United States Patent [19]

Lendermon et al.

[11] **Patent Number: 4,744,424**

[45] **Date of Patent: May 17, 1988**

[54] **SHAPED CHARGE PERFORATING APPARATUS**

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[73] Assignee: **Schlumberger Well Services**, Houston, Tex.

[21] Appl. No.: **898,962**

[22] Filed: **Aug. 21, 1986**

[51] **Int. Cl.**[4] **E21B 43/117**

[52] **U.S. Cl.** **175/4.51;** 175/4.6

[58] **Field of Search** 175/2, 4.51, 4.6; 160/55, 55.1

[56] **References Cited**

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Primary Examiner—Stephen J. Novosad

Assistant Examiner—William P. Neuder

[57] **ABSTRACT**

In the representative embodiment of the new and improved perforating apparatus described herein, shaped charge cases are provided with matching upper and lower supports with parallel abutment surfaces and alignment means cooperatively arranged to enable a plurality of these charge cases to be stacked together for erecting an intertwined assembly of cases. By appropriately selecting the combined heights of the matching supports, adjacent ones of the charge cases can be closely spaced one above the other and directed outwardly along selected radial perforating axes at uniform angular spacings.

21 Claims, 3 Drawing Sheets

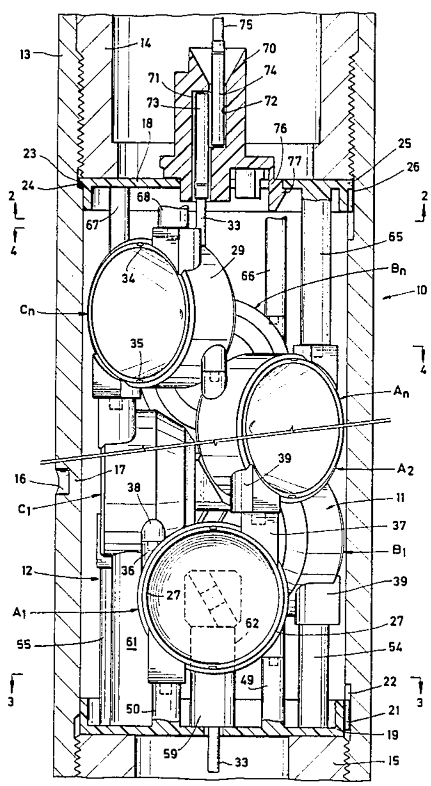
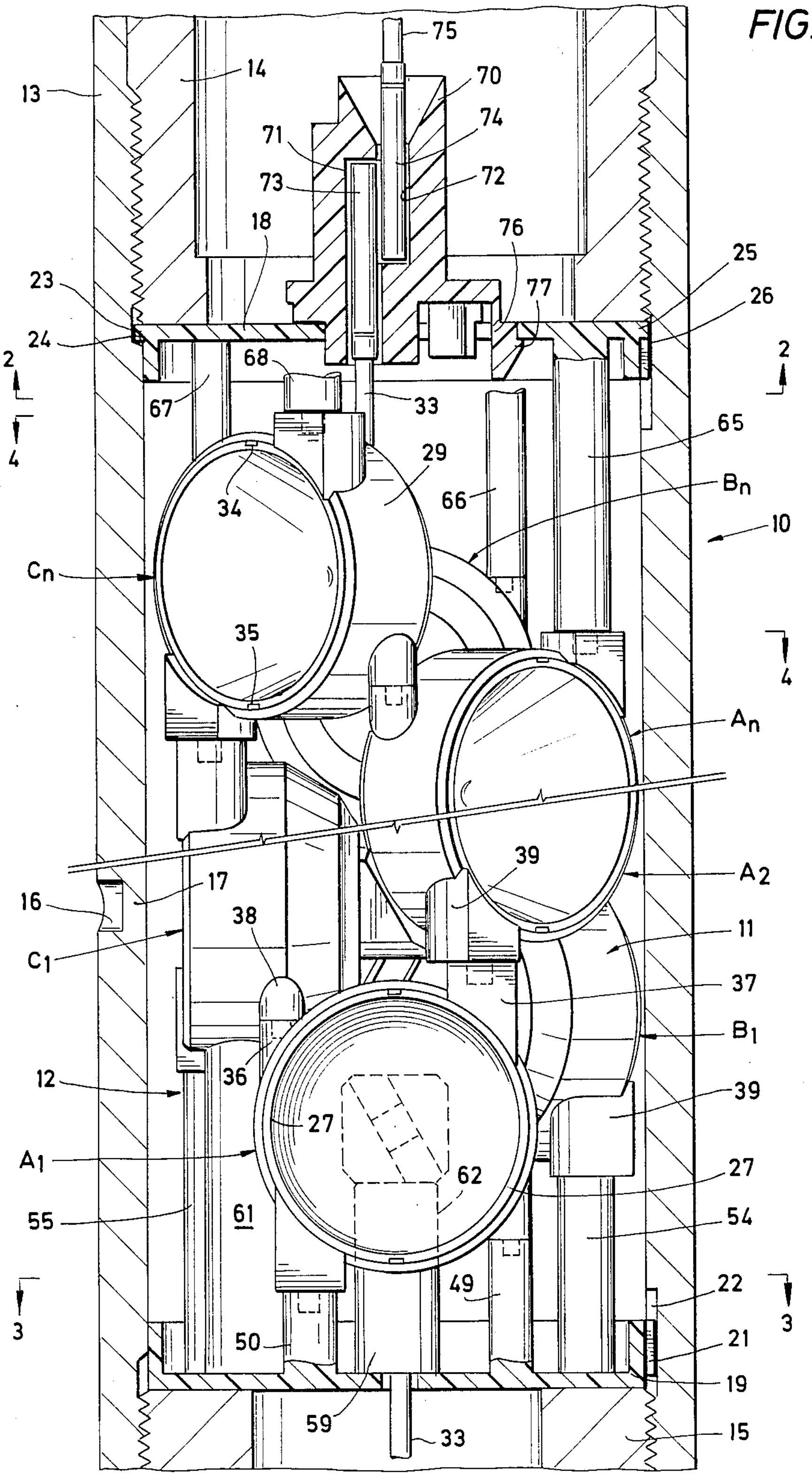


FIG.1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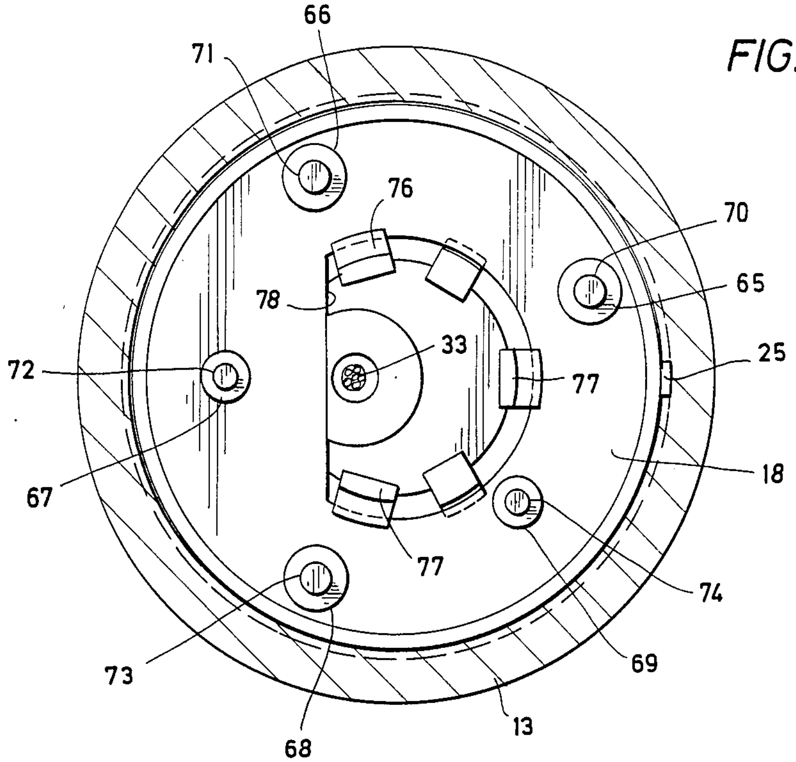
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FIG. 2

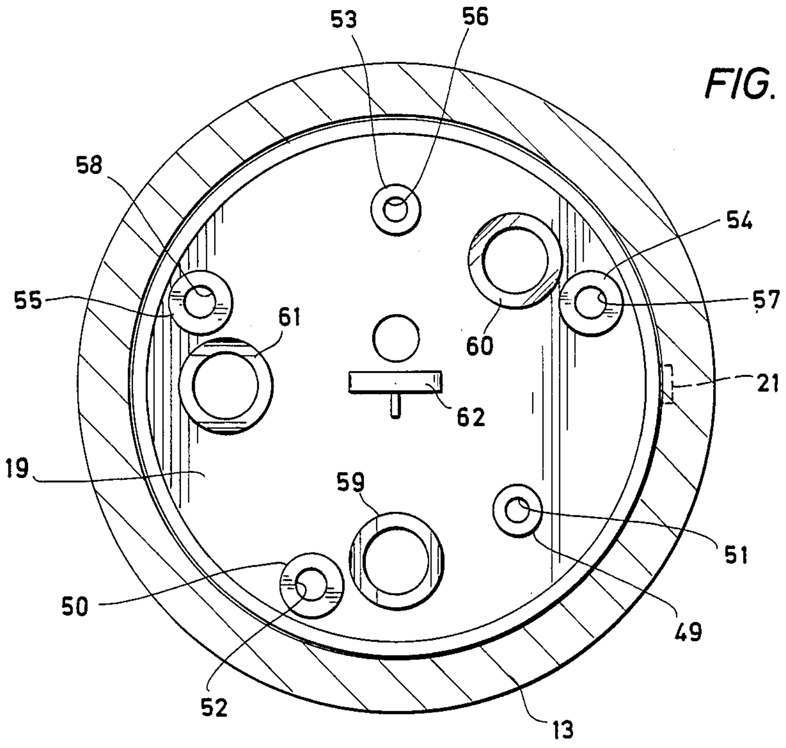
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FIG. 3

FIG. 4

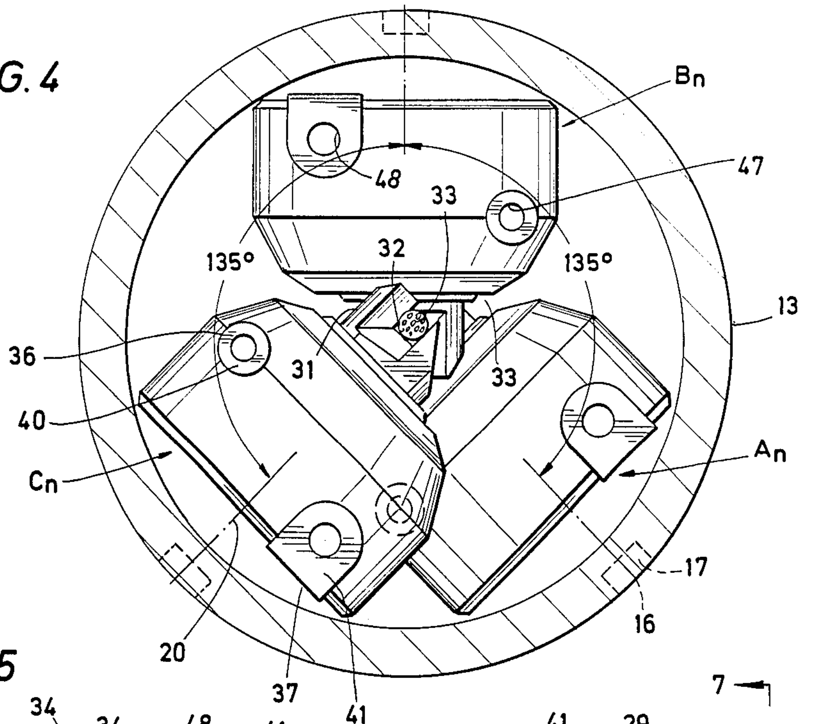
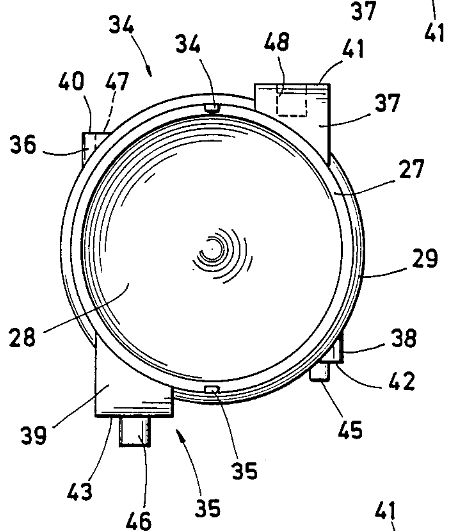


FIG. 5



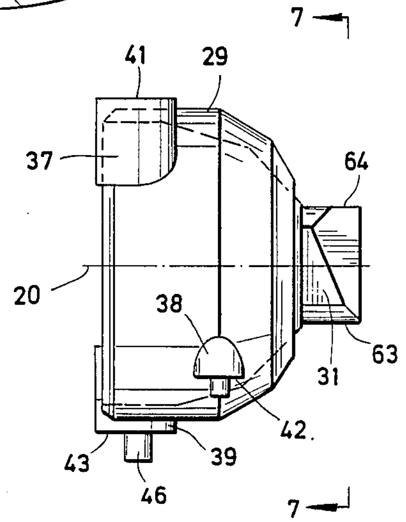


FIG. 6

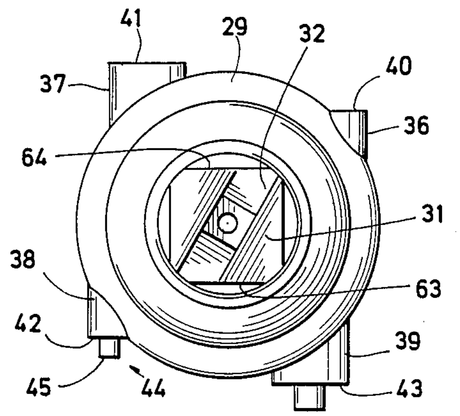


FIG. 7

SHAPED CHARGE PERFORATING APPARATUS

FIELD OF THE INVENTION

This invention relates to new and improved well bore perforating apparatus operatively arranged to be dependently suspended in a well bore and selectively operated for producing multiple perforations in a cased well bore. More particularly, this invention involves new and improved perforating appartus including a plurality of uniquely-interfitting shaped explosive charges adapted to be assembled together to provide an optimum arrangement of the maximum number of the largest possible charges which can be installed in a tubular carrier of a given diameter.

BACKGROUND ART

The typical enclosed expendable perforators which are used for perforating well bores generally utilize an elongated tubular housing or so-called "carrier" in which a plurality of laterally-directed shaped explosive charges are cooperatively mounted at longitudinally spaced intervals. To fire the charges, a length of detonating cord is disposed within the carrier and cooperatively positioned within detonating proximity of the base of each charge and one end of the cord is coupled to a detonator which is appropriately arranged to be selectively actuated from the surface. These enclosed carriers are typically fashioned from steel tubing having a wall thickness sufficient to withstand the extreme pressure conditions ordinarily encountered in most well bores. Once the charges and detonating means have been mounted in the carrier, suitable end closure members or heads are positioned in the opposite ends of the tubular body to block the entrance of well bore fluids into the interior of the carrier.

Those skilled in the art will recognize, of course, that for an enclosed carrier of a given diameter, significantly larger shaped charges can be employed where the charges are inserted into one end of the carrier rather than being installed through lateral ports in the carrier wall. Nevertheless, the typical end-loaded carrier still presents several problems. For instance, steps must be taken to reduce the interference to the perforating jets that takes place as they pass through the wall of the carrier. One common technique involves mounting the charges in the carrier and angularly aligning them so that, when they are detonated, the perforating jet produced by each charge will pass through a small-diameter lateral opening in the carrier wall that is plugged by a thin closure member. As an alternative for these lateral openings and closure members, small-diameter countersunk or blind holes can instead be drilled at appropriate locations in the outer wall of the carrier during its fabrication so as to leave only reduced-thickness wall portions to be penetrated by the perforating jets when the charges are subsequently fired.

Those skilled in the art will, of course, appreciate that regardless of whether thin closures or reduced-thickness wall portions are employed, in either case some provision must be made for installing the shaped charges into the carrier in such a manner that each shaped charge will be accurately aligned with its associated reduced-thickness wall portion. Heretofore, this problem has been resolved by simply mounting the shaped charges intended for a given carrier on an elongated tubular support that is cooperatively arranged to be inserted longitudinally into the carrier and positioned as needed for aligning the several charges with their respective reduced-thickness wall portions. Typically these elongated supports have been fabricated by cutting a series of longitudinally spaced lateral openings in the opposing side walls of elongated metal or plastic tubes which have either a square or circular cross-section of suitable dimensions to snugly fit the internal bore of the carrier body.

These elongated tubular supports have, of course, been generally satisfactory for use in end-loaded carriers where it is considered adequate to mount the charges in the carrier at such typical longitudinal spacings as two or four shaped charges per foot of length of the carrier. With these spacings, the forward and rear portions of the charge cases are retained in the opposed openings in the charge supports and there is sufficient material remaining in a given support tube to keep the charges from being misaligned by rough handling or by impact forces on the carrier as it is being lowered into a well bore. As described in U.S. Pat. No. 3,773,119, for example, support tubes such as these have been successfully used heretofore by forming the supports from tubes of heavy cardboard or fiberglass having sufficient strength for supporting the charge cases during perforating operations as well as by using square tubes that can be easily flattened where necessary to also resolve a shipping or storage problem.

In the past few years it has been found that in some situations it is necessary to significantly increase the number of perforations per foot in a given perforated interval of a well bore. In particular, recent developments in conducting gravelpack operations have made it advantageous to put at least ten or twelve perforations per foot in each well bore interval that is to be gravel packed. Those skilled in the art will realize, of course, that there is a practical limit to the number of shaped charges of a given size that can be mounted in a given length of a typical support tube. For instance, if the overall length of the charges is greater than the radius of the internal bore of the carrier, only one shaped charge can be mounted in any given transverse plane. Conversely, if more than one charge is to be mounted in the same transverse plane, the overall length of each charge is limited to something less than the internal radius of the carrier and the overall performance of these charges will be correspondingly reduced. In any case, it will be recognized that if a typical support tube is to be arranged to carry more than four shaped charges per foot, the overall strength of the tube will be greatly reduced so that it will be difficult to protect these tubes during their shipment and storage. It has also been found that these weaker tubes can be easily damaged by rough handling once the perforator carrier is loaded and is ready for operation.

Other proposals which have been made for installing a large number of shaped charges in an end-loaded carrier involve the use of three or four shaped charges which are loaded in a unitary container and respectively aligned to be fired along a separate perforating axis that is angularly displaced from the perforating axes of the other charges in the same container. A number of these charge clusers are then stacked in a typical end-loaded carrier and cooperatively associated with a detonating cord extending along the central axis of the stacked containers.

Those skilled in the art will, of course, recognize that in addition to the problems mentioned above regarding

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