Aug. 7, 1962 M. P. LEBOURG 3,048,101

PERFORATING APPARATUS

Filed Feb. 23, 1960 2 Sheets-Sheet 1

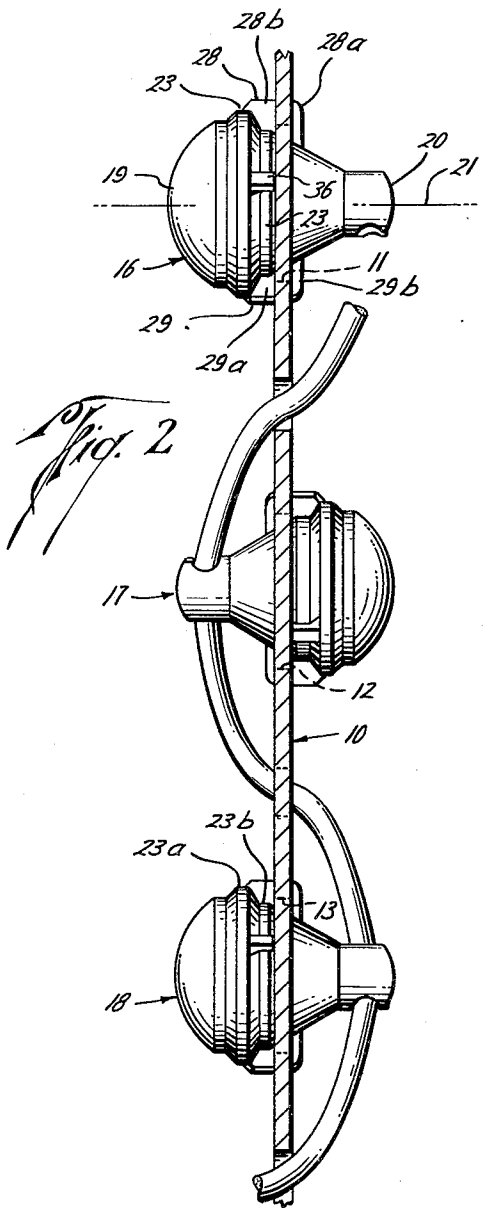


Fig. 2

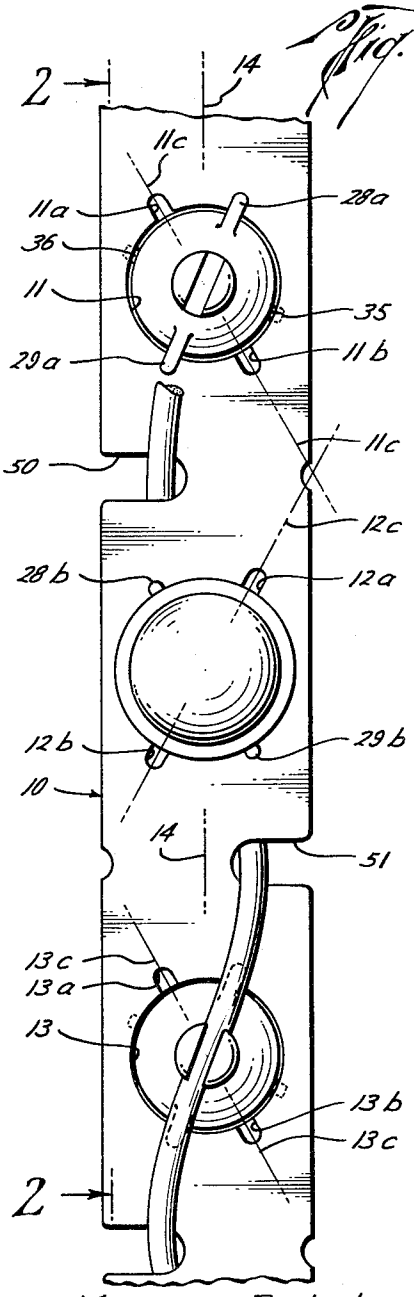


Fig. 1

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Filed Feb. 23, 1960 2 Sheets-Sheet 2

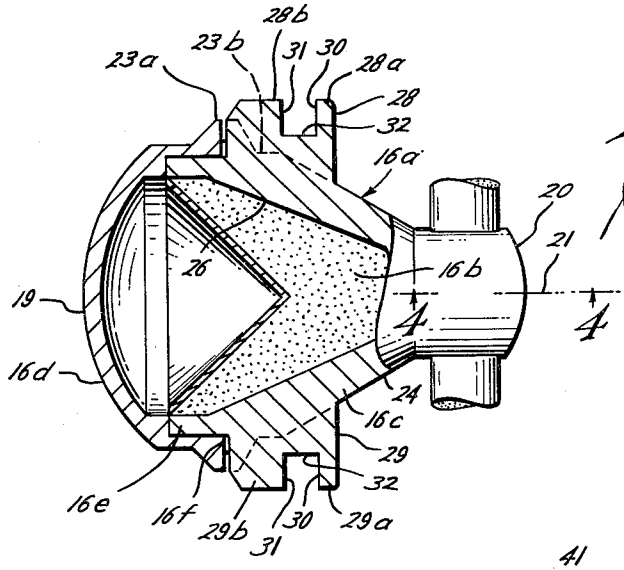


Fig. 3

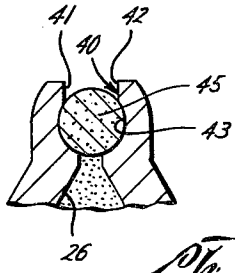
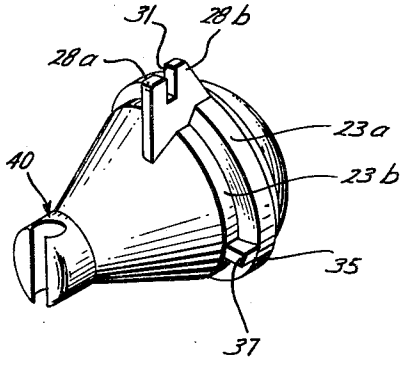


Fig. 4

Fig. 5



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3,048,101

Patented Aug. 7, 1962

3,048,101

PERFORATING APPARATUS

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Filed Feb. 23, 1960, Ser. No. 10,433
10 Claims. (Cl. 102—20)

This invention relates to well perforating apparatus, and more particularly, to expendable type perforating apparatus for use in well strings of small diameter.

In many types of well completion presently practiced, it is both necessary and desirable that a perforating apparatus for producing perforations in formations be passed through a tubing having a diameter on the order of two or two and one-half inches. Particularly in the case where the perforating apparatus is operated within a tubing of small diameter, it is most desirable to reduce the amount of debris of the perforating apparatus that is left in the tubing. Many factors, of course, enter into the design and selection of perforating apparatus for passage through a tubing and the amount of debris a perforating apparatus will produce but, in general, the types of perforating apparatus may conveniently be divided into a so-called carrier type apparatus and a so-called capsule type apparatus. The advantages and disadvantages between the two types of apparatuses need not be described herein, it being sufficient to specify that the present invention relates particularly to perforating apparatus of the so-called capsule type.

Generally, in a capsule type perforator apparatus, a number of shaped charges in capsule containers are linked to one another by a linking mechanism on the containers to form a chain or link assembly of charges. A suitable blasting cord initiating means is interconnected between the various containers to detonate the shaped charges. The debris that is produced from this capsule type perforator results mainly from the capsule container itself and the linkage mechanism necessary to interconnect the capsules. In the present invention, an assembly of capsule type shaped charges is presented in which the debris left in the borehole is resultant solely from the capsule container, the means for interconnecting the capsule containers being retrievable. In this manner, the amount of debris left in the borehole can be considerably reduced.

Accordingly, it is an object of the present invention to provide new and improved capsule type, shaped charge perforating apparatus including capsule containers arranged together with a retrievable interconnecting device so as to minimize debris.

It is a further object of the present invention to provide new and improved capsule-type shaped charge perforating apparatus including capsule containers arranged together with a retrievable interconnecting device in which both the containers and device are simple and inexpensive in construction and operation.

Apparatus in accordance with the present invention includes an elongated and continuous strip member having a plurality of openings spaced from one another along a length of the strip member. A plurality of capsulated shaped charge devices are provided, each having an intermediate section with a portion sized to be received in the coresponding strip opening and having forward and rearward ends along the firing or jet axis of the charge device. About the openings in the strip member are radially extending slots. Attaching means for the charge devices includes a set of radially extending lug portions and radially extending abutment portions on the intermediate section which are spaced axially from one another a distance corresponding generally to the thickness to the strip member so that the lug portions may be inserted

into the slots and rotated thereby permitting the lugs and abutment portions to engage opposite sides of the strip. The forward ends of the charge devices alternately face in opposed directions, and, to insure the rotative positioning of the shaped charge devices in the strip, a blasting cord means extends along the length of the strip member and is received within the rearward ends of the shaped charge devices so as to hold the devices in a rotatively attached position.

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 drawing in which:

FIG. 1 illustrates a front view of a portion of apparatus embodying the present invention;

FIG. 2 is a view in cross-section taken along line 2—2 of FIG. 1;

FIG. 3 is a view in cross-section taken through one of the shaped charge devices;

FIG. 4 is a partial view in cross-section taken along line 4—4 of FIG. 3; and

FIG. 5 is a perspective view of a shaped charge device from its rearward end.

Referring now to the drawings, in FIGS. 1 and 2, a carrier, or more specifically, an elongated strip member **10** is shown which may be constructed of common, inexpensive ductile, moderately flexible sheet material, for example, common steel and have, say a width of 1⅝" and a thickness of ⅛". Hence, the width of the strip is suitable for passing through a 2" diameter tubing. The length of the strip **10** may be any suitable or desired length, for example, a convenient length being about 12 feet. As fas as material for the strip, it need only be strong enough to withstand the explosive pressures generated without fragmenting.

Along the length of the strip member is a plurality of relatively large diameter circular holes or openings which may be drilled or punched into the strip generally along the central axis of the strip member and preferably of uniform spacing, that is, the spacing between the holes being such as provides a desired number of openings per foot of strip. For example, on three inch centers, four holes per foot, may be provided. In FIGS. 1 and 2, only three such openings identified by the numerals **11–13** are illustrated, this number being sufficient for an understanding of the present invention. It will also become apparent from the discussion to follow that an arrangement pattern exists wherein one set of alternate openings have a certain arrangement while another set of alternate openings have another arrangement.

In the strip member, considering first the opening **11** (FIG. 1), a pair of radially-extending slots **11***a*, **11***b* are provided which are at 180° from one another along a diametrical axis **11***c* which intersects the central axis **14** of the strip as well as the center of the opening **11**. Axis **11***c* is disposed at a preferred negative angle of 30° relative to the central axis **14** of the strip member. The alternate opening **13** has similarly disposed, radially extending slots **13***a*, **13***b*, respectively, along an axis **13***c* inclined 30° relative to the central axis similar to the inclination of axis **11***c*.

Opening **12** similarly has slots **12***a*, **12***b*, which are disposed along a diametrical axis **12***c* intersecting the central axis **14** and center of opening **12**; however, axis **12***c* is disposed at a preferred positive angle of 30° relative to the central axis **14**. Openings **11** and **12**, with their corresponding slots **11***a*, **11***b* and **12***a*, **12***b* are respectively typical of the arrangements of the two sets of alternate openings along the length of the strip member. The rea-

sons for the angular displacement of the slots relative to the central axis will become more apparent from the discussion to follow.

The capsule devices which are to be received by the large diameter openings are identical in construction. For convenience of description, the numerals 16–18 (see FIG. 2) are applied to the capsule devices in openings 11–13, respectively; however, only device 16 will be described since a description of one capsule device will suffice for the others. Device 16 has a forward end 19 and a rearward end 20 disposed along an axis 21 of the device, and along the length of the strip member, the forward ends of successive devices are alternately disposed to face in opposite directions with the axes of the devices being disposed perpendicular to the central axis 14 of the strip member in a manner which will be more fully described hereinafter.

The capsule device 16 includes a hollow container 16*a* (FIG. 3), which encloses a conventional explosive shaped charge 16*b* provided with the usual conically-shaped liner in its shaped recess. The container 16*a* is comprised of a hollow case 16*c* and hollow cap 16*d* which is received over an annular lip portion 16*e* of the case, an O ring 16*f* providing a fluid-tight seal between the cap and case.

The outer configuration of the container includes the forward end 19 which is hemispherical and an intermediate section 23 having cylindrical surfaces 23*a*, 23*b* of different diameters and a tapered surface 24, the cylindrical surface 23*b* having the smaller diameter and adjoining the tapered surface 24. The tapered surface 24 is inclined from the cylindrical surface 23*b* inwardly towards the axis 21 to the rearward end 20 which is generally cylindrical and has a relative small diameter.

On the intermediate section 23 is a pair of attaching devices 28 and 29 (see FIGS. 3 and 5) in the form of rectangularly-shaped projections which extend outwardly or radially of the section 23 along an axis which is perpendicular to and intersects the axis 21 of the charge device. The projections 28, 29 include a rearward set of lugs 28*a*, 29*a* and a forward set of abutment portions 28*b*, 29*b*, each having facing surfaces 30, 31 respectively spaced axially of one another a distance just slightly greater than the thickness of the strip. The facing surfaces 30, 31 of the lugs and abutment portions adjoin bottom surfaces 32 on each of the projections, the overall diametrical dimension between surfaces 32 being just slightly less than the diameter of the opening 11. The width of the set of lugs 28*a*, 29*a* is less than the width of slots 11*a*, 11*b* and the radial extension of the lugs is such that they may pass through the slots 11*a*, 11*b* and yet extend beyond the diameter of the opening 11. The abutment portions 29*a*, 29*b*, similarly have a radial extension greater than the diameter of the opening 11 but need not be sized to pass through the slots 11*a*, 11*b*. Thus, the lugs 28*a*, 28*b* on the device 16 may be inserted through the slots 11*a*, 11*b* and when the lugs and abutment portions 29*a*, 29*b* are disposed on opposite sides of the strip member, rotation of the device permits the facing surfaces 30, 31 to engage opposite sides of the strip member while the bottom surfaces 32 slide along the surface of the opening 11.

It will be appreciated that the projections provide support for the capsule device at two locations. To insure against tilting or rocking of the capsule device in the strip member, another pair of radially-extending projections 35, 36 (see FIGS. 1 and 5) which extend outwardly from the intermediate section 23 are located along an axis disposed at an angle of 90° from the axis of first mentioned projections 28 and 29. The pair of projections 35 and 36 likewise may be rectangularly shaped and extend outwardly a distance greater than the diameter of the opening 11 and have rearward flat surfaces 37 (only one shown in FIG. 5) which lie on a plane perpendicular to the axis 21 of the device and corresponding to the plane on which the surfaces 31 of the abutment portions 28*b*, 29*b* lie. In this manner, four equally spaced contact surfaces are provided against one side of the strip member thereby preventing rocking or tilting of the devices when they are attached to the strip.

To hold the capsule device 16 in a rotatively attached position, the rear end 20 of the device is provided with a slot like opening 40 (FIG. 4) formed from spaced, parallel wall surfaces 41, 42 opening into a bore 43 of greater diameter than the spacing between wall surfaces. The bore 43 has a diameter roughly equal to the diameter of a blasting cord 45 and the spacing between the walls 41, 42 is such that the blasting cord 45 may be squeezed into the bore 43 between the parallel walls and then expand in the bore thereby to be firmly secured in the rear end of the device. The axis of the bore 43 is disposed perpendicular to axis 21 of the device and lies in a plane intersecting the axis of the attaching projections 28, 29. Thus, by fastening the blasting cord 45 to the strip member 10 and in the slot of the device, the stiffness of the blasting cord and the location of the bore 43 permits the securing of capsule devices in a rotatively attached position.

The blasting cord 45 is fastened to the strip member by providing a series of notches or openings (FIG. 1) alternately formed in the edges of the strip member 10 between adjacent capsule openings, the notches having a width and depth sufficient to permit blasting cord to be threaded therethrough from one side of the strip member to the other. For example, notch 50 in FIG. 1 is disposed between openings 11 and 12 while notch 51 is disposed between openings 12 and 13. The notch 50, for example, is located in the edge of the strip member opposite to the point of intersection of axes 11*c* and 12*c* of the slots 11*a*, 11*b* and 12*a*, 12*b* of opening 11. Notch 51 is located in the edge of the strip member opposite to the point of intersection of axes 12*c* and 13*c* of slots 12*a*, 12*b* and 13*a*, 13*b* of openings 12 and 13. Hence, the blasting cord extending over an opening is angularly disposed relative to the axis of the slots in the opening. Since the blasting cord when attached to one device is aligned in a plane with the attaching projections on the device, the projections may be disposed at an angle relative to the axis of the slots in the opening.

In the assembly and operation of the apparatus, the capsules are individually disposed in the strip openings by inserting the lug portions of each capsule through the slots in the corresponding opening and rotating the capsule. Since the lugs and blasting cord slot opening of a capsule are angularly aligned, when a capsule is rotated into an attached position, the axis of the blasting cord slot opening in the capsule intersects the notches in the strip edges on either side of the opening. Thus, the blasting cord can be threaded through one notch from one face of the strip across the rear end of the capsule and through the other notch to the other face of the strip. The blasting cord is thereby disposed in a helix extending lengthwise of the strip and alternates from side to side and from one face to the other face of the strip. This feature permits the blasting cord to be tautly fixed to the strip member thereby to hold the capsule device in a rotatively secured position.

When the assembly is positioned in a string of tubing by a conventional winch and cable (not shown), a conventional blasting cap (not shown) may be employed to initiate detonation of the shaped charges. The shaped charges, of course, develop penetration jets in a conventional manner, the explosive forces serving to fragment the capsule containers. The strip member being of infrangible material is then retrievable so that the debris remaining in the tubing is solely from the capsule container.

The foregoing described arrangement has considerable advantages. For example, the assembly consists of only three components, the strip, the blasting cord and the capsules. No separate attaching means for either the blasting cord or capsules is required since the arrangement eliminates their need. By eliminating extraneous attaching means, the debris is minimized. The capsule

constructions are identical, and the arrangement between the capsules and strip is such that assembly of the gun is fool-proof. It should further be noted that the individual small projections yield a minimum of debris.

It will be appreciated that the preferred arrangement is shown and that the notches or openings could be disposed at locations other than the strip edges to accomplish the rotational securing of the capsules. Likewise, the slots in the openings as well as the alignment of the blasting cord slot opening with the projections can be varied within the principles of the invention. Similarly, the charges can be aligned so that all face in one direction and the blasting cord lies entirely to one side of the strip member.

In summary, the arrangement permits the attachment of capsules to a strip member by the insertion of capsule projections through slots in openings in the strip member and the securing of the capsules in a rotatively attached, engagement position by means of a tautly disposed blasting cord extending lengthwise of the strip member.

While 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 for use in a well bore comprising: an elongated, thin, continuous strip member having a plurality of openings spaced from one another along the length of the strip member; a plurality of shaped charge devices respectively having an intermediate section with a portion sized to be received by a strip opening and having forward and rearward ends disposed along the axes of a device; each of said devices having attaching means on said intermediate section including a radially-extending set of lugs and radially-extending abutment portions, said lugs and abutment portions being spaced axially of one another a distance corresponding generally to the thickness of said strip member; said strip having slots disposed about said openings to pass a set of lugs therethrough whereby said charge devices may be inserted into said strip openings and rotated thereby permitting a set of lugs and abutment portions to respectively engage opposite sides of said strip member; said charge devices being arranged in said strip member such that said rearward ends are alternately faced in opposed directions and further having openings in said rearward ends arranged transverse to the axes of said charge devices; and blasting cord means arranged to extend along the length of said strip member and be received in said shaped charge openings thereby to prevent rotation of said shaped charge devices when in said strip member.

2. Perforating apparatus for use in a well bore comprising: an elongated, thin, continuous strip member having a plurality of openings spaced from one another along the length of the strip member; a plurality of shaped charge devices respectively having an intermediate section with a portion sized to be received by a strip opening and having forward and rearward ends disposed along the axes of a device; each of said devices having attaching means on said intermediate section including a radially-extending pair of lugs and at least four radially-extending abutment portions spaced circumferentially from one another and having surfaces lying on a plane perpendicular to the axis of a device, said lugs and abutment portions being spaced axially of one another a distance corresponding generally to the thickness of said strip member; said strip having slots disposed about said first openings to pass a set of lugs therethrough whereby said charge devices may be inserted into said strip openings and rotated thereby permitting a set of lugs and said abutment portions to respectively engage opposite sides of said strip member; said charge devices being arranged in said strip member such that said rearward ends are alternately faced in opposed directions and further having openings in said rearward ends arranged transverse to the axes of said charge devices; and blasting cord means arranged to extend along the length of said strip member and be received in said shaped charge openings thereby to prevent rotation of said shaped charge devices when in said strip member.

3. Perforating apparatus for use in a well bore comprising: an elongated, thin, continuous strip member having a plurality of first openings spaced from one another along the length of said strip, a plurality of shaped charge devices respectively having an intermediate section with a portion sized to be received by a first opening and having forward and rearward ends disposed along the axis of a device, each of said charge devices having attaching means on said intermediate section including a plurality of radially-extending lugs and radially-extending abutment portions spaced axially from said lugs a distance slightly greater than the thickness of said strip; said strip having slots extending radially outwardly from the respective first openings and arranged to pass said lugs therethrough whereby said charge devices may be inserted into said first openings and rotated thereby permitting the lugs and abutment portions to engage opposite sides of said strip in an attached engaging position; said strip member having a plurality of second openings located intermediate of said first openings; said charge devices having openings in said rearward ends of said devices, a device opening being arranged generally along an axis transverse to the axis of a charge device for receiving blasting cord means and the axis of the opening being angularly oriented with respect to at least one of said lugs; and blasting cord means threaded through said second openings in said strip and through said openings in said charge devices whereby said blasting cord means retains said charge devices in an attached engaging position.

4. Perforating apparatus for use in a well bore comprising: an elongated, thin, continuous strip member having a plurality of first openings spaced from one another along the length of the strip member; a plurality of shaped charge devices respectively having an intermediate section with a portion sized to be received by one of said strip openings and having forward and rearward ends disposed along the axes of the respective device; each of said devices having attaching means on said intermediate section including a radially-extending set of lugs and radially-extending abutment portions, said lugs and abutment portions being spaced axially of one another a distance corresponding generally to the thickness of said strip member; said strip having slots disposed about said first openings to pass a set of lugs therethrough whereby said charge devices may be inserted into said strip openings and rotated thereby permitting a set of lugs and abutment portions to respectively engage opposite sides of said strip member; said charge devices being arranged in said strip member such that said rearward ends are alternately faced in opposed directions, each of said rearward ends having an opening along an axis transverse to the axis of the corresponding charge device; said strip member having second openings spaced intermediate of said first openings; and blasting cord means threaded through said second openings so as to extend along the length of said strip member and be received in said shaped charge openings thereby to prevent rotation of said shaped charge devices when in said strip member.

5. Perforating apparatus for use in a well bore comprising: an elongated, thin, continuous strip member having a plurality of first openings spaced from one another along the length of the strip member; said strip member having a slot extending radially from each alternate first opening in a first direction and from each remaining second opening in a second direction inclined relative to said

first direction; a plurality of shaped charge devices respectively having an intermediate section with a portion sized to be received by an opening and having forward and rearward ends disposed along an axis of a device; each of said devices having attaching means on said intermediate portions including a radially-extending set of lugs and radially-extending abutment portions, said lugs and abutment portions being spaced axially of one another a distance corresponding generally to the thickness of said strip member; said set of lugs being sized to pass through said slots in an opening whereby said charge devices may be inserted into a first opening and rotated thereby bringing said set of lugs and said abutment portions to respectively engage opposite sides of said strip member; said charge devices being arranged in said strip member such that said rearward ends are alternately faced in opposed directions, each of said rearward ends having an opening along an axis arranged transverse to the axis of a charge device and angularly oriented relative to at least one of said lugs; and blasting cord means arranged to extend along the length of said strip member and be received in the charge device openings when the axis of an opening is inclined relative to the axis of the slot of the strip opening thereby to prevent rotation of said shaped charge devices when in said strip member.

6. Perforating apparatus for use in a well bore comprising: an elongated, thin, continuous strip member having a plurality of first openings spaced from one another along the length of the strip member; said strip having a pair of slots disposed about each of said openings, a pair of the slots in said openings which are disposed alternately of one another lying on first axes intersecting the centers of the alternate openings, a pair of the slots in the remaining alternate openings lying on second axes intersecting the centers of said remaining alternate openings, said first and second axes being inclined relative to one another and in the plane of said strip member, a plurality of shaped charge devices respectively having an intermediate section with a portion sized to be received by an opening and having forward and rearward ends disposed along an axis of a device; each of said devices having attaching means disposed on said intermediate portions at 180° from one another and including a radially-extending set of lugs and radially-extending abutment portions, said lugs and abutment portions being spaced axially of one another a distance corresponding generally to the thickness of said strip member; said set of lugs being sized to pass through said slots in an opening whereby said charge devices may be inserted into said first openings and rotated thereby permitting said set of lugs and said abutment portions to respectively engage opposite sides of said strip member; said charge devices being arranged in said strip member such that said rearward ends are alternately faced in opposed directions, each of said rearward ends having an opening along an axis arranged transverse to the axis of a charge device and lying in a plane intersecting the attaching means; and blasting cord means arranged to extend along the length of said strip member and be received in the charge device openings when the axis of an opening is inclined relative to the axis of the slot of the strip opening thereby to prevent rotation of said shaped charge openings thereby to prevent rotation of said shaped charge devices when in said strip member.

7. A shaped charge capsule construction comprising: a hollow, thin-walled container comprised of a hollow case and hollow cap sealingly received on said case, said container having a forward end, an intermediate section and a rearward end disposed along an axis of said container; a shaped charge explosive disposed in said container and having a shaped recess facing said cap; said container having an outer configuration wherein the forward end is hemispherical, said intermediate section includes cylindrical portions and portions tapered inwardly toward the axis of the container, and said rearward end is cylindrical with a relatively small diameter as compared to the intermediate cylindrical portions; said container further having at least two projections extending radially outwardly of said intermediate section and including a set of lugs and a set of abutment portions spaced axially of one another; said rearward end of said container having a blasting cord receiving opening disposed along an axis transversely arranged relative to the axis of said container.

8. A shaped charge capsule construction comprising: a hollow, thin-walled container comprised of a hollow case and hollow cap sealingly received on said case, said container having a forward end and intermediate section and a rearward end disposed along an axis of said container; a shaped charge explosive disposed in said container and having a shaped recess facing said cap; said container having an outer configuration wherein the forward end is hemispherical, said intermediate section includes cylindrical portions and portions tapered inwardly toward the axis of the container, and said rearward end is cylindrical with a relatively small diameter as compared to the diameter of the intermediate cylindrical portions, said container further having at least two projections disposed at 180° relative to one another and extending radially outwardly of said intermediate section and including a set of lugs and a set of abutment portions spaced axially of one another, said rearward end of said container having a slot-like opening disposed along an axis transversely arranged relative to the axis of said container and sized to receive a blasting cord means, said opening axis being angularly aligned with respect to said projections.

9. Perforating apparatus for use in a well bore comprising a plurality of capsulated shaped charges having spaced radial projections and a slotted rear end, blasting cord sized for retention in the slotted rear ends of said charges, and an integral strip of ductile material having openings spaced along its length to receive said charges with the projections thereof spaced to engage on either side of said strip and having edgewise slots spaced intermediate and laterally of said first openings for receiving said blasting cord along said strip in a generally helical path including said slotted rear ends, said charges being restrained from rotation in said strip solely by said blasting cord.

10. Perforating apparatus for use in a well bore comprising a plurality of capsulated shaped charges having spaced radial projections and a rear end with a blasting cord receiving opening, a blasting cord sized for retention in said blasting cord receiving openings in the rear ends of said shaped charges, and an integral strip of infrangible material having openings spaced along its length to receive said shaped charges, said strip having radially-extending slots about said openings to receive said projections, said projections having grooves therein to permit said projections on said shaped charges to engage opposite sides of said strip when said shaped charges are rotated relative to said strip, said blasting cord extending along the length of said strip and through said receiving openings so as to hold shaped charges in fixed rotated position thereby preventing release of said shaped charges from said strip.

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