Feb. 17, 1959 B. M. CALDWELL 2,873,676

MULTIPLE SHAPED CHARGE ASSEMBLY

Filed Aug. 31, 1953

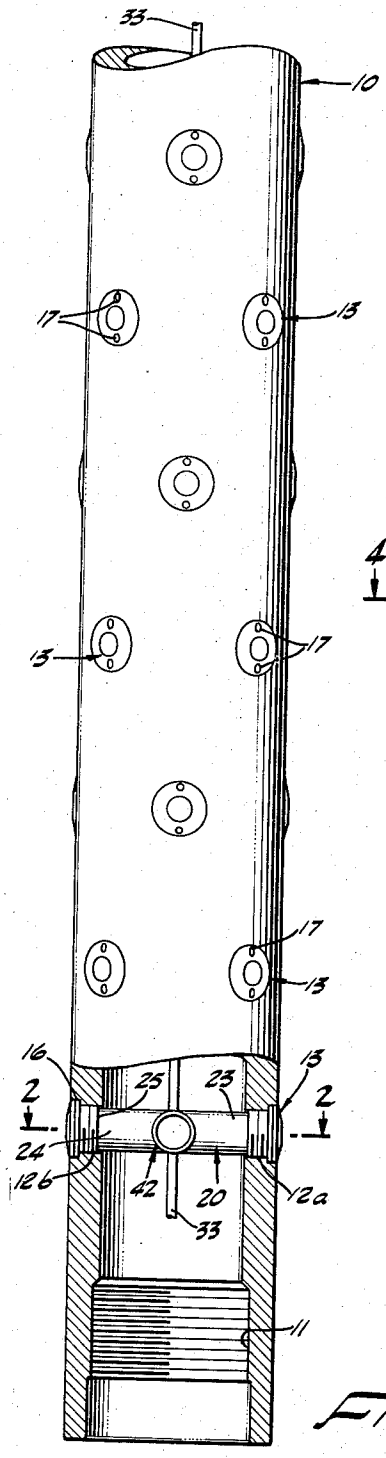


FIG.

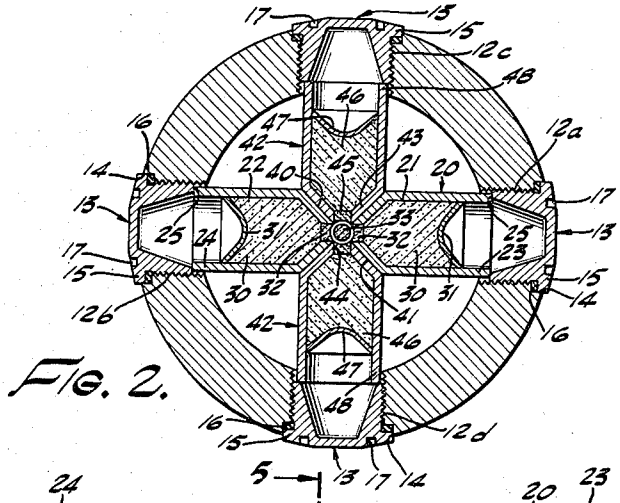


FIG. 2.

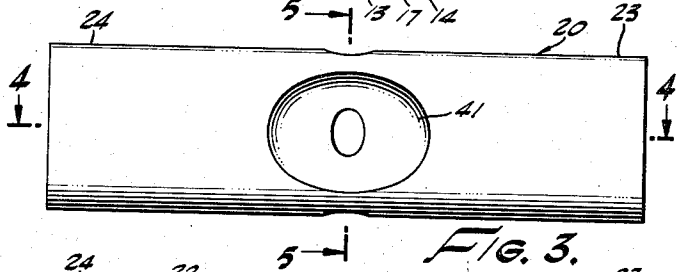


FIG. 3.

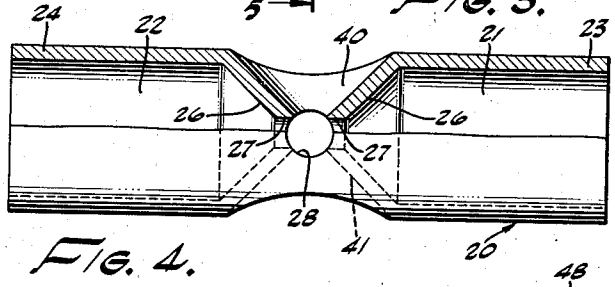


FIG. 4.

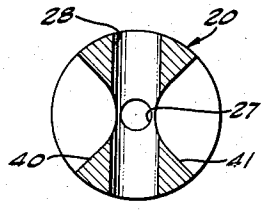


FIG. 5.

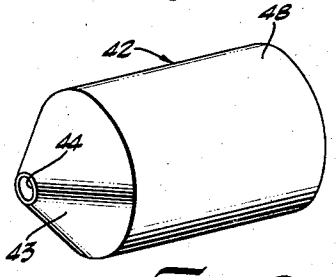


FIG. 6.

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MULTIPLE SHAPED CHARGE ASSEMBLY

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6 Claims. (Cl. 102—20)

This invention relates to the perforation of well casings and/or the penetration and fracturing of earth formations surrounding a well bore. The invention is particularly concerned with perforating means utilizing shaped charges i. e. explosive charges provided with surface cavities lined with inert material by which explosive force is directed as a jet outwardly from such surface cavities and contemplates the provision of multiple assemblies of such charges constructed and arranged to perform a plurality of perforations, penetrations or fractures in each of one or more selected transverse planes of a well.

The use of individual shaped charges for perforation of casings and/or penetration and fracture of well bore formations has achieved generally accepted recognition. In many instances this practice is deemed preferable to the predecessor practice of utilizing explosively propelled bullets for a like purpose. One limitation of both practices has been the number of perforations, penetrations or fractures possible in a given area of casing or formation.

In present day practice each perforating unit, whether bullet or shaped charge, is individually mounted in a carrier and each unit is longitudinally spaced from each other unit. Thus the number of units available in a given length of carrier is restricted. By spiral arrangement a substantial increase in number of units was achieved over the original straight line arrangement since the required distance of separation could thus be maintained within a minimum longitudinal distance. Such increase however, even where multiple spiral arrangements have been used, has not achieved the ultimate concentration of perforations, penetrations or fractures desired. In oil well cementing for instance it has been found that perforations formed by a conventional perforating gun may result in the deposit on the outside of the casing of a spiral fin of cement instead of the desired fully surrounding collar or pancake. Investigation has indicated that on an average the cement exuded through a single perforation encompasses only about 270° of the pipe while in some instances only 45° of circumference of the pipe is enshrouded by the cement. Obviously for this and like purposes a perforation pattern of greater intensity is desirable.

It has been suggested that the number of perforations per unit of length could be increased by the use of a plurality of charges fired from the same plane at different radial angularity. While this suggestion was theoretically feasible a number of problems heretofore unsurmounted have precluded a commercially successful adaptation of this theory. In the single unit shaped charge assembly considerable ingenuity, skill and expert designing is required to provide a unit which could be properly secured and sealingly engaged within a carrier and which could be readily loaded without skilled operators or special tools and instruments. In a unit which may simultaneously fire a number of shaped charges in the same plane such problems are obviously multiplied. Another problem with respect to multiple units which has engaged the attention of inventors is the provision of means for insuring simultaneous detonation of the individual charges and the location of firing means by which such simultaneous detonation may be insured. With these and like problems to be solved there is also the matter of simplicity of design whereby an automatic interfitting registration and orientation of parts may be accomplished and for commercial success it is obviously necessary that such problems be solved in a manner well suited to the demands of economic manufacture.

It is therefore among the primary objects of the present invention to provide a shaped charge assembly and a carrier therefor, whereby a multiplicity of shaped charges may be simultaneously fired in a single plane and in angularly divergent trajectories.

Another object of the invention is to provide a multiple shaped charge assembly with means for insuring the simultaneous detonation of each of the charges thereof in such manner as to provide for the concurrent and uniform propagation of the perforating jets produced thereby.

A further object of the invention is to provide a multiple shaped charge assembly which may be readily loaded within a gun carrier and sealingly secured therein in predetermined location without requiring the use of skilled operators or special loading equipment.

Another object of the invention is to provide a multiple shaped charge assembly comprising a primary charge unit readily insertable and securable in a gun carrier so constructed and arranged as to act to receive, support, locate and orient one or more secondary charge units, in order to provide a unitary assembly having multiple charges adapted for simultaneous firing in angularly related radial trajectories of a single plane.

It is also an object of the invention to provide unitary multiple shaped charge assemblies in combination with a carrier whereby a plurality of spaced planes may be perforated by a plurality of angularly divergent jets and whereby the angular relation of the perforations produced by one multiple assembly will be oriented with respect to the perforations produced by a similar assembly spaced longitudinally therefrom.

An additional object of the invention is to provide a carrier and multiple charge assembly including means for centrally locating a single detonating fuse in such manner as to insure the simultaneous detonation of each charge of each assembly and to provide for the protection and insulation of such firing cord from contact or contamination as the gun is lowered into firing position in a well bore or casing.

Numerous other objects and features of the present invention will be apparent from a consideration of the following specification taken in conjunction with the accompanying drawings in which:

Figure 1 is a fragmentary side elevation partly in section of one form of the present invention;

Figure 2 is a horizontal section through the carrier and multiple shaped charge assembly taken on line 2—2 of Figure 1;

Figure 3 is a side elevation of the primary double charge unit of the multiple charge assembly of the present invention;

Figure 4 is a central longitudinal sectional view of the unit shown in Figure 3, taken on line 4—4 of Figure 3;

Figure 5 is a vertical transverse section through the primary unit taken on the line 5—5 of Figure 3; and

Figure 6 is a perspective view of one of the secondary shaped charge units of the multiple assembly.

In general terms the structure of the present preferred form of the invention may be defined as including a cylindrical carrier of substantial thickness and strength having a plurality of transverse areas perforated by two

pairs of diametrically opposite and equally spaced apertures. Located between one pair of such apertures there is transversely mounted a primary double charge unit having opposed outwardly facing shaped charges. Opposite sides of the primary unit, at the center thereof, are appropriately recessed to receive and support the inner ends of a pair of secondary charge units which are mounted through the other pair of apertures and positioned and oriented by the reception of their conforming inner ends within the side recesses of the primary unit. The side recesses of the primary unit intersect a vertical fuse bore and the inner ends of the secondary members communicate therewith as do the charge chambers of the primary unit. Thus a central opening is formed through which a fuse extends in central axial position longitudinally of the carrier and in equal relation to each of the charges of each unit so that such units will be simultaneously detonated as the fuse burns.

Referring to the drawings, the gun carrier is indicated by the numeral **10** and comprises a circular elongated cylindrical member preferably formed of steel or like material of such thickness and strength as to withstand the shock of the firing of the charges supported therein. As indicated at **11** the ends of the carrier body **10** may be recessed and threaded to provide for the coupling of a plurality of carriers to form a single unit of any desired length and/or to facilitate the securement of the carrier to a drill string or to an appropriate firing head or cable connection.

At suitable longitudinally spaced transverse planes, preferably equidistant, the body **10** is apertured to provide for insertion of the charge units and for the discharge of the perforating and penetrating jets. While the invention is not limited to the number and arrangement illustrated they are here shown as four in number comprising two diametrically opposed pairs arranged on axes circumferentially spaced 90° apart. As seen in Figure 2 one pair of apertures is designated **12***a* and **12***b* while the other pair is designated **12***c* and **12***d*. The apertures are of uniform diameter and each is adapted to receive a charge securing closure cap **13**. The bore of each aperture is counter bored as at **14** to receive therein the flange **15** of the cap. Each flange **15** engages a sealing ring **16** mounted within the counter bore **14** whereby the interior of the carrier is sealed against the intrusion of well fluids when the gun is lowered to the zone to be perforated. As indicated at **17** the caps may be recessed to receive a conventional spanner wrench to facilitate the threaded securement thereof within the apertures.

The shaped charge assemblies mounted through the apertures **12** include a double primary shaped charge unit **20** of generally cylindrical form having axially disposed outwardly directed cylindrical shaped charge chambers **21** and **22**. The outer diameter of the primary charge unit **20** conforms with the internal diameter of the apertures **12** so that the unit may be readily inserted through such apertures to be positioned in a horizontal plane transversely of the carrier. The outer ends **23** and **24** of the primary units engage the inner ends of the threaded walls of the apertures **12***a* and **12***b* as shown in Figure 2 so as to be retained in the transverse position normal to the axis of the carrier **10** as illustrated. When the primary unit **20** is so arranged the caps **13** are threaded inwardly so that their inner edges **25** may abut the terminal ends **23** and **24** to secure the unit **20** in such position. The inner ends of the chambers **21** and **22** are formed with frusto conical walls **26** terminating in axial bores **27** which communicate between the chambers and a vertically disposed transverse passage **28** which is disposed centrally of the carrier to lie coaxially therewith. The chambers **21** and **22** are loaded with suitable explosive material indicated at **30** and a shaped retaining sheath of material such as copper indicated at **31**, forms the outwardly faced charge cavity by which the explosive force is directed outwardly as a jet, in the well-known manner common to shaped charges. The bores **27** are loaded with a booster charge **32** and the passage **28** receives therethrough an axially disposed detonating fuse **33** the arrangement being such that as the fuse is fired the booster charges will be simultaneously detonated to ignite the powder **30** for simultaneously firing the charges in both the chambers **21** and **22**.

Intermediate the chambers **21** and **22** the primary unit **20** is formed with side recesses **40** and **41** which are of frusto conical formation with their axes in the plane and normal to the axis of the member **20**. Thus the recesses **40** and **41** face outwardly in registration with the apertures **12***c* and **12***d* respectively. The complete assembly is formed by the provision of two secondary charge units **42** of the type shown in Figure 6, each secondary unit having a cylindrical casing terminating in a fruto conical inner end wall **43** having a central bore **44**. The configurations of the walls **43** conform with the configurations of the recesses **40** and **41** so that the ends of the units **42** may be received and supported within the recesses as indicated in Figure 2. The bores **44** of the units **42** are loaded with a booster charge **45** in communication with the fuse **33** in the same manner as booster charges **32**. The main explosive charge is indicated at **46** and is formed with an outwardly facing recess and sheath **47** similar to the sheath **31** of the charges of the primary units **20**. The outer terminal edge **48** of the units **42** conform to and are received within the apertures **12***c* and **12***d* to be supported and retained in alignment thereby. The inner ends of caps **13** of apertures **12***c* and **12***d* may abut the outer edges **48** in the same manner as set forth with respect to the engagement of the ends of the primary units by the caps of the apertures **12***a* and **12***b*.

From the foregoing it will be seen that the units may be readily located, secured and retained in the assembly shown by first inserting, locating and orienting the primary charge unit **20** with its recesses **40** and **41** disposed with their axes normal to the axis of the carrier. After threading the fuse **33** through the axial passage **28**, by a suitable threading needle, not shown, the secondary units **42** are then inserted through the apertures **12***c* and **12***d* with their frusto conical walls **43** received with the conforming recesses **40** and **41**. In such relation it will be seen that the bores **44** are in open communication with the axial passage **28** through which the fuse **33** is threaded. After arrangement of the units as shown the caps **13** are tightly secured to sealingly enclose the assembly and retain the units against accidental displacement. By this arrangement it will be noted that the booster charges are all in uniform communication with the fuse so that upon ignition thereof all booster charges will be simultaneously detonated and hence the shaped charges will be fired simultaneously to produce horizontally radiating jets of perforating force.

As indicated in Figure 1 the invention contemplates the orientation of adjacent charge units 45° from each other longitudinally of the carrier so that the result is a perforation pattern consisting of parallel multiple perforations in spaced planes with the perforations staggered as between such planes. It will of course be understood that the present invention is in no way limited to the exact construction and configuration of elements here shown and that various arrangements of multiple charges may be selected so as to provide any desired number of radiating perforations in any desired number and spacing of planes and that the invention is not restricted to the 45° orientation of the charges between the planes. Thus numerous changes and modifications and full use of equivalence may be resorted to in the practice of the invention without departure from the spirit or scope thereof as outlined in the appended claims.

I claim:

1. A shaped charge assembly for a perforating gun comprising in combination a substantially cylindrical primary shaped charge unit having diametrically opposed outwardly facing shaped charges therein and including opposed, outwardly directed intermediate radial recesses, a pair of secondary shaped charge units each including a shaped charge and a terminal end portion received within the recesses of said primary unit to form an assembly in which the shaped charges of said primary and secondary units lie in a single plane and are directed radially outward at a circumferential angularity of 90° with respect to each other, said primary shaped charge unit having a fuse aperture therein in firing communication with the shaped charges of said primary and secondary shaped charge units, and a gun carrier supporting said primary and secondary shaped charge units.

2. A shaped charge assembly for a perforating gun comprising in combination a substantially cylindrical primary shaped charge unit having diametrically opposed outwardly facing shaped charges therein; a transverse fuse aperture between said charges having firing communication therewith; said primary unit including opposed, outwardly directed, intermediate radial conical recesses, said recesses having their axes in mutual alignment and intersecting the axis of said primary unit at right angles, a pair of secondary shaped charge units each including a shaped charge and a terminal frusto conical end portion received within the recesses of said primary unit with their charges in firing communication with said fuse aperture to form an assembly in which the shaped charges of said primary and secondary units lie in a plane and are directed radially outward at a circumferential angularity of 90° with respect to each other, and a gun carrier supporting said primary and secondary shaped charge units.

3. A multiple shaped charge gun assembly comprising a cylindrical gun carrier having a plurality of apertures comprising two pairs angularly related at 90° from each other and disposed in a single transverse plane normal to the axis of the carrier; a primary charge unit of substantially cylindrical form having its ends supported in one pair of said apertures and including opposite outwardly directed shaped charges and booster charges, a central vertical aperture through said primary unit communicating with said booster charges, a pair of outwardly directed intermediate recesses formed in said primary unit and a pair of inwardly frusto conical secondary shaped charge units having their inner frusto conical ends supported in the recesses of said primary unit and including outwardly facing shaped charges and booster charges in communication with the vertical passage of said primary unit and a detonating fuse extending through said primary unit in communication with all of said booster charges.

4. A multiple shaped charge gun assembly comprising a cylindrical gun carrier having a plurality of longitudinally spaced and angularly oriented sets of apertures the apertures of each set comprising two pairs angularly related at 90° from each other and disposed in a single transverse plane normal to the axis of the carrier; a primary charge unit for each set of apertures of substantially cylindrical form having its ends supported in one pair of said apertures and including opposite outwardly directed shaped charges and booster charges, a central vertical aperture through said primary unit communicating with said booster charges, a pair of outwardly directed intermediate recesses formed in said primary unit and a pair of inwardly frusto conical secondary shaped charge units for each set of apertures having their inner frusto conical ends supported in the recesses of said primary unit and including outwardly facing shaped charges and booster charges in communication with the vertical aperture of said primary unit and a detonating fuse extending through said primary unit in communication with all of said booster charges.

5. A multiple shaped charge gun assembly comprising a cylindrical gun carrier having a plurality of longitudinally spaced and angularly oriented sets of threaded apertures the apertures of each set comprising two pairs angularly related at 90° from each other and disposed in a single transverse plane normal to the axis of the carrier; a primary charge unit of substantially cylindrical form having having its ends supported in one pair of said apertures and including opposite outwardly directed shaped charges and booster charges, a central vertical aperture through said primary unit communicating with said booster charges, a pair of outwardly directed intermediate recesses formed in said primary unit and a pair of inwardly frusto conical secondary shaped charge units having their inner frusto conical ends supported in the recesses of said primary unit and including outwardly facing shaped charges and booster charges in communication with the vertical aperture of said primary unit, a detonating fuse extending through said carrier and through said central vertical aperture of said primary unit in communication with all of said booster charges and closure caps for said plurality of longitudinally spaced and angularly oriented sets of threaded apertures.

6. A multiple shaped charge gun assembly comprising a cylindrical gun carrier having a plurality of apertures comprising two pairs angularly related at 90° from each other and disposed in a single transverse plane normal to the axis of the carrier; a primary charge unit of substantially cylindrical form having its ends supported in one pair of said apertures and including opposite outwardly directed shaped charges and booster charges, a central vertical passage through said primary unit communicating with said booster charges, a pair of outwardly directed intermediate recesses formed in said primary unit; a pair of inwardly frusto conical, outwardly cylindrical secondary shaped charge units having their inner frusto conical ends supported in the recesses of said primary unit and their outwardly cylindrical ends supported in the other pair of said gun carrier apertures and including outwardly facing shaped charges and booster charges in communication with the vertical passage of said primary unit; and a detonating fuse extending through the vertical passage of said primary unit in firing communication with all of said booster charges.

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