

July 4, 1961

L. W. TOELKE

2,990,773

APPARATUS FOR PERFORATING WELL CASING

Filed May 13, 1957

3 Sheets-Sheet 1

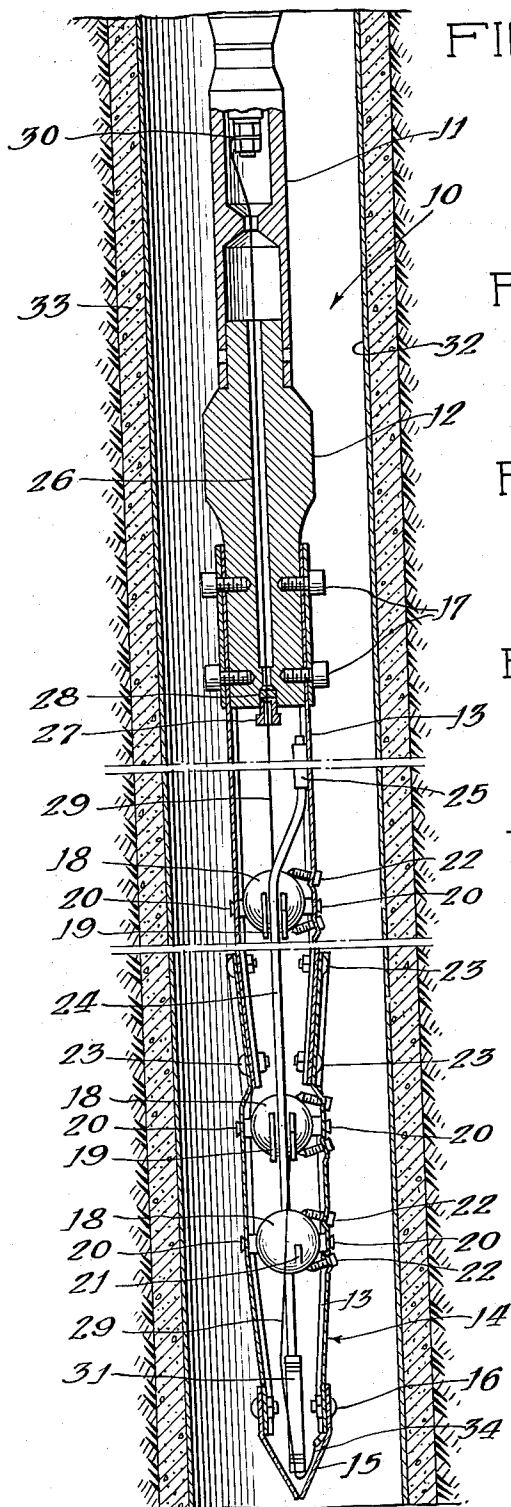


FIG. 1

FIG. 5

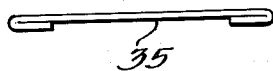


FIG. 6

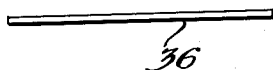


FIG. 7

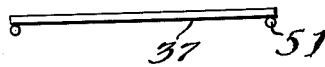


FIG. 8

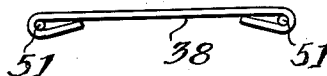


FIG. 9

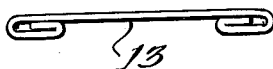
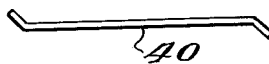


FIG. 10



FIG. 11



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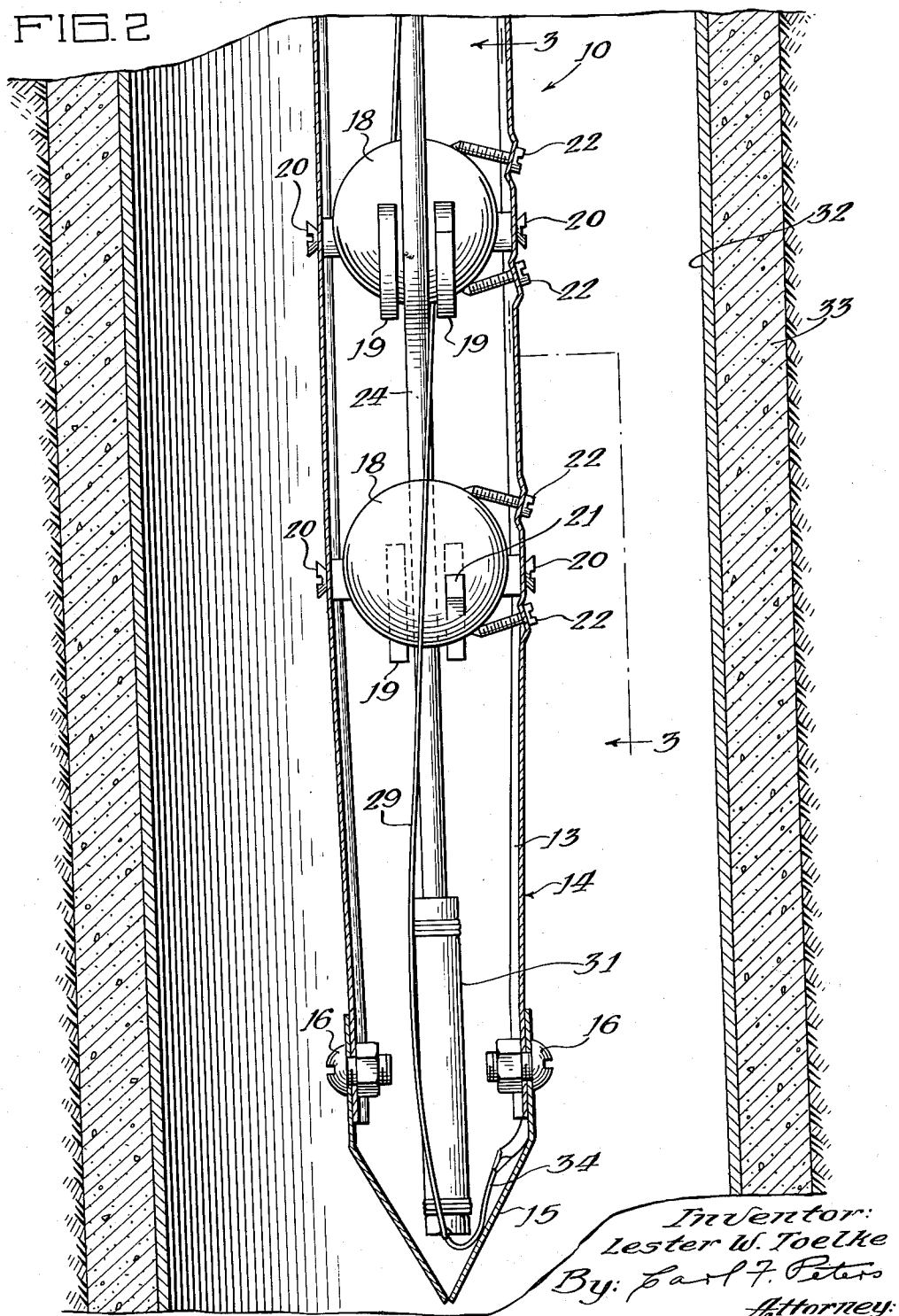
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FIG. 2



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FIG. 3

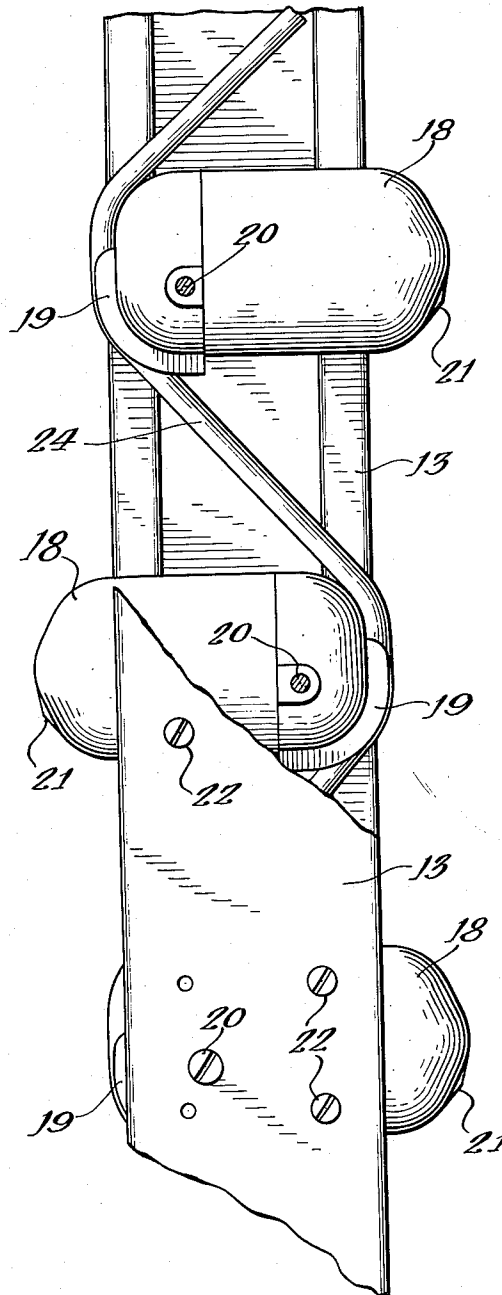
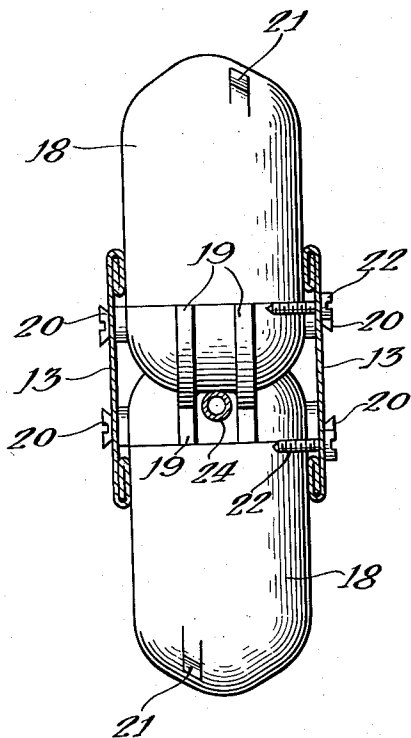


FIG. 4



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APPARATUS FOR PERFORATING WELL CASING
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This invention relates to devices employed in the perforating of well bores and casing positioned therein, and particularly to an improved form of carrier assembly supporting so-called lined shaped charge explosive units of the "jet" type.

The technique of perforating casing and well bores has been considerably advanced by the use of so-called explosive hollow "jet" or "lined shaped charges." The construction of these charges and their utilization in perforating equipment has been described by McLemore in the Oil and Gas Journal, December 28, 1946; and in U.S. Letters Patents Nos. 2,399,211 and 2,494,256. It has been the practice to install charges of this type in recoverable carriers which are generally of the tubular steel type. These carriers may be solid or hollow and are provided with a plurality of barrels into which the perforating units may be inserted, usually being protected by sealing means to prevent intrusion of well fluids. All of the units are fired by a suitable detonating train, such as Primacord which extends longitudinally through the interior of the carrier. These recoverable carriers are very expensive to machine and require a considerable amount of steel, often a critical material. Constant maintenance is required because with each firing of the gun, it becomes distorted until the barrels reach a diameter which render the gun unsafe to use. It must then either be discarded or extensively reworked. Furthermore, such carriers are relatively heavy and bulky and must be of considerable length in order to support the required number of charges employed in a single run. Also, because of their size they are difficult to maneuver and retrieve from the well bore.

In order to obviate some of the above difficulties several expendable carriers have been designed. However, these carriers also have many unsatisfactory features. Generally they are constructed of a thin strip of metal having large diameter holes in the medial or web portion of the strip to receive the charge cases. The charges are positioned in these holes by means of tape, clips, etc., none of which hold the charge firmly enough for rough usage in transporting the tool or in lowering it and maneuvering it in a well. Since the strips are quite flexible they cannot be handled roughly because the charges will become loosened and misaligned resulting in poor perforating performance. Also it is quite difficult to accurately ascertain the depths to which such expendable carriers are lowered because they are quite flexible and will not support much weight. Others have proposed to weight the bottom portion of such carriers but this is undesirable because the weights are often sheared off by the explosion and left in the well. Also, such expendable strip carriers are torn beyond use after each shooting operation and while they may, in some cases, be retrievable from the well, such carriers leave a considerable amount of fragmented junk metal in the hole.

Accordingly it is a principal object of this invention to provide a relatively inexpensive yet durable carrier for lined shaped charge explosives which is completely retrievable from the well after firing, and which leaves a minimum amount of material in the well resulting only from the fragmentation of the explosive charge cases.

It is a further object of the invention to provide an

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improved carrier for lined shaped charge explosives which can be retrieved from the well after firing.

It is a further object of the invention to provide an improved carrier for lined shaped charge explosives which does not require the use of holes, slots, etc. in the carrier body itself through which Primacord or other detonator is threaded, thereby eliminating the possibility of cutting and wetting the detonator in the well which often results in misfiring of the charges.

More specifically, the improved carrier assembly in accordance with one embodiment of my invention comprises a single pair of oppositely disposed and substantially parallel and uniformly spaced continuous strips of relatively thin, flexible and impact-resistant sheet material, a plurality of elongated shaped charge units securely positioned between and affixed to the strips, the longitudinal axes of the shaped charge units being substantially normal to the longitudinal edges of the strips, means for connecting the upper end of said strips to a lowering means, and means for detonating the shaped charge units.

The foregoing, as well as other objects of this invention, will become apparent from the following detailed description and in view of the accompanying drawings which illustrate useful embodiments of the invention as well as modifications thereof.

In the drawings:

FIGURE 1 is a vertical section showing one form of the carrier assembly in accordance with this invention, after lowering the device into a well bore lined with metal casing;

FIGURE 2 is an enlarged fragmentary view in section of the lower portion of the device shown in FIGURE 1;

FIGURE 3 is a side elevation, partly in section, taken along the line 3-3 of FIGURE 2 and showing the explosive charges in minimum extension;

FIGURE 4 shows a modified form of the invention exemplifying means for forming a gun wherein the explosive charges are in greater extension than FIGURE 3;

FIGURES 5 through 11 are cross-sectional views of modified forms of the carrier strips which are a feature of this invention.

Referring first to FIGURE 1, which shows a preferred embodiment of my invention, the device is shown generally at 10 after having been lowered into well casing 32 backed up by cement 33. The carrier assembly 10 consists of a single pair of relatively thin flexible continuous and impact-resistant metallic strips 13 which are disposed opposite each other in substantially parallel alignment and with substantially uniform spacing, except where the strips are tapered inwardly or flared at the ends to join several sections of the carrier assembly. The strips 13 are spaced sufficiently apart to accommodate a number of lined shaped explosive charge units 18 which are fixed and secured between the strips by threaded means, such as fastening screws 20 which traverse appropriate openings in the strips. Only the exterior or casing portion of these charges is shown in the drawings for purposes of illustration. In the particular embodiment shown in the drawings the movement of the charges is further restricted by the employment of support screws 22 which are machine screws intersecting the web of the strips 13 and which frictionally engage the outside of the explosive charge casing, as shown. It is to be understood, however, that the employment of the supporting screws 22 is not essential to the successful operation of the carrier assembly.

The strips 13 may be constructed of relatively pliable and impact resistant sheet material such as ordinary mild steel $\frac{1}{16}$ " thick. Other equivalent materials may be used. The width of the strip is a matter of convenience and is governed by the size of the shaped charge units 18 and

the inside diameter of the well casing. The length of the strips may be any suitable or desired length and several sections of the carrier assembly may be secured together by bolts 23 as shown in FIGURE 1. The side margins or longitudinal edges of the strips 13 are suitably reinforced by crimping the edges of the strips such as shown in FIGURES 5, 8, 9 and 10, or they may be suitably reinforced by strong steel wire 51 as illustrated in FIGURES 7 and 8.

The carrier strips 13 are fastened at the top end of the carrier assembly to a coupling member 12 by means of bolts or screws 17. In the bottom portion of the carrier assembly the strips 13 are tapered slightly inwardly and fastened to an inwardly tapered member 15 by fastening screws 16. The tapered bottom member 15 facilitates lowering the carrier assembly through the casing.

Above the coupling member 12 to which the carrier assembly is attached there is provided a socket head 11 which contains an electrical conductor wire 29 attached to electrode terminal 30. This head is designed to permit increasing the weight of the carrier assembly for conditions where the casing size or the well fluid require extra weight for rapid descent of the gun. The conductor wire 29 runs longitudinally through the coupling adapter member 12 through a bore 26. Where the conductor wire leaves the coupling member 12 there is provided a plastic seal 28 fastened in position by compression nut 27. The conductor wire 29 runs longitudinally of and between the strips 13 to the bottom portion of the carrier assembly at which point it is attached to a detonator 31 such as a blasting cap and booster, which in turn is fastened and sealed to the end of a length of a detonating train such as Primacord 24. The Primacord is strung lengthwise upwardly and between the carrier strips 13 to contact the rear face of each shaped charge casing 18, the latter being fixed in a position substantially normal to the longitudinal edges of the strips 13 so that the high velocity gases which are produced by firing of the charges will be directed substantially horizontally, or perpendicularly with respect to the casing wall. The upper end of the Primacord detonating train is sealed from well fluids as designated by No. 25. There is further provided a ground lead from the point where the lead wire 29 is attached to the detonator 31, the ground being to the bottom of the carrier assembly as shown.

The detonating train for the shaped charge units 18 preferably consists of a length of flexible Primacord 24 which runs lengthwise and inside of the carrier strips 13, passing successively over and in contact with the rear face of each perforating unit as shown in FIGURE 1, 3 and 4. The rear faces of the shaped charge units are provided with notches or guide lugs 19 to receive the Primacord. If desired, this cord may also be secured to the charge casing wall by tape, clips, or other fastening means. In the arrangement illustrated in the drawings the detonating train is fired from its lower end but it should be understood that either top or bottom firing arrangements may be used successfully.

In operation the carrier assembly, having the perforating units 18 securably mounted and aligned between the carrier strips 13, as shown in FIGURES 1, 3 and 4, is connected to a socket and electrical lead wire assembly 11 and coupling member 12. The carrier assembly is then lowered by means of a cable attached to the socket head. When the carrier assembly has reached the desired depth in the casing electric current is supplied from the surface through lead wire 29 to blasting cap and booster assembly 31, thereby detonating the Primacord 24 and successively causing all of the shaped charge units 18 to explode. While the gaseous jets from the perforating units are primarily directed horizontally against and through the casing 32 and cement 33, there is a substantial radial force or moment developed which acts laterally against the strips 13. Since the latter are flexible these will be

slightly bowed in the immediate charge area resulting in a slight deformation where each charge has exploded. This action is particularly beneficial to the operator because it enables him to ascertain whether all the charges have fired and adequate perforations have been obtained in the casing. Even though the carrier strips 13 may be slightly deformed they will nevertheless be completely intact and the entire carrier assembly, including the bottom member 15 may be readily withdrawn from the well.

FIGURES 5 through 11 illustrate in cross section other suitable shapes for the strips 13 of the carrier assembly. FIGURE 6 shows a flat metal strip which, in FIGURES 5, 8, 9 and 10 has been bent back or crimped along the longitudinal edges to form reinforcing beads. In FIGURES 7 and 8, heavy wire 51 has been affixed to the longitudinal edges of the strips for reinforcing properties. In FIGURE 11 the metal strip of FIGURE 6 has been bent in opposite directions along the two longitudinal edges.

The carrier assembly of this invention may be made in any desired length and may be made up of inter-connected sections as shown in FIGURE 1 to obtain a length sufficient to support any desired number of perforating charge units.

It will thus be seen that this invention provides a retrievable perforating carrier assembly for shaped charge units which has sufficient rigidity to support weight but still providing sufficient flexibility to pass tight places in the casing. The carrier assembly can also be spirally twisted to permit a shot pattern of any desired degree of angular orientation. The charges may be positioned to shoot uni-directional or in opposite directions (180°), the latter being the pattern generally used. Also, the charges can be fixed at any of the location holes to form a gun of various diameters to suit the well bore. This is evident from an analysis of FIGURE 4 wherein two lines of such location screw holes 20 are exemplified and employed in strip members 13. It will be appreciated that the charges 18 which are shown in this figure are at different levels just as are the charges shown in figure.

While the embodiment of the invention illustrated in the drawings shows certain preferred mechanical details, such as the means for securably fixing the shaped charge units between the strip members 13 and for fastening several sections of carrier assembly together by means of correspondingly tapered and flared end portions of the strips, it should be understood that other equivalent means for accomplishing these results can be used and are contemplated by the invention which is limited in scope only by the appended claims.

I claim:

1. A retrievable shaped charge carrier assembly for perforating well casing comprising a single pair of oppositely disposed and substantially parallel and uniformly spaced continuous flat strips of relatively thin, flexible and impact-resistant sheet metal, a plurality of elongated shaped charge units secured in fixed position between and to said strips by threaded means which traverse openings in said strips and threadedly engage said units, the longitudinal axes of said shaped charge units being substantially normal to the longitudinal edges of and parallel to the flat faces of said strips, means for connecting the upper end of said strips to a lowering means, and a detonating train running longitudinally of and between said strips and in contact with the rear face of said charge units.

2. A retrievable shaped charge carrier assembly for perforating well casing comprising a single pair of oppositely disposed and substantially parallel and uniformly spaced continuous flat strips of relatively thin, flexible and impact-resistant sheet metal, reinforcing elements disposed longitudinally along the side edges of said strips, a plurality of elongated shaped charge units secured in fixed position between and to said strips by threaded means which traverse openings in said strips and threadedly engage said units, the longitudinal axes of said shaped charge

units being substantially normal to the longitudinal edges of and parallel to the flat faces of said strips, means for connecting the upper end of said strips to a lowering means, and a detonating train running longitudinally of and between said strips and in contact with the rear face of said charge units.

3. A device according to claim 2 wherein the metal strips are approximately $\frac{1}{16}$ inch thick and each longitudinal edge of said strips has been bent inwardly upon itself to form the reinforcing elements.

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