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Shore

[11] **3,773,119**

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[54] **PERFORATING APPARATUS**

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[52] **U.S. Cl.** **175/4.6**

[51] **Int. Cl.** **E21b 43/117**

[58] **Field of Search** 175/4.6, 4.53; 102/20

[56] **References Cited**

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Primary Examiner—David H. Brown
Attorney—Ernest R. Archambeau, Jr. et al.

[57] **ABSTRACT**

In the representative embodiment of the present invention disclosed herein, a group of shaped explosive charges are respectively mounted in diametrically-opposed lateral openings formed at spaced intervals along the length of an elongated expendable tubular member sized for reception in a typical end-loaded perforating carrier. Opposed locking lugs are cooperatively arranged on the shaped charges for interlocking engagement with the edges of the openings to secure the charges to the expendable tube. Once the charges are mounted, the assembly is installed in the carrier so that the charges are respectively facing and aligned with lateral ports in the side walls of the carrier. In this manner, when port plugs are installed in the ports, a domed retainer of a yieldable material on the forward end of each charge will be partially collapsed for tightly anchoring the shaped charges in position in the carrier.

18 Claims. 5 Drawing Figures

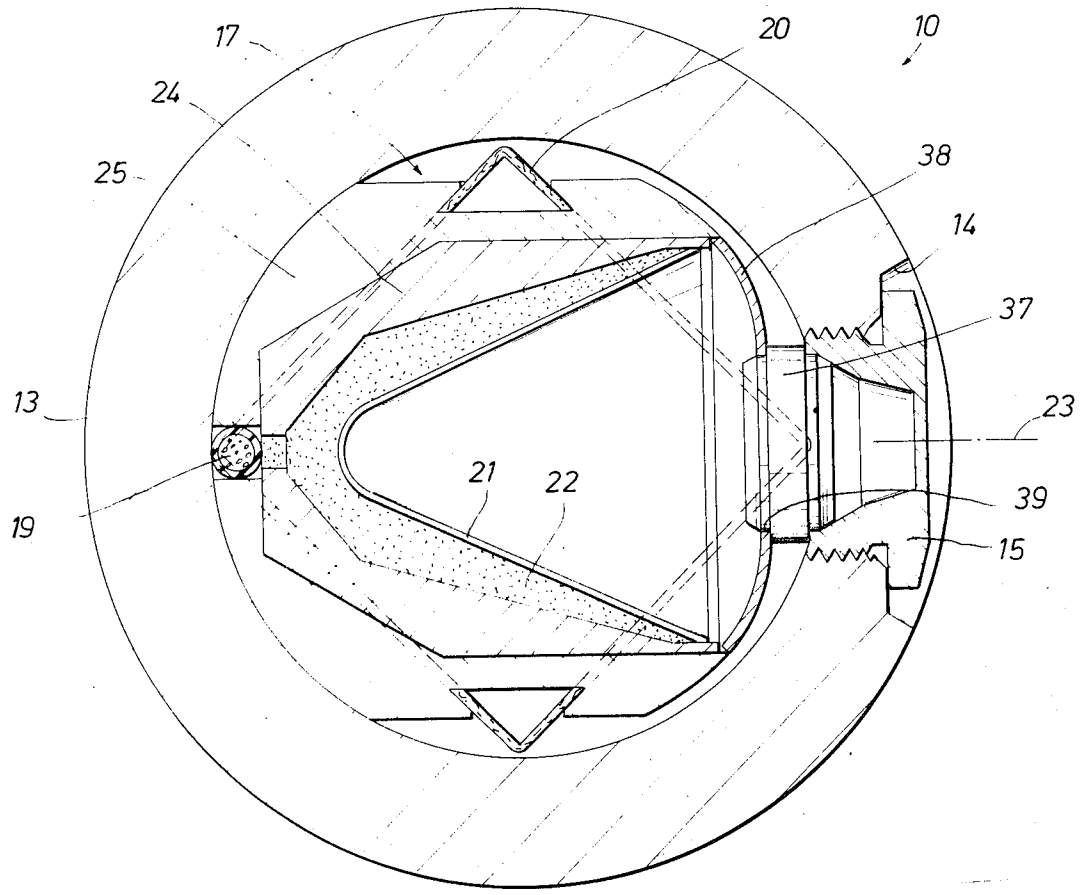
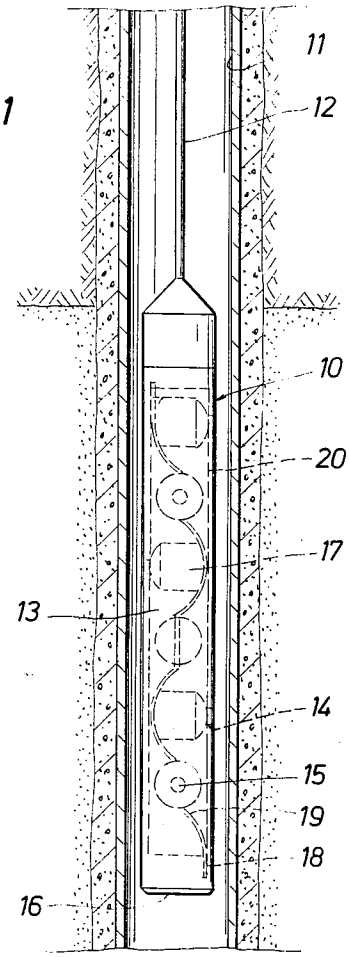


FIG. 1



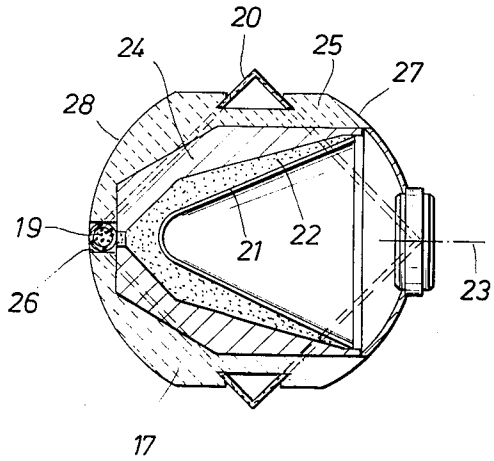


FIG. 3

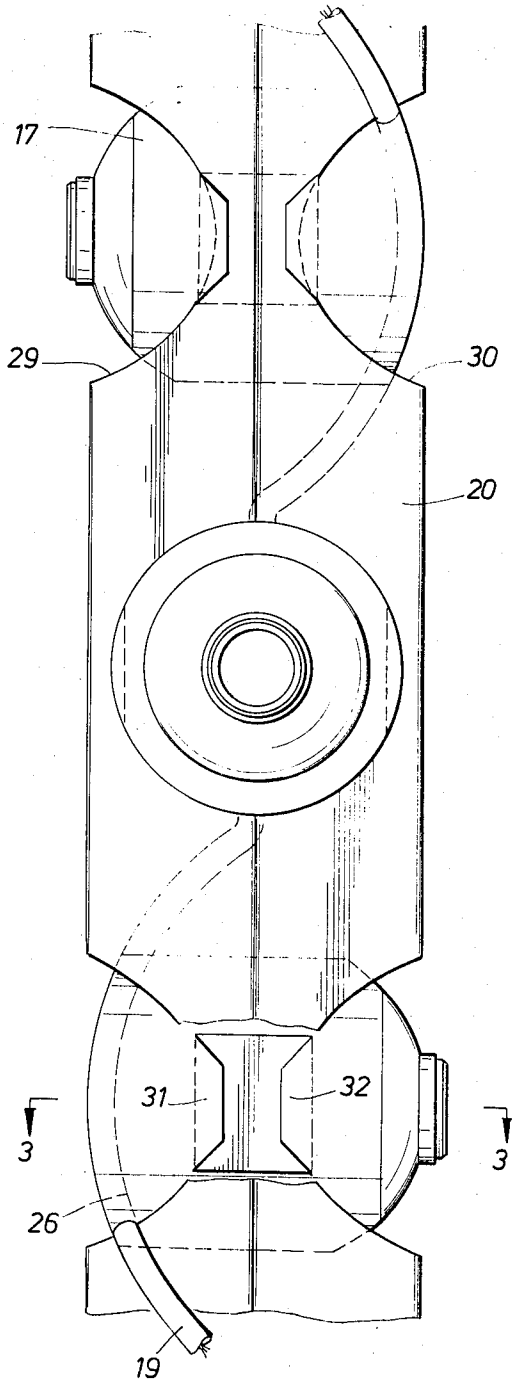


FIG. 2

FIG. 4

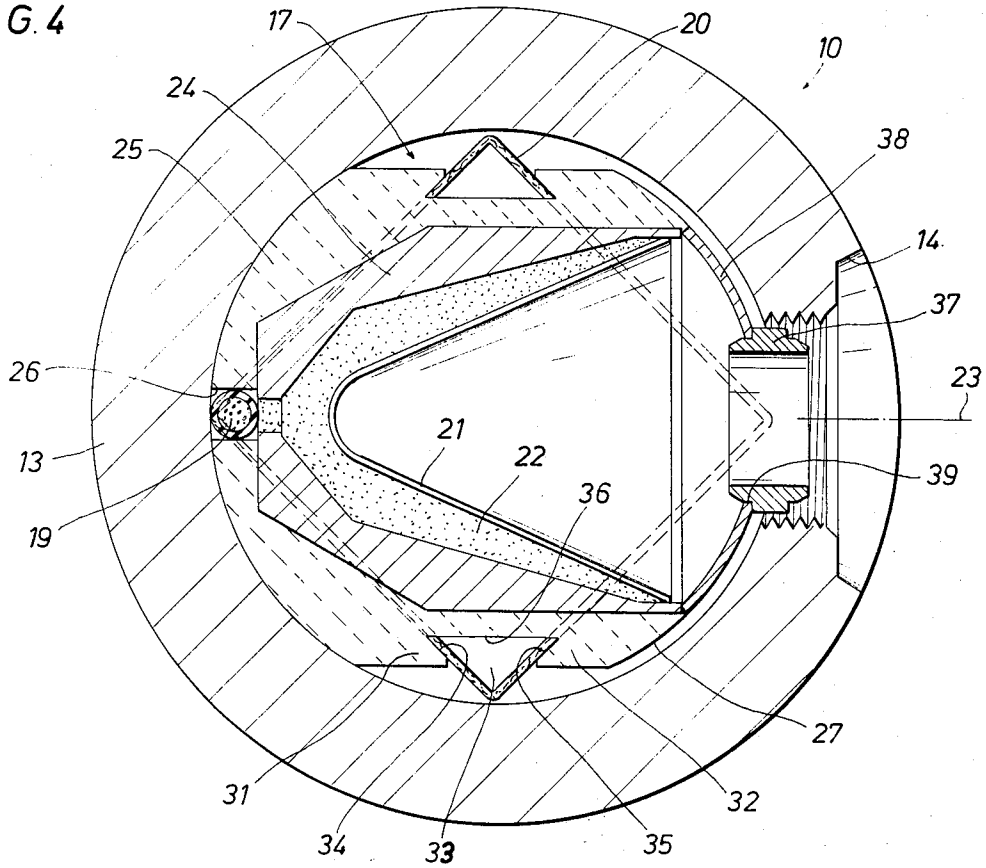

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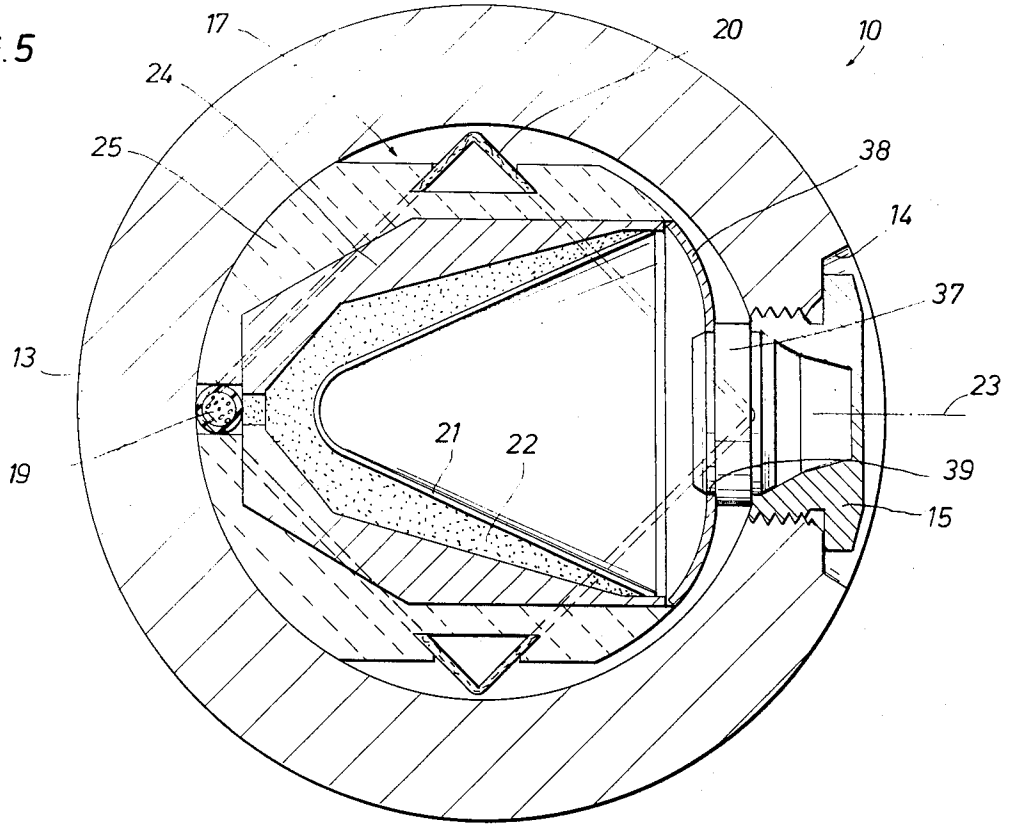
FIG. 5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PERFORATING APPARATUS

One of the more typical oil-field perforators in common usage today is comprised of an enclosed tubular body having a number of laterally-directed shaped explosive charges mounted at longitudinally-spaced intervals therein and operatively associated with electrically-responsive detonating means. As is typical, the perforator body or so-called "carrier" is a heavy-walled cylinder designed to withstand te extreme explosive forces produced by the detonation of the explosives carried therein. To permit the carrier to be reused, each shaped charge is respectively faced toward a lateral port in the carrier body which is customarily sealed by an expendable port-closure member such as a threaded plug.

Those skilled in the art will recognize, of course, that for a given carrier, significantly-larger shaped charges can be employed where the charges are inserted into one end of the carrier rather than being installed through necessarily-large lateral ports in the carrier wall. Thus, to secure maximum operational performance, it is generally preferred to employ such "end-loaded carriers" wherever possible. The typical end-loaded carrier does, however, present several problems. For example, provisions must be made for installing the shaped charges into the carrier; and then, once they are properly positioned, retaining the charges accurately aligned with their respective ports despite the sharp impacts and shocks usually encountered during a typical perforating operation.

One typical technique which has been widely used heretofore is to employ an elongated hand-operated loading tool for individually locating each shaped charge one at a time adjacent to its assigned port and then holding it in this position until the port plug is installed. Another common arrangement is to mount the shaped charges in complementary openings formed at spaced intervals along the length of an elongated flat metal strip which is then slipped into the carrier as a unit. In either case, some device must also be provided for securing the shaped charges in alignment with their respective ports without impairing the operation of the shaped charges. One typical mounting arrangement (as shown at "60" in U.S. Pat. No. 3,246,707) employs a truncated conical metal sleeve which is secured over the forward end of a shaped charge and contacted by its associated port plug to firmly secure the charge in position when the plug is installed.

Those skilled in the art will appreciate, however, that none of the previous loading arrangements employed heretofore are entirely satisfactory. For example, when the charges are individually installed, a considerable amount of time is required for loading the perforator. The problem is, of course, greatly increased should last-minute changes make it necessary to revise the loading arrangement. Furthermore, in those arrangements where the charges are mounted along an elongated metal strip, the charges can be fired in only one or both of two lateral directions. This will, of course, preclude perforating a well bore at commonly-desired angular orientations of 90° increments. Moreover, in either situation, it is not at all uncommon for either the detonating cord or the electrical detonator leads to be inadvertently damaged during the loading operation so that the perforating apparatus cannot be successfully operated.

Accordingly, it is an object of the present invention to provide new and improved perforating apparatus having shaped explosive charges which can be quickly and reliably installed as a group in a typical end-loaded carrier and firmly secured in precise alignment with their respectively-associated port-closure members.

This and other objects of the present invention are attained by mounting a plurality of shaped charges in opposite side openings formed at spaced intervals and desired angular orientations along the length of an expendable tubular member. To secure the charges to the expendable tubular member, opposed locking lugs are cooperatively arranged on each charge for engaging the edges of each side opening. Once the assembled charges and tubular member are positioned in the carrier with the charges respectively in alignment with their associated side port in the wall of the carrier, a port plug is installed in each of the ports for partially collapsing a domed retainer for securing each charge between the port plug and the rear wall of the carrier opposite the lateral port.

The novel features of the present invention are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may be best understood by way of the following description of exemplary apparatus employing the principles of the invention as illustrated in the accompanying drawings, in which:

FIG. 1 shows typical perforating apparatus employing the principles of the present invention;

FIGS. 2 and 3 depict a preferred embodiment of a charge-mounting tube and a group of shaped charges for the new and improved perforating apparatus of the present invention; and

FIGS. 4 and 5 are enlarged cross-sectional views respectively illustrating the installation of the assembly of FIGS. 2 and 3 within a typical perforator carrier as shown in FIG. 1.

Turning now to FIG. 1, new and improved perforating apparatus 10 incorporating the principles of the present invention is depicted as it will appear when suspended in a well bore 11 by a typical electrical cable 12. As illustrated, the perforating apparatus 10 includes a typical thick-walled tubular body or carrier 13 of steel or the like having a plurality of longitudinally-spaced side openings or ports 14 which are respectively fluidly sealed and closed by port-closure members such as threaded plugs 15. To provide access to the interior of the carrier 13, its lower end is closed by a removable end-closure member 16.

The perforating apparatus 10 further includes perforating means comprised of a plurality of laterally-oriented shaped explosive charges 17 which are disposed at longitudinally-spaced intervals within the carrier 13 and, as will subsequently be explained, are cooperatively secured therein to each face an assigned one of the lateral ports 14. Although the shaped charges 17 could alternatively be all faced in either the same lateral direction or alternately faced in diametrically-opposite directions, by virtue of the present invention the ports 14 can also be oriented so as to face the charges at selected angular increments of 90° for distributing the resulting perforations uniformly about the circumference of a selected interval of the well bore 11. As is typical, the perforating means further include selectively-operable detonating means such as an electrically-responsive blasting cap 18 operatively cou-

pled to a length of detonating cord 19 that is mounted within the carrier 13 in detonating proximity of each of the shaped charges 17. As will subsequently be explained by reference to FIGS. 2 and 3, the new and improved perforating apparatus 10 further includes an elongated tubular support 20 which is adapted to be inserted longitudinally into the carrier 13 for supporting the shaped charges 17 at appropriately-spaced intervals in alignment with their respectively-assigned ports 14.

As best seen in FIGS. 2 and 3, in the preferred embodiment of the shaped charges 17, a typical shaped charge liner 21 is operatively disposed in the hollowed forward end of an explosive pellet 22 for producing, upon detonation, a perforating jet which is directed toward the right (as viewed in FIG. 3) along a selected perforating axis 23. The shaped charges 17 respectively include a cylindrical container which, in the illustrated preferred embodiment, is comprised of a metallic inner jacket 24 that is complementally fitted in a hollowed outer case 25 of a suitable plastic material for minimizing the effects of laterally-directed explosive forces on the interior walls of the carrier 13. The rear of the outer case 25 is shaped as illustrated to provide a rearwardly-facing elongated groove 26 for retaining the detonating cord 19 within detonating proximity of the explosive pellet 22. Since the outer case 25 must complementally fit the interior configuration of the carrier 13, the forward and rearward ends of the case are rounded, as at 27 and 28, in a plane perpendicular to the cutting plane of FIG. 3.

As best seen in FIG. 2, the elongated tubular support 20 is provided with a plurality of diametrically-opposed openings, as at 29 and 30, which are cooperatively arranged in the sides of the tubular support for snugly receiving the forward and rearward portions of the shaped charges 17. As best seen in FIG. 3, in its preferred embodiment, the tubular support 20 is formed with a square cross-section of suitable dimensions for locating its corners in touching engagement or immediately adjacent to circumferentially-spaced portions of the interior walls of the carrier 13. In this preferred embodiment, the elongated support 20 is formed of a relatively-thin flexible material such as cardboard or fiberglass to permit the tubular support to be collapsed or flattened to facilitate its storage and shipment.

To selectively secure the shaped charges 17 in the elongated support 20, each side of the outer cases 25 is provided with identical or similar diametrically-opposed locking lugs 31 and 32 which are cooperatively shaped for snug engagement over the adjacent edge portions of each of the several openings 29 and 30 in the tubular support 20. In the preferred embodiment of the present invention, the lugs 31 and 32 are provided by cutting or forming generally-dovetailed recesses, as at 33, on opposite sides of the outer case 25 to define inclined inward surfaces 34 and 35 on the lugs on opposite ends of and overhanging a flat surface 36 between the lugs. Although the shapes of the lugs 31 and 32 could be non-symmetrical, it is preferred to symmetrically shape them as respectively illustrated to facilitate manufacture of the outer cases 25.

Accordingly, it will be appreciated from FIGS. 2 and 3, that upon insertion of the shaped charges 17 into their respective aligned openings 29 and 30 in the tubular support 20, the adjacent portions of the tubular support surrounding these openings can be readily manipulated as required for disposing the edge portions around the openings into the notches respectively defined by the surfaces 34–36 thereby leaving the lugs 31 and 32 overlapping the exterior of the tubular support. In this manner, by virtue of the cooperation between the tubular support 20 and the lugs 31 and 32 on each side of the charge cases 25, each of the shaped charges 17 will be firmly retained against both axial movement as well as rotation about its perforating axis 23. It will also be noted that once the several shaped charges 17 are inserted into their respective openings 20 and 29 along the length of the tubular support 20, the tubular support will be substantially reinforced against being collapsed into a flattened configuration.

As each of the several shaped charges 17 are respectively being installed on the support 20, the detonating cord 19 is wound around the support and progressively fitted into the elongated grooves 26 as each shaped charge is inserted into its respective openings 29 and 30. Accordingly, as best seen in FIG. 2, once the several shaped charges 17 are installed, the detonating cord 19 will be substantially supported on the tubular support 20 and will be ready for connection to the detonator 18. Moreover, as best seen in FIGS. 4 and 5, it will be appreciated that the square cross-section of the support 20 will result in the detonating cord 19 being wrapped around the flat sides of the support and recessed in the several openings 29 and 30 as it crosses the longitudinal edges of the support. This will, of course, maintain the cord 19 out of contact with the interior walls of the carrier 13 as the support 20 and charges 17 are being slid into the carrier.

It should be noted at this point that, by virtue of the ease with which the several shaped charges 17 can be installed into the tubular support 20, they could be easily repositioned or removed should this subsequently be necessary before the perforating apparatus 10 is lowered into the well bore 11. For example, it is not at all uncommon for a last-minute change in operations to require an additional or reduction in the total number of the shaped charges 17 which are to be used in a given perforating operation. It will, be appreciated that one or more of the several shaped charges 17 can be either readily removed from or mounted on the tubular support 20 without disturbing the other charges or disrupting their engagement with the detonating cord 19.

Turning now to FIG. 4, the perforating apparatus 10 of the present invention is illustrated as it will appear when the tubular support 20 and the several shaped charges 17 have been installed within the carrier 13 and the port plugs 15 are to be installed into the ports 14. As illustrated, as the port plug 15 is screwed into the port 14, its forward or inner end will initially encounter a plastic ring 37 loosely disposed on the forward end of a somewhat frusto-conical or domed annular retainer 38 of a yieldable material which is mounted on the forward end of the jacket and sized to provide an optimum stand-off distance. Thus, as the port plug 15 is threaded further into the port 14, the rearward curved wall 28 of the case 25 will initially be moved against the adjacent rear wall of the carrier 13. Then, as will be recognized by comparison of FIGS. 4 and 5, as the port plug 15 is finally tightened, the domed retainer ring 38 will be partially collapsed so as to tightly jam the shaped charge 17 between the port plug and the rear wall of the carrier 13. The detonating cord 19 will be safely confined in the several grooves, as at 26, so as to prevent it from being either moved or crushed.

It will, of course, be recognized that by virtue of the snug or tight fit provided by the rear wall **28** of the case **25** and the collapsed ring **38**, the shaped charge **17** will be firmly locked into position within the carrier **13** for withstanding even the severest of shocks as the perforating apparatus **10** is being lowered into the well bore **11**. It should also be noted that by virtue of the relatively-large central openings **39** in the domed retainers **38**, there will be little or no interference with the formation of the perforating jets upon detonation of the charges **17**.

Accordingly, it will be appreciated that the present invention has provided new and improved perforating apparatus in which one or more shaped charges can be easily mounted in an end-loaded carrier and accurately positioned in coincidental alignment with their respectively-assigned lateral ports. Moreover, by virtue of this new and improved apparatus, once the shaped charges have been installed into the perforating carrier, they can be tightly retained in position without interfering with the operational performance of the charges.

While only a particular embodiment of the present invention has 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. Perforating apparatus adapted for producing perforations in a well bore and comprising:

an enclosed carrier including a tubular body having at least one end opening providing access into the internal bore of said body, and end-closure means adapted for fluidly sealing said one end opening;

perforating means including at least one shaped explosive charge having an external case sized for reception within said internal bore with said shaped charge positioned for firing along a selected perforating axis; and

means adapted for supporting said shaped charge at a selected firing position within said internal bore and including a tubular support member sized for reception within said internal bore and having aligned openings in opposite walls thereof adapted for receiving spaced portions of said case, and means cooperatively arranged on said case for locking engagement with at least one of said walls adjacent to at least one of said aligned openings to prevent substantial movement of said shaped charge relative to said support member.

2. The perforating apparatus of claim **1** wherein said tubular body has a side port opening into said body bore ahead of said selected firing position of said shaped charge, and further including:

port-closure means adapted for fluidly sealing said side port; and

means cooperatively arranged between said shaped charge and said port-closure means for securing said shaped charge in its said selected firing position upon installation of said port-closure means in said side port.

3. The perforating apparatus of claim **2** wherein said perforating axis is substantially perpendicular to the longitudinal axis of said body, and said side port is coincidentally aligned with said perforating axis.

4. The perforating apparatus of claim **2** wherein said securing means include:

an annular retainer of a yieldable material interposed between said case and said port-closure means and adapted to be compressed therebetween upon installation of said port-closure means in said side port.

5. The perforating apparatus of claim **1** wherein said support member has first and second intersecting walls diverging outwardly on opposite sides of said one aligned opening and said locking means include:

first and second lugs on opposite sides of said case and respectively having outwardly-diverging inner surfaces adapted to abut outer surfaces of said first and second walls adjacent to said one aligned opening.

6. The perforating apparatus of claim **5** wherein said tubular body has a side port opening into said body bore ahead of said selected firing position of said shaped charge, and further including:

port-closure means adapted for fluidly sealing said side port; and

means cooperatively arranged between said shaped charge and said port-closure means for securing said shaped charge in its said selected firing position upon installation of said port-closure means in said side port.

7. The perforating apparatus of claim **6** wherein said perforating axis is substantially perpendicular to the longitudinal axis of said body, and said side port is coincidentally aligned with said perforating axis.

8. The perforating apparatus of claim **6** wherein said securing means include:

a frusto-conical tubular retainer of a yieldable material interposed between said case and said port-closure means and adapted to be compressed therebetween upon installation of said port-closure means in said side port.

9. Perforating apparatus adapted for producing perforations in a well bore and comprising:

an enclosed carrier including an elongated cylindrical body having an internal bore with at least one open end, a plurality of lateral ports opening into said internal bore and arranged at spaced intervals along said body, an end-closure member adapted for fluidly sealing said open body end, and a plurality of port-closure members cooperatively arranged for fluidly sealing said lateral ports;

perforating means including a plurality of shaped explosive charges having external cases sized for reception within said internal bore with each of said shaped charges positioned for firing along a lateral perforating axis; and

means adapted for securing said shaped charges within said internal bore in facing alignment with said lateral ports and including a multi-walled tubular support sized for reception in said internal bore and having a plurality of first and second aligned case openings arranged at said spaced intervals in opposite walls of said support for receiving the forward and rearward end portions of said charge cases to respectively position each of said shaped charges in axial alignment with one of said lateral ports, and at least a first lug on each of said charge cases cooperatively arranged to respectively project outwardly from said first case openings into engagement with at least a first one of said walls to

prevent substantial movement of said shaped charges relative to said support.

10. The perforating apparatus of claim 9 further including:

a second lug on each of said charge cases spatially disposed from said first lugs and cooperatively arranged to respectively project outwardly from said second case openings for engagement with at least a second one of said walls.

11. The perforating apparatus of claim 9 wherein said first case openings are formed in the intersection of said first wall with a second adjoining wall of said support and said second case openings are formed in at least a third one of said walls opposite to said first and second walls, and further including:

a second lug on the opposite side of each of said charge cases from said first lugs and cooperatively arranged to respectively project outwardly from said first case openings for engagement with said second wall.

12. The perforating apparatus of claim 9 wherein said first case openings are formed in the intersection of said first wall with a second adjoining wall of said support and said second case openings are formed in the intersection of adjoining third and fourth ones of said walls opposite to and respectively adjoining said first and second walls, and further including:

a second lug on the opposite side of each of said charge cases from said first lugs and cooperatively arranged to respectively project outwardly from said first case openings for engagement with said second wall; and

third and fourth lugs on opposite sides of said charge cases and cooperatively arranged to respectively project outwardly from said second case openings for engagement with said third and fourth walls.

13. The perforating apparatus of claim 12 wherein said perforating means further include:

electrically-responsive detonating means including a blasting cord disposed along said tubular support and having a plurality of loops mounted around said rearward end portions of said charge cases.

14. The perforating apparatus of claim 12 wherein said securing means further include:

a plurality of frusto-conical annular retainers of a yieldable material respectively interposed between said forward end portions of said charge cases and said port-closure members and adapted to be compressed therebetween upon installation of said port-closure members in said lateral ports.

15. Perforating apparatus comprising:

an elongated tubular member having first and second adjoining walls diverging outwardly in relation to one another and third and fourth adjoining walls diverging outwardly in relation to one another and respectively opposing said first and second walls;

first and second series of laterally-aligned openings respectively formed at longitudinally-spaced intervals along the intersection of said first and second walls and the intersection of said third and fourth walls;

a plurality of shaped explosive charges having external cases respectively disposed in each opposed pair of said first and second aligned openings and having its forward and rearward end portions projecting therefrom; and

means adapted for securing said shaped charges on said tubular member including a first dovetailed recess formed on one side of the intermediate portion of each of said charge cases and defining opposed complementary surfaces respectively engaged with the outer surfaces of said first and third walls between said first and second aligned openings to substantially secure said shaped charges against either rotation or longitudinal movement in relation to said tubular member.

16. The perforating apparatus of claim 15 further including:

a second dovetailed recess formed on the opposite side of said intermediate portion of each of said charge cases and defining opposed complementary surfaces respectively engaged with the outer surfaces of said second and fourth walls between said first and second aligned openings.

17. The perforating apparatus of claim 16 wherein said first and third walls are adjoining and said second and fourth walls are adjoining to give said tubular member a substantially square cross-sectional configuration.

18. The perforating apparatus of claim 17 wherein said walls are flexibly joined to one another to enable said tubular member to be laterally collapsed.

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