Feb. 14, 1956 W. G. SWEETMAN 2,734,456

GUN PERFORATOR

Filed April 21, 1949 2 Sheets-Sheet 1

FIG. 1

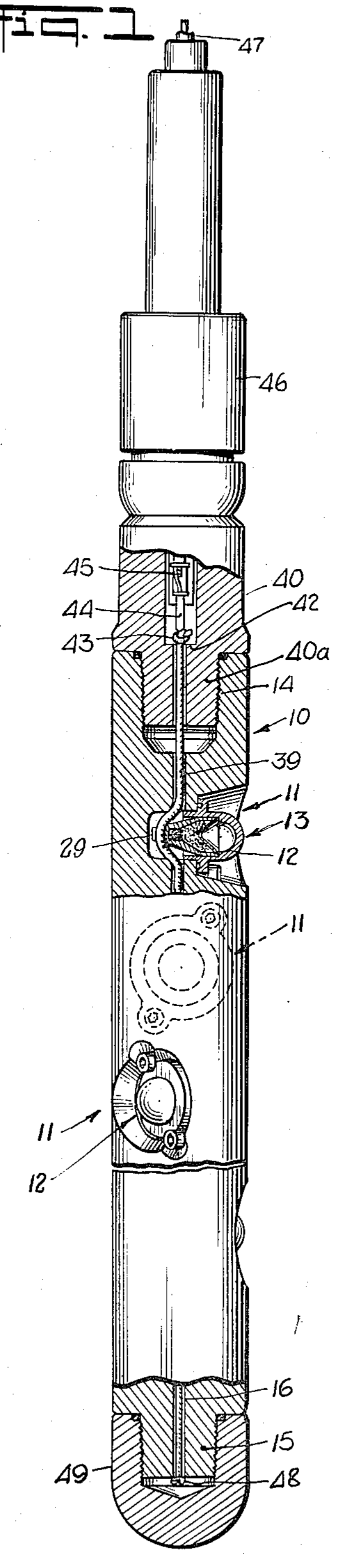
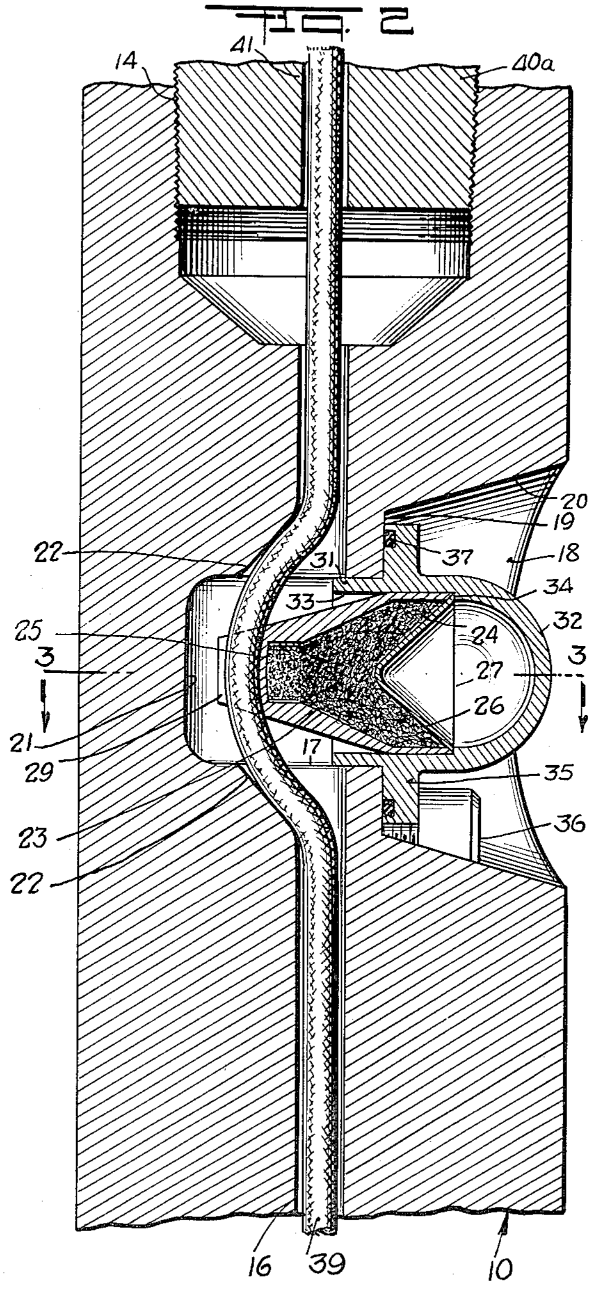



FIG. 2

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Filed April 21, 1949 2 Sheets-Sheet 2

Fig. 6

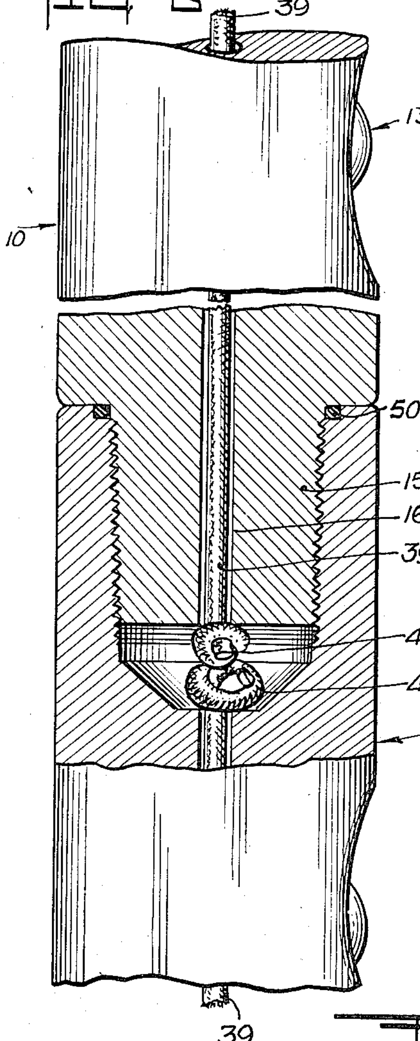



Fig. 3

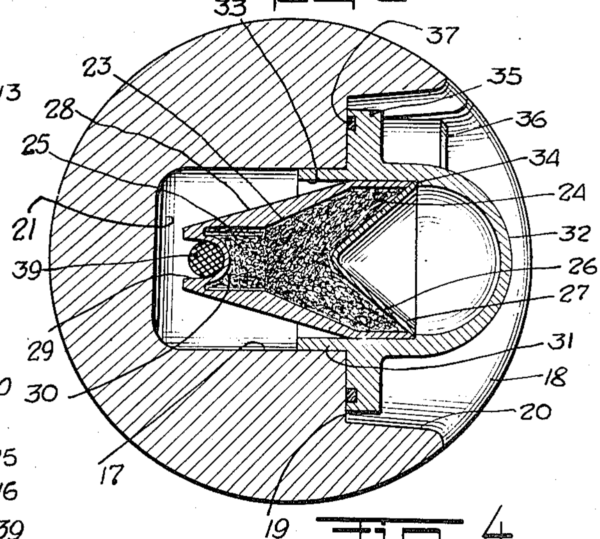



Fig. 4

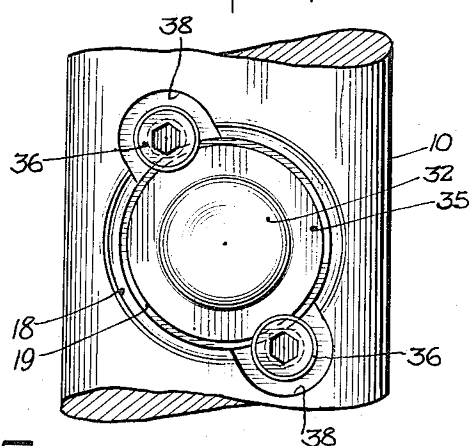
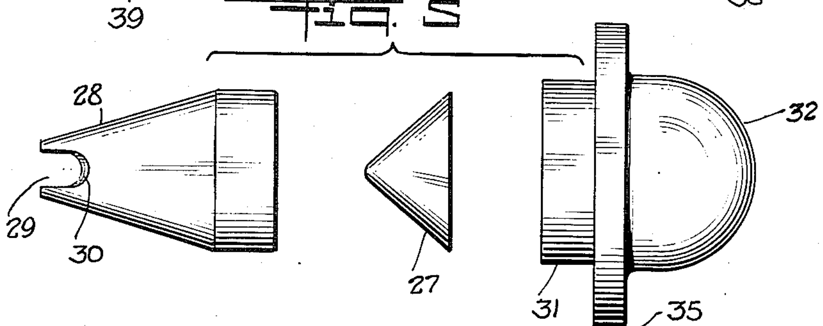



Fig. 5

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# GUN PERFORATOR

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Application April 21, 1949, Serial No. 88,740

4 Claims. (Cl. 102—21.6)

This invention relates to perforating devices, commonly called "guns," which are employed to perforate the walls of wells, such as oil or gas wells, to provide communication between the well bore and the fluids in the surrounding formations. More particularly, this invention is directed to perforating devices of the type which employ hollowed explosive charges rather than the more conventional bullet-type projectiles as the perforating elements.

The cavity or hollow charge principle, widely employed in World War II in connection with explosives, has more recently been applied to the perforation of metal well casings and other well bore linings because of the superior penetrating power obtainable with such charges. For well perforating purposes, such charges are usually constructed in the form of small relatively high density bodies of high-brisance types of detonating explosives, having an end thereof facing the object to be pierced provided with a cavity or hollow, generally of conical shape, which is lined with a thin metal liner. When suitably detonated, the major proportion of the generated explosive force is concentrated, by virtue of the shape of the hollow and liner, into a relatively narrow gaseous jet of tremendous power and penetrating force which is directed largely along the longitudinal axis of the hollow. Such perforating charges do not employ projectiles but depend substantially entirely upon the penetrating power of the gaseous jet to effect the desired degree of perforation.

Although, as noted, the major proportion of the force of such hollowed charges will be concentrated in a relatively narrow jet along the longitudinal axis of the cavity, nevertheless, very substantial radial forces and pressures will be generated at the same time which have proven difficult to control and confine in a manner which will prevent serious damage to the supporting gun bodies. The prevention of such damage to the gun bodies is important from the standpoint of maintaining the firing efficiency in repeated re-use and from an economic standpoint.

Perforating guns are operated in wells which are ordinarily filled with hydraulic fluids, such as heavy muds and the like, and the guns will, therefore, be subjected to hydrostatic pressures ranging to several thousand pounds per square inch in deep wells. This necessarily requires very careful machining of the gun bodies and particularly of the receptacles and seats for the perforating charges and the closures therefor, in order to assure fluid-tightness under such high pressures, since seepage of fluid into the charge receptacles and the interior passages in the gun body will cause mis-fires and other undesirable damage thereto. Such gun bodies are, therefore, relatively expensive to construct and their repeated re-use is necessarily dictated for reasons of economy.

Accordingly, it is a primary object of this invention to provide an improved perforating gun employing hollowed-type perforating charges.

An important object is to provide a gun which is adapted for the repeated re-loading and firing of hollowed-type perforating charges.

Another important object is to provide such a gun in which a particular arrangement of the charges relative to their receptacles in the gun body is employed to protect the gun body from damage by the explosion of the charges.

Another object is the provision of an improved form of explosive perforating unit of the hollow-charge type.

Other and more specific objects and advantages of this invention will become apparent from the following detailed description when read in conjunction with the accompanying drawings which illustrate useful embodiments in accordance with this invention.

In the drawings:

Fig. 1 is an elevational view of a gun in accordance with an embodiment of this invention assembled preparatory to lowering in a well and having some of the parts thereof broken away for purposes of better illustration;

Fig. 2 is an enlarged view in longitudinal section of a portion of the gun showing one of the perforating units in place therein;

Fig. 3 is a cross-sectional view along line 3—3 of Fig. 2;

Fig. 4 is an elevational view of a portion of the gun looking directly at the end of one of the perforating units;

Fig. 5 is a separated view of a perforating unit and closure therefor; and

Fig. 6 is an enlarged view, partly in section, showing the means for connecting two gun units together.

The gun perforator, in accordance with one embodiment of this invention, comprises a gun body **10** in the form of an elongated steel cylinder, preferably constructed from a solid billet, having a plurality of radially directed receptacles, indicated generally by the numerals **11**, in which are seated perforating units, designated generally by the numerals **12**, and closure elements, indicated generally by the numerals **13**. Body **10** is preferably made from a solid steel billet, heat treated and otherwise constructed in the manner commonly used for the construction of the more conventional bullet-type perforating guns.

An internally threaded connection box **14** is provided at one end of body **10** and an externally threaded pin **15** at the other end thereof. A narrow passageway **16** extends axially through body **10** from the bottom of box **14** to the extremity of pin **15**.

Receptacles **11**, in the illustrative embodiment, are axially spaced and spirally oriented along the gun body but may all face in one direction or alternately in opposite directions, as may be desired.

Each of receptacles **11** includes a socket **17**, of generally cylindrical form, which intersects passageway **16**, and an outer mouth section **18** opening to one side of body **10**. Outer section **18** is of substantially larger diameter than socket **17**, thereby forming an annular shoulder **19** of substantial width about the outer end of socket **17**. The peripheral wall **20** of outer section **18** diverges outwardly from shoulder **19** to its intersection with the outer periphery of body **10**, thereby defining a frusto-conical shape for outer section **18**. Socket **17** has an inner end wall **21** which may be of generally plane form as illustrated, or may be generally spherical, parabolic or conical, or may be raised or embossed, if desired. The bore of passageway **16**, at the points of its intersection with each of the sockets **17** may be laterally flared at one side, as at **22**, to merge more or less smoothly into end wall **21**.

Each of the perforating units **12** comprises an explosive material **23** which may be molded, compressed or otherwise formed by conventional methods to provide a body having an overall generally conical shape but which may have a cylindrically shaped base portion 24 and a generally cylindrical apex portion 25. Base portion 24 is provided with an axially outwardly directed cavity or hollow 26, which is preferably of a generally conical shape, but may be hemispherical, parabolic or of other suitable shape, and is lined with a correspondingly shaped liner 27, preferably constructed of a suitable thin metal such as copper, aluminum, steel or the like which is deformable and even rupturable.

Explosive material 23 is preferably one of the well known high-brisance types of chemical detonating explosives, which include such materials are pentaerythritol tetranitrate (PETN), trinitrotoluene (TNT), "Pentolite" (50% PETN and 50% TNT), "Tetryl," "Amatol," "Cyclonite," "Tetrytol" (60% "Tetryl" and 40% TNT), and many others well known in the explosive art. Apex portion 25 may be in the form of a booster charge composed of explosive material of the same general character as that composing the main body of explosive 23, or may be a different individual one, or may be the very same explosive material but of different density, for example, to supply the desired boosting effect upon the main body of the explosive, such combinations and variations being well understood in the explosive art.

All of the explosive material is preferbaly encased within a relatively thin-walled container 28, the inner walls of which closely correspond in shape to the external configurations of the body of explosive material. The exterior wall of container 28 may be generally conical, as shown, although other external shapes may be used. Container 28 may be constructed of any suitable material, which may most conveniently be one of the numerous synthetic plastics, which possesses sufficient rigidity and mechanical strength to support and hold the enclosed explosive in the desired shape and to permit effective handling of the explosive charge as a unit, as in shipping and in loading into the gun body. The apex end of container 28 is provided with a transverse notch 29, perferably having a transversely rounded bottom wall 30 (Fig. 3), which extends axially somewhat into the interior of the container, the booster explosive comprising apex portion 25, being correspondingly shaped to pack closely about the inner curved surface of the bottom wall of the notch, and to thereby extend upwardly on each side of the bottom of the notch to approximately the center of curvature thereof, in the manner illustrated particularly in Fig. 3. Bottom wall 30 is preferably also curved on a radius longitudinally of notch 29 (Fig. 2) to increase the length of the surface in the bottom of the notch and the inside wall of the portion 25 is curved to follow the curve of the notch, for purposes to be described hereinafter. The base end of container 28 is circular and substantially flush with the end face of the base portion 24 of the explosive and is adapted to form an annular seat for the periphery of liner 27 when the latter is properly positioned in hollow 26. The maximum diameter of the explosive body, being the diameter of base portion 24, is made substantially smaller than that of the bore of socket 17 to provide a substantial clearance space therebetween for purposes to be described hereinafter. The external diameter of container 28, while necessarily somewhat greater than that of base portion 24 due to its wall thickness, is also made somewhat less than that of the bore of socket 17 so as to provide an annular clearance space between the exterior of container 28 and socket 17.

Each of the closure elements 13 comprises a tubular sleeve 31 formed with a closed outer end wall 32, preferably spherical or dome shaped, as shown, and is adapted to have its open inner end slidingly inserted into socket 17 through the clearance space provided, as above described, between container 28 and the bore of the socket. The bore 33 of sleeve 31 is adapted to receive the base end of container 28 and is dimensioned to form a close sliding fit therewith. An internal shoulder 34 is pro-



vided in bore 33 axially spaced from end wall 32 to provide a spacing stop for positioning the hollowed end of the perforating unit at some suitable predetermined axial distance from end wall 32. The distance between the base of the explosive and the end wall forms the so-called "stand-off" distance. Closure element 32 is adapted to seal the stand-off space to exclude therefrom any extraneous material, such as mud, well fluid and the like, which might interfere with the development of an effective perforating jet. An outwardly extending annular flange 35 is provided about the exterior of sleeve 31, being preferably formed integral therewith, and is adapted to seat against shoulder 19. The external diameter of flange 35 is made somewhat less than that of shoulder 19 so that some degree of annular clearance is provided between the periphery of flange 35 and wall 20. A pair of cap screws 36—36 are adapted to be screwed into body 10 on diametrically opposite sides of flange 35 and are so positioned adjacent thereto that their heads will overlap the edge of flange 35. With this arrangement cap screws 36, when screwed into suitable threaded holes in body 10, may be employed to clamp closure element 13 against shoulder 19 and thereby to the gun body. A circular packing ring 37 is seated in the inner face of flange 35 and is adapted, when the closure element is clamped against body 10 by means of cap screw 36, as described, to form a fluid-tight seal between shoulder 19 and the inner face of flange 35 thereby also forming a fluid-tight seal between the closure element and socket 17. Wall 20 is provided with suitable recesses 38—38 to receive the cap screws so that they may be screwed down inside the periphery of the gunbody. Closure element 31 may be constructed of any suitable metal which, generally speaking, is softer than the steel of which body 10 is constructed but which has sufficient strength to withstand hydrostatic pressures of the magnitudes which may be encountered in wells in which the gun is operated. Various aluminum and zinc alloys, copper, steel and the like may be used. A cast metal which is adapted to be fully shattered by the explosion of the perforating unit will be preferable in most cases. Flange 35 is positioned along the exterior of sleeve 31 inwardly relative to shoulder 34, so that when the closure element is in place, shoulder 34 will always be radially spaced outwardly relative to the outer end of socket 17 as defined by shoulder 19. Thus when the perforating unit is inserted in the closure element with its base portion lodged against shoulder 34, the base portion of the explosive charge will be positioned exteriorly of the outer end of socket 17 and within the enlarged mouth section 18.

A suitable and generally conventional fuse element, which may be a length or flexible detonating cord 39, such as the well known "Prima Cord," is threaded through passageway 16 and has the portions thereof passing through sockets 17 seated in notches 29 in detonating relation to the inner ends of the explosive charges.

A firing head 40, having a threaded pin 40*a*, is adapted to be screwed into box 14, to form a fluid-tight closure therefor, and has an axial passage 41 registering with passageway 16 through which the upper end of fuse cord 39 may be threaded. The upper portion of passage 41 is enlarged somewhat in diameter to form a shoulder 42. The upper end of the fuse cord may be knotted, as at 43, so that it will lodge against shoulder 42, to prevent its being pulled downwardly out of the firing head. A conventional electrically-fired explosive initiator 44 is inserted in the enlarged portion of passage 41 in contact with the knotted end 43 of the fuse cord and is connected to a suitable electrical conductor 45, which extends to the upper end of the firing head and makes connection in the usual manner by means of a conventional cable connector 46, which is adapted to be separably connected to the firing head, to an electric cable 47 which is also employed for lowering the gun into a well. It will be understood that cable 47 is adapted to extend to the ground surface where it may be connected to a conventional firing mechanism, and an appropriate source of electric current (not shown). The lower end of fuse cord 39 may also be knotted, as at 48, as it emerges from the end of pin 15 to hold the fuse cord in place in the gun body, and a metal cap 49 is screwed on pin 15 to form a fluid-tight closure for the lower end of the gun body.

The gun may be assembled and loaded in the following manner preparatory to lowering in a well: A piece of fuse cord 39 of suitable length is inserted through passage 41 of the firing head and knotted at its upper end at 43 to retain it in the head. The free end of the cord is then threaded through passageway 16 and firing head 40 is screwed down tightly into box 14, the lower end of cord 39 being extended through the end of pin 15 and knotted at 48 to prevent its retraction through passageway 16.

The perforating units 11 are preferably formed into subassemblies with closure elements 13, as illustrated by the exploded view shown in Fig. 5. A container 28 having the explosive material enclosed therein and a liner 27 in place in hollow 26 will be inserted into the open end of sleeve 31 and pushed home against shoulder 34. A coating of adhesive may be applied to the engaged surfaces of container 28 and bore 33 of the sleeve to hold the perforating unit in place and to exclude moisture from the stand-off space during further handling. The subassembly thus formed may then be inserted into one of the sockets 17, being oriented so that notch 29 will register longitudinally with the portion of the fuse cord 39 which traverses the socket. As the sub-assembly is pushed into the socket, the fuse cord will be engaged in notch 29 of the perforating unit and will be forced radially toward the rear wall 21 of the socket when the unit is fully inserted. The fuse cord will thus be placed under tension, and the normal reaction of the laterally displaced portions under this tension will serve to maintain the displaced portions of the fuse cord in tight engagement with the curved bottom 30 of notch 29, and to hold the perforating unit in firm engagement with shoulder 34. It will be understood that the length of the fuse cord inserted in the gun body will have been predetermined to accommodate the several perforating units which are thus connected to the fuse cord in the gun body. As each sub-assembly is inserted in its socket, cap screws 36 will be put in place and screwed down to clamp the assembly tightly in place. Enlargements 22 at the intersections of passageway 16 with socket 17 provide smoothly tapering surfaces to accommodate the lateral displacement of the fuse cord by the thrust of the perforating units to thereby avoid the formation of sharp angular bends in the fuse cord, which would adversely affect the fusing action of the cord in transmitting the detonating wave to the successive charges connected thereto. By providing the transverse inward curvature of bottom wall 30 of notch 29, in the manner previously described, the portion of the detonating cord seated in the notch will thereby be at least partially surrounded by explosive material, so that upon detonation of the cord, the detonating wave will be transmitted radially into the main explosive charge over a relatively wide spread portion of the charge, thereby more effectively applying the detonating force to the charge. Moreover, by curving the bottom wall of the notch outwardly longitudinally of the notch, in the manner previously described and as illustrated particularly in Figs. 2 and 5, a greater effective length of the detonating cord is placed in contact with the booster portion of the charge, thereby additionally increasing the effectiveness of detonation and assuring high order detonation of the explosive charge.

When the gun has been loaded, as described above, cap 49 will be put in place to close the lower end of the gun body, initiator 44 will be inserted in passage 41 into a pressure contact with the knotted end 43 of fuse cord 39, cable connector 46 will be connected to the upper end of firing head 40 and the gun will be ready for lowering into a well.

When a gun constructed and assembled as above described is fired, fuse cord 39 will first be detonated by the explosion of initiator 44 and will, in turn, detonate the several perforating charges in contact therewith. The detonation of the perforating charges will generate a gaseous jet of extremely high velocity and high pressure which will be directed outwardly along the longitudinal axis of the charge, shattering or disintegrating liner 27 and closure element 13 and, upon striking the well wall, will produce the desired penetration.

Upon detonation of the hollowed charge the resulting gases are directed generally along an axis. However, in accordance with the illustrative embodiments of this invention, there is interposed along such axis and in the path of the gases means which is rupturable by the gases, which is in the form of liner 26, the gases will be converged to a relatively narrow column. This liner which acts as a converger, has such an angle and is made of such a material and thickness of material that it will rupture upon detonation of the charge in a manner so as to deform the converger in the direction of the issuing gases in order to converge those gases to a relatively narrow column.

The construction is, therefore, such as to not only cause the converging means to converge the resulting gases into a relatively narrow column, but to actually cause penetration of the gases through the converger, so that the resulting jet will pass beyond the converging means rather than have the latter precede it, as in the case of the propelling of a projectile. Moreover, the gases will be maintained in the form of a narrow column for an extended distance after convergence.

Although the major proportion of the energy of the explosive will be concentrated in the relatively narrow axially directed jet, very substantial radial forces will be simultaneously generated. By providing an annular air space, as described above, between the exterior of the body of the explosive material comprising the perforating charge and the wall of socket 17 and by positioning the base portion of the charge exteriorly of the end of the socket, in a manner substantially as illustrated in Figs. 2 and 3 particularly, the radial forces emanating from the sides and base portion will dissipate without serious deleterious action on the surrounding portions of the gun body. This desirable result is heightened by making the exterior of the explosive body conical in shape, as illustrated, whereby the exterior surfaces converge inwardly of the socket and away from the socket wall thus enlarging the free air space between the explosive and the socket wall. Moreover, in a hollow explosive, fused to detonate from the end opposite the hollow toward the latter, the maximum explosive force will, generally speaking, be developed at the hollowed portion of the charge, and the radial forces emanating from this portion of the charge are probably of correspondingly increased magnitude. Accordingly, by positioning the explosive charge so that its base or hollowed end portion is outside the outer end of socket 17, the radial forces from this portion of the charge will be caused to discharge into the relatively large unconfined space formed by mouth section 18 and will rapidly dissipate therein without damage to the adjacent portions of the gun body. The outward taper of wall 20 also aids in obtaining this result. An annular clearance of about ⅛ inch or more between the exterior of the explosive body at its greatest diameter and the wall of socket 17 will ordinarily be sufficient for effectively protecting the parts of the gun body from the lateral forces generated by explosion of the perforating charge. The outer end of the explosive may be positioned at a distance of one-sixteenth inch or more outside the outer end of the socket. In the case of a perforating unit of the form illustrated in the drawings, this spacing will apply to the inner end of cylindrical portion **24**. The fact that container **28** and sleeve **31** are interposed in the space between the explosive and the wall of socket **17** will not affect the advantageous results flowing from the provision of the clearance space so long as the materials comprising these elements are appreciably softer or less dense than the steel from which gun body **10** is constructed.

This invention overcomes the objections of the previous gun perforators in the following respect: Where such a gun perforator has the hollow detonating charges arranged transversely in a hollow pipe, then upon detonation of the charges the waves of detonation from one charge will be transmitted to the next charge so as to displace the same, because the velocity of detonation is greater than the detonating velocity in the detonating cord. In accordance with this invention, therefore, means are provided for restricting the transmission of the detonating waves from charge to charge along the carrier. This is accomplished by providing solid material between the charges, which can be conveniently accomplished by making the carrier solid rather than in the form of a pipe, and by providing sockets in the carrier for the detonating charges. This construction, moreover, prevents damage to the carrier itself, which it is desired to retain in order that it may be recharged.

Furthermore, in accordance with this invention, damage to the carrier, incident upon detonation of a charge, is prevented by providing a chamber in the carrier adjacent and surrounding the charge, as shown particularly in Figure 2. If the charge were set directly into a socket, then upon detonation of the charge the socket would be damaged so as to prevent replacement of another charge, except by remachining; in most cases the damage will be such that the carrier could not be used at all. However, the spacing around the charge preserves the carrier itself so that after the carrier has been employed, another charge or set of charges can be inserted.

It will also be noted that the detonating charge is arranged in the carrier with a seat for the charge projecting the major part of the charge outwardly beyond the seat, as also shown in Figure 2. This prevents damage to the seat upon detonation of the charge. If the charge were set wholly within the carrier, then upon detonation of the charge, the seat would be so damaged as to render the carrier unusable for replacement of other charges.

As shown in Figure 2, the carrier is provided with an outwardly flaring opening **20** at the outer end of the charge. If this flare were not provided, then upon detonation of the charge, the stray gases projecting directly against the casing in a well would damage and even split the pipe. However, by the flared construction, the gases are sufficiently dissipated to avoid such damage. The flare is, however, made sufficiently sharp so that there will not be a continuous impact of these stray gases against the pipe from charge to charge. In practice the angle to the horizontal Figure 2 is made about 15°.

Guns constructed in accordance with the present invention may be made in any desired size and length and with any suitable shot spacing, and may be made in the form of units adapted for end-to-end connection. One suitable gun unit may be about five feet long having charge sockets spirally oriented along the body on four inch axial spacing, thus providing a total of fifteen shots distributed over the five foot length of the unit. A plurality of similar gun units may be connected end-to-end to provide guns of greater length, as may be required.

Fig. 6 shows a second gun unit **10***a* which may be substantially identical in construction to the unit previously described, connected to the bottom of the latter by screwing pin **15** into the box **14***a* of the lower unit. The latter is provided with the same cord-type fuse **39** having its upper end knotted at **48***a*, so that when the units are screwed together knot **48** in the upper unit will be in pressure contact with knot **48***a* and compressed against the latter by the thrust of pin **15**. When detonation of the fuse cord is initiated at the upper end of such a gun string, the detonation wave will travel from one unit to the next setting off the perforating charges in all of the units. By this simple expedient, a large number of gun units may be connected togetherm and fired simultaneously as a single gun. Gaskets **50** are provided between the various sections.



By placing knots **48** and **48***a* in contact in the manner described, the knots function as a booster for the detonation wave. It is characteristic of such cord-type detonating fuses that the detonation wave decreases in intensity as it travels from the initiating end to the other terminal. By providing the knotted ends in contact, the knots serve to boost the intensity of the detonating wave as it leaves one section of the fuse cord and enters the succeeding section thus maintaining high order detonation throughout the entire string of perforating units and assuring high order detonation of all of the charges connected to the cord throughout the entire string.

By the employment of closure elements **13** constructed as described, it will be seen that the sealing pressure of flange **35** upon shoulder **19** will increase as the pressure applied to the exterior of the closure element is increased. Accordingly, cap screws **36—36** need be tightened down only sufficiently to prevent leakage of fluid into sockets **17** at the relatively low pressures at the top of the well, and that the seal will automatically become tighter as the gun is lowered into regions of increasing hydrostatic pressure in the well bore. A relatively simple and cheaply constructed sealing arrangement is thus provided which is effective under any pressures likely to be encountered in wells in which the gun is used.

A practical dimensioned embodiment of this invention is as follows:

Fig. 2 is an actual drawing to scale of a perforating gun in which the carrier has an outside diameter of 3.75 inches. The detonating cord **39** is a standard Prima Cord. The explosive container **28** is of high temperature thermosetting plastic loaded with a charge of 17 grams of Cyclonite to a density of 1.53 grams through the main body of the charge. The liner **27** is of pure copper having a thickness of about .035 inch, with a diameter of 1.25 inches, with an interior angle of 90° and with .25 inch radius in the apex. The stand-off part of cap **32** is of the rupturable aluminum alloy capable of withstanding high pressures and yet shatterable. The distance from the inside of the cap at its center to the base of the liner **27** is 6.25 inch. The distance from the front of the seat **19** to the base of the liner at **34**, Fig. 2, is .5625 inch. An actual test of such a well perforating gun with a charge described as above, resulted in perforating through one string of a 5.5 inch diameter 20 pounds per ft. weight casing and through over 10 inches of cement.

It will be understood the various modifications and alterations may be made in the details of the illustrative embodiment within the scope of the appended claims but without departing from the spirit of this invention.

What I claim and desire to secure by Letters Patent is:

1. A perforating gun comprising, a plurality of elongated gun body units adapted to be connected together in end-to-end relation, each unit carrying one or more explosive charges, a separate length of a cord-type detonating fuse extending longitudinally through each of said gun units in detonating relation to the charges carried thereby, and means for transmitting the detonating wave from the fuse in one of said gun units to the fuse in the next gun unit, said means comprising knots formed in the adjacent ends of said fuses and arranged in the adjacent ends of their respective gun units for axial compression when said units are connected together.

2. A well perforating gun, comprising, a sectional carrier designed for placement inside of the well and em-

bodying a series of coupled sections, a hollow detonatable chemical charge on each section, a single length of a cord-type detonating fuse arranged along each section and connected to the charge thereon and mutually contacting knots upon the fuses of adjacent sections compressively engaged when the sections are connected together.

3. A well perforating gun, comprising, a sectional carrier designed for placement inside of a well and embodying a series of coupled sections, each section having a series of longitudinally spaced seats and a series of hollow detonatable chemical charges supportable in said seats, holder means on said seats for supporting the hollowed ends of said charges outwardly beyond said seats, a single length of a cord-type detonating fuze extending longitudinally through each section in detonating relation to the charges seated therein, and means for transmitting the detonating wave from the fuze in one of the sections to the fuze in the next section, said means comprising knots formed in the adjacent ends of said fuzes and arranged in the adjacent ends of their respective sections for axial compression when said units are connected together.

4. In a multi-unit perforating gun, a gun unit, comprising, a tubular body, connection means on the ends of the body for connecting it in end-to-end relation with similar



gun units, one or more explosive charges carried by the body, a single length of a cord-type detonating fuze extending longitudinally through said body in detonating relation to the charges carried thereby, and a knot in an end of said fuze positioned in one of said connection means for compressive engagement with a similarly positioned knot on the fuze of an adjacent gun unit when said units are connected together.

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