembly adapted to be inserted axially into the bore of the said tubular body of the perforator. Such liner assembly was arranged to position each shaped charge unit in precise radially directed alignment with the center of its respective port in the wall of the perforator body.

However, it was soon found that after one or several firings the tubular body of the perforator which was subjected to the detonating shock extending in all directions from the shaped charge unit became elongated or otherwise distorted to such an extent that upon attempting to reload with a new shaped charge liner assembly at least some of the charges failed to register accurately with

the body ports and were, in frequent instances, misaligned therewith sufficiently to cause the penetrating blast or jet projected from the forward end of the shaped charge unit when fired to graze or partially strike the edge of the port with resultant damage to it of such an extent that a fluid tight fit often could no longer be obtained between the port closing seal disc and the port. Furthermore, the resulting interference with the penetrating jet from the charge at such a critical point relatively close to the forward shaped end of the charge reduced to some extent its penetrating ability.

It is therefore an object of this invention to provide a perforator structure for shaped charge perforator units which is not destroyed on first use but can be retrieved from the well, reloaded and reused repeatedly without substantial damage to it or impairment in its working efficiency.

Another object of the invention is to provide a simplified method and apparatus for loading and reloading shaped charge type perforators.

Another object is to incorporate a method of holding such shaped charge units which is simple and quick in application and by which the shaped charge unit will be positioned to direct the explosive force of the shaped charge unit accurately through the fire ports.

Another object is to provide holding means for the shaped charge which will be sufficiently positive and flexible to stand the shock of firing semi-selective guns.

Another object is to reduce the number of parts required to center and to retain each shaped charge unit in place substantially to a single element.

Still another object is to provide a novel method for mounting shaped charge units in a perforator body with a minimum of parts and labor.

The objects of the present invention are accomplished, in general, by providing a shaped charge type perforator structure having a heavy walled, cylindrical body containing a plurality of radially directed ports therein and in which the shaped charge or charges are each individually and independently mounted in accurately aligned position with respect to the center of each port and by resilient locating means cooperating with each port in the perforator independent of the overall dimensions of perforator body thereby minimizing if not entirely avoiding the ill effects from distortion created by prior and repeated use of the perforator.

Other objects, advantages and features of novelty of the invention will be evident hereinafter. In order to illustrate one preferred embodiment of the invention and the manner of its use, attention is now directed to the accompanying drawings, in which:

Figure 1 is a view partly in elevation and partly in longitudinal section of a completely assembled perforator device ready to be lowered into a well borehole.

Figure 2 is a view on an enlarged scale taken on line 2—2 of Figure 1 but showing a typical shaped charge unit therein partly in plan view and partly in section.

Figure 3 is a sectional view similar to Figure 2 taken on 2—2 of Figure 1 showing the charge in position in alignment with a port prior to its being secured in place.

Figure 4 is a perspective view on a still larger scale of the retainer member for the charge.

Figure 5 is an elevational view (on the same scale as Figures 2 and 3) partly in vertical section and partly cut away showing tongs suitable for gripping and inserting the shaped charge units into the perforator, one charge being shown in end elevation held by the jaws of the tongs.

Figure 6 is an elevational side view of the lower portion of the tongs shown in Figure 5.

The perforator apparatus comprises a perforator body 10, as shown in Figures 1, 2 and 3, in the form of a thick

walled, elongated tube or cylinder closed at its lower end by a tapered bull plug 11. The thick wall of the body 10 has a series of longitudinally spaced radially directed openings or ports 12 extending therethrough to the inside of the central bore or chamber 13, each port being enlarged on the outside by a short counterbore 15. Such series of port 12 (only two of which are shown in Figure 1 due to the fact that for convenience of illustration duplicate portions thereof have been omitted) may be arranged along the body 10 in any desired pattern. One suitable arrangement or pattern which is frequently used is to place the ports 12 in a spiral arrangement along the body.

At each port 12 a shaped charge unit such as shown at 16 is adapted to be mounted so that the jet shaped blast projected from the forward end thereof will issue through the center of the port. To assist in positioning and accurately maintaining each such charge 16 in centered relation to its respective port 12, the inner wall of gun body 10 diametrally opposite each port is provided with suitable means to engage the rear end of the charge unit. Preferably such means takes the form of a radially directed cylindrical recess 17, and the adjacent rear end 18 of the charge is cooperatively shaped to fit within the recess 17.

To support the other or forward end of the shaped charge unit 16, and to maintain end 18 securely seated in recess 17, a retainer means is employed as shown at 20, such retainer means also serving to center the adjacent forward end of charge 16 in accurate axial alignment relative to the center of its port 12. The retainer 20, shown in large perspective view in Figure 4, is in the general form of a hollow truncated cone with thick end portions 21 and 22 for telescoping engagement with the forward end of the charge unit and gun port respectively, and a thinner, conical interconnecting portion or web 23. This web portion 23 must be of flexible resilient material such as rubber, neoprene or the like material to enable it to bend upon itself so that one end portion of the retainer can collapse or be telescoped within the other end portion in the manner shown in Figure 3. When retainer 20 is mounted in the front end of charge 16 with retainer end 21 seated on a short counterbore 27 formed in the forward end of the charge and the other retainer end 22 in collapsed position as shown in Figure 3, the assembled charge and retainer can be inserted through the axial bore 13 of gun body 10 to position before a gun port 12. Retainer 20 is then extended into and seated within the port as shown in Figure 2. When extended the resiliency of the conical or web portion 23 of retainer 20 exerts a rearward force on charge 16 which holds end 18 in the recess 17 while the forward end of the charge is maintained by retainer 20 in centered relation to port 12.

While retainer 20 may be made of any suitable material or any suitable combination of materials, it is preferably molded of synthetic rubber. Either or both end portions may be reinforced or stiffened by more rigid material. In the form of retainer illustrated herein, end portion 21 has a stiffening ring 24 of metal, bonded to the rubber of which the rest of the retainer is formed. When assembled as shown in Figures 2 and 3 this stiffening ring 24 engages the abutment shoulder 25 formed by counterbore 27 in each charge 16.

For convenience reference character 16 has herein been utilized to indicate both the charge unit casing and the shaped charge of explosive A therein, the latter being of the detonating type described in the above-mentioned Davis et al. Patent No. 2,399,211 shaped or molded with a suitable concavity or conical depression therein facing toward port 12 as shown in partial section in Figures 2 and 3. The casing for the explosive charge may be of any suitable materials such as for example, Bakelite, Lucite and the like plastic materials. The small or rearward end 18 of charge 16 has a suitable opening or passage 25*a* extending transversely therethrough to receive a detonating fuse or cord 26 as shown. The forward end of charge 16 is of greater diameter than the diameter of the fire ports 12, and has its forward face rounded in the diametral plane of the body as viewed in Figure 3 to conform generally to the internal curvature of the bore 13 of the body 10.

In loading the perforator body, charges 16 are inserted one at a time, axially, into the bore 13 of the body 10 and each charge is individually mounted in relation to its port 12. Due to the length of the gun body suitable means are needed to insert and support charges 16 therein in alignment with their respective ports until they can secure in place. Tongs suitable for this purpose are illustrated in Figures 5 and 6, and provide movable jaws 30 of a size and shaped to releasably grip, therebetween, the sides of charges as there shown. Jaws 30 are integral with arms 31 which are pivotally mounted at 32 to extensions 33 on a cylindrical head 34 which is partly cut away on opposite sides to give access to a knurled sleeve member 35 which is in turn secured by set screw 36 to a rotatable shaft 37. Shaft 37 has a tubular extension 38 which in turn has a stub shaft 39 secured thereto which extends through a bearing block 40 and has an actuating knob or actuator 41 keyed and attached to its extremity. Bearing block 40 is attached to and forms a closure for the long tubular member or handle 47 which encloses shaft 38 and which is attached at its forward end to cylindrical head 34.

Forwardly of knurled cylinder 35, shaft 37 is exteriorly threaded as at 43 and has threaded engagement with a nut or block 44 which is loosely supported between lateral bifurcated extensions 31*a* on arms 31. Extensions 31*a* are substantially at right angles to arms 31 and extend toward each other from pivots 32 in overlapping arrangement as indicated and on opposite sides of extensions 33 on cylinder head 34. Bifurcated extensions 31*a* have slots concealed by the heads 46 of pins attached to and projecting from nut 44 with the result that when nut 44 is moved back toward handle 47 or forward toward jaws 30 through rotation of shaft 37 (by either knurled cylinder 35 or knob 41) the jaws 30 are moved toward each other to grip a charge 16 or away from each other to release the charge. Knurled cylinder 35 being close to jaws 30 is convenient to use when a charge is to be gripped by jaws 30 and knob 41 to release the charge when it has been positioned within the gun body 10.

The method of loading gun body 10, or of reloading after use is as follows:

Fuse 26 is fastened in bore 25*a* of the first charge 16, a hollow retainer 20 is attached to the charge by forcing the end 24 of the retainer to telescope within the counterbore 27 of the charge until ring 24 abuts shoulder 25 in the charge, and the retainer is collapsed by forcing end portion 22 within end portion 21 as best shown in Figure 3. Tongs such as shown in Figures 5 and 6 are manipulated to grip the charge with the retainer collapsed therein and to insert the same within the axial bore 13 of the gun body and to move it into the level of lowest port 12; rear end 18 of the charge is aligned with recess 17 in the inner wall of the gun body opposite lowest port 12 and pushed back to seat therein (the parts then being in the positions shown in Figure 3): the retainer 20 is then extended to take the position shown in Figure 2 by reaching through port 12 with a suitable instrument such as a rod having a hooked end by which end portion 22 of retainer 20 is pulled forward out of nested or telescoped relation with end portion 21 (the hooked rod may be inserted through the port and within the charge to test the accurate positioning and attachment of the charge): with the lowest charge securely in place the tongs are released from this charge and withdrawn from the gun body and a sealing disc or cap 50 (Figures 1 and 2) is forced into counterbore 15 of the port to prevent ingress of any fluid which may surround the gun body 10 when the

charges are to be fired: the above steps are repeated with succeeding charges, fuse **26** being threaded through passage **25***a* and retainer **20** being mounted and collapsed in each charge **16**, before the charge and retainer is inserted into the axial bore **13** of the gun body.

When the gun body has been completely loaded and all ports sealed by discs **50**, the open end of the gun body is closed and sealed. A washer **51** with union **52** crimped to the end of fuse **26** is first placed in the open end of the gun body and is secured in place by sleeve **53** which has threaded engagement with the inner wall of the gun body. The detonating mechanism (not shown) is contained in a casing **54**, the lower end of which fits within sleeve **53** and has threaded engagement with the latter as shown. A detonating cap **56** on a flexible conductor **57** is secured to the upper end of fuse terminal union **56** before casing **54** is secured in place. Fluid tight packings at **59** and **60** seal the upper end of gun body **10** against any entrance of fluid. A cable **61** attached to casing **54** serves to lower the perforator into the well and to communicate the firing impulse thereto.

The use of a single element for mounting, centering and securing in place a shaped detonating charge in the gun body of a perforator as herein set forth represents a distance advance in the art by reason of its extreme simplicity and of the economy effected in time, labor and materials. The retainer especially when molded in one piece in synthetic rubber or other suitable flexible and resilient material is inexpensive and is substantially completely vaporized by the exploding charge so as to leave a minimum of debris in the hole after the charge has been fired. The retainer, by maintaining the charge always centered relative to its fire port directs the blast or jet of the explosive accurately through the fire port thereby protecting the ports against expansion and distortion. However, such retainers can still be used with very satisfactory results even after the ports have been considerably distorted, thereby adding to the useful life of the gun body. The collapsible feature of the retainer makes the loading and reloading of gun bodies exceptionally simple and rapid.

While the invention has been herein described in what are now considered to be preferred forms of its method and apparatus aspects, it is to be understood that the invention is not limited to the specific details of such forms but covers all changes, modifications and adaptations within the scope of the appended claims.

What is claimed is:

1. Perforator apparatus comprising: a tubular body having an outwardly directed port extending through the wall thereof; a shaped charge within said body spaced from and directed toward said port; and an axially resilient, deformation resistant, annular spacer member resiliently collapsible axially upon itself, one end of which detachably engages the forward end portion of said shaped charge, and the other end of which detachably engages said body about said port to support and retain said charge in said position relative to said port.

2. Perforator apparatus comprising: a tubular body having an outwardly directed port extending through the wall thereof; a shaped charge within said body spaced from and directed toward said port; and a resilient, annular spacer member, one end of which detachably engages one end of said shaped charge, and the other end of which detachably engages said body about said port to support and retain said charge in said position relative to said port, said resilient annular member being collapsible axially within itself to reduced length upon application thereto of axial compressive force, to permit the free insertion of the assembled shaped charge and resilient member crosswise within said body.

3. Perforator apparatus comprising: a tubular body having a laterally directed port extending through the wall thereof; an inwardly facing recess formed in the inner side of said wall opposite said port; a laterally directed shaped charge within said body and positioned with its rear end in retaining engagement with said recess; a resilient, deformation resistant, annular supporting member resiliently collapsible axially upon itself, attached to and extending longitudinally from the forward end of said shaped charge, one end of which member normally extends into and detachably engages the inside of said body about said port to support the forward end of said shaped charge in spaced position opposite said port and to retain the rear end of said shaped charge in engagement with said recess.

4. Perforator apparatus comprising: a tubular body having an inner, longitudinal passage and a laterally directed port extending through the wall thereof; an inwardly facing recess formed in the inner side of said wall opposite said port; a laterally directed shaped charge within said body and positioned with its rear end in retaining engagement with said recess; a resilient, annular member, one end of which engages the forward end of said shaped charge, and the other end of which normally extends into and detachably engages the inside of said body about said port to support the forward end of said shaped charge in position opposite said port and to retain the rear end of said shaped charge in engagement with said recess, said assembled shaped charge and resilient member being initially of greater length than the width of said inner passage but the annular member being collapsible axially within itself to reduced length upon application thereto of axial compressive force, to permit the free insertion of the said assembled shaped charge and resilient member crosswise within the said passage of said body.

5. Perforator apparatus comprising an elongated tubular body having an inner, longitudinal bore and a plurality of longitudinally spaced, laterally directed ports extending through the wall thereof; a plurality of recesses formed in the inner wall of said bore, each recess being positioned laterally opposite a corresponding one of said ports; a plurality of shaped charges contained within said bore, each charge being spaced from and directed laterally toward one of said ports, and positioned with its rear end in retaining engagement with one of said recesses; a resilient, deformation resistant, axially resiliently collapsible, annular retainer member for each charge, one end of each such retainer member making supporting engagement with the forward end of such charge and the other end of each such retainer making telescopic detachable engagement with the inner edge portion of one of said ports, whereby each retainer member maintains its charge centered axially relative to and spaced axially from its port and applies rearward holding pressure to such charge to maintain its rear end in engagement with its said recess opposite said port.

6. Perforator apparatus according to claim 5 and having sealing means closing said ports exterior to said resilient retainer members; means forming an external fluid closure for said bore in said body; and means to detonate said charges.

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