

May 17, 1955

W. J. SWEETMAN
WELL PERFORATING DEVICE

2,708,408

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2 Sheets-Sheet 1

Fig. 1

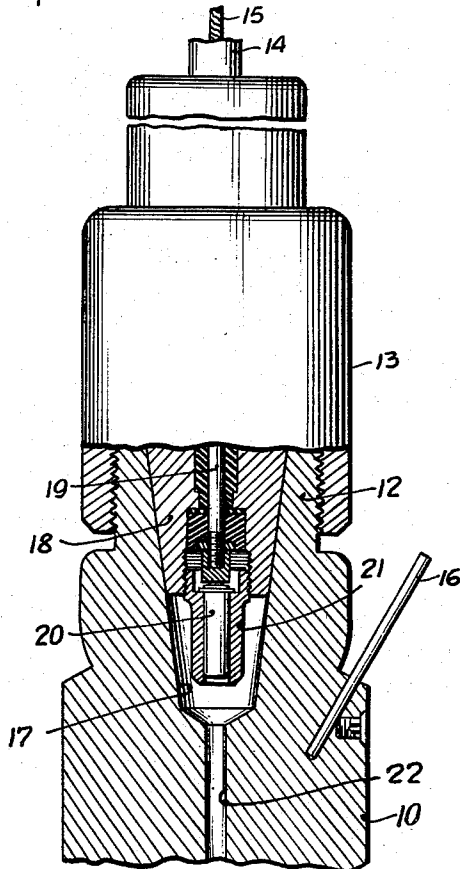


Fig. 1A

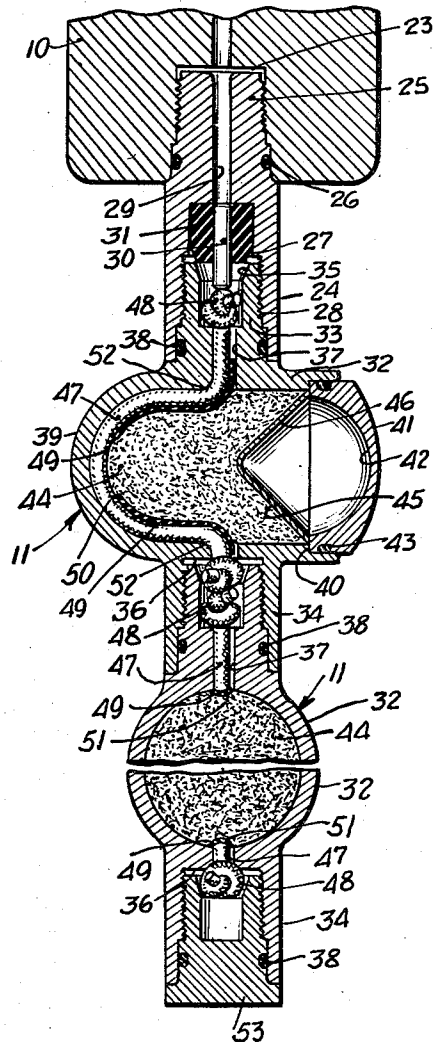
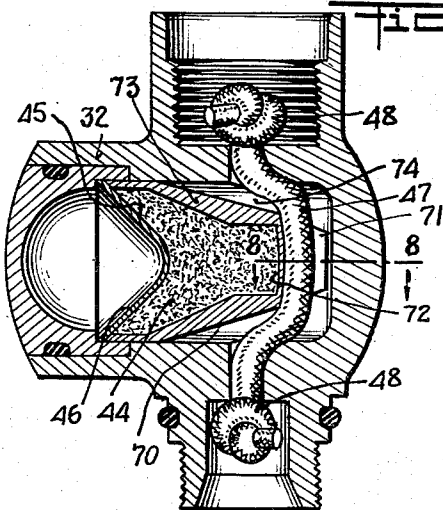


Fig. 2



INVENTOR.
William G. Sweetman
BY
Rever
ATTORNEY.

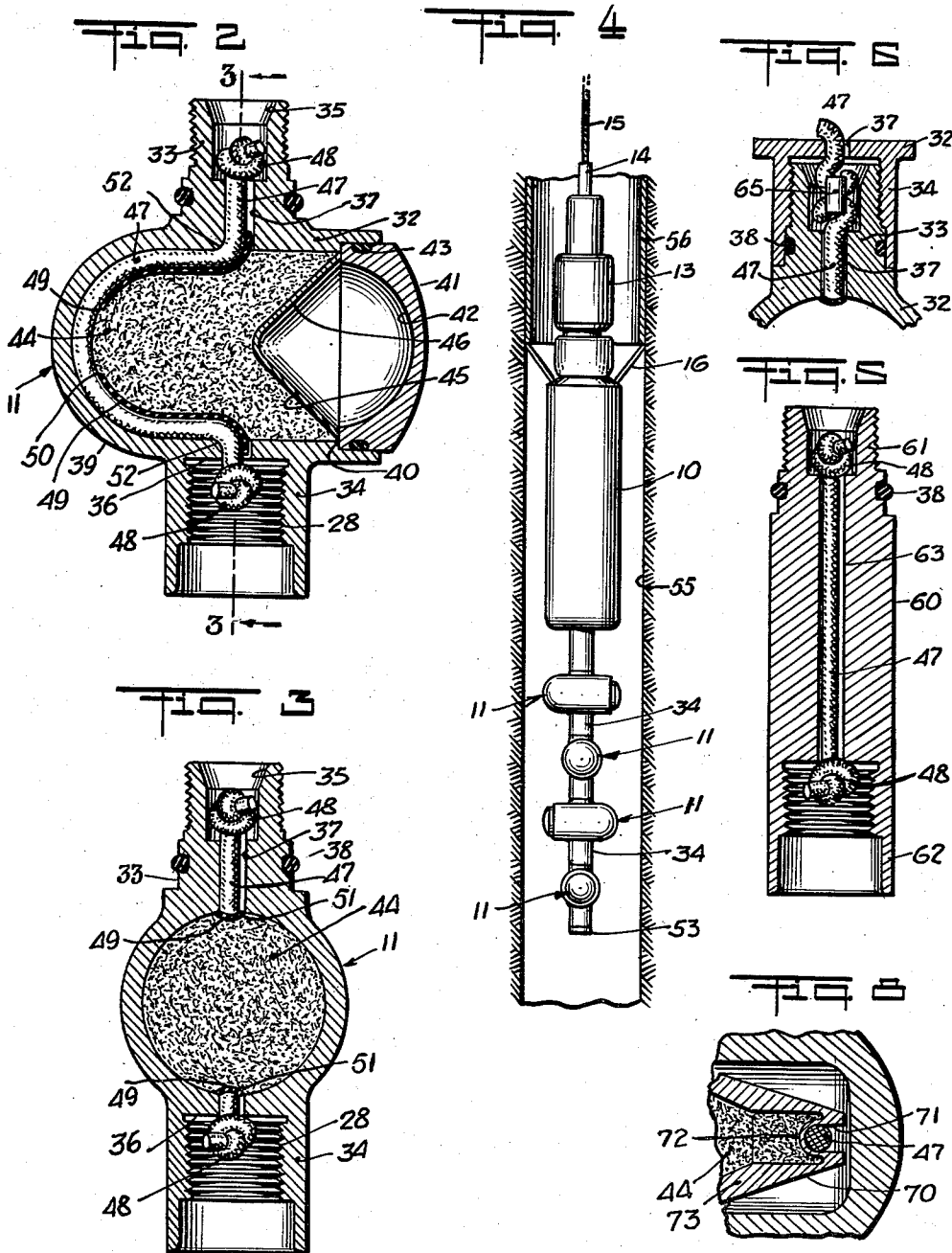
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INVENTOR.
William G. Sweetman
BY

R. W. ...
ATTORNEY

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WELL PERFORATING DEVICE

William G. Sweetman, Houston, Tex.

Application November 14, 1949, Serial No. 127,083

7 Claims. (Cl. 102—20)

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 surrounding formations to permit flow of the formation fluids into the well bore. 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 perforating elements.

The cavity or hollow-charge principle has been applied by applicant to the perforation of the walls of wells and of the metal casings and other well bore linings because of the superior penetrating power obtainable with such charges. For well perforating purposes, such charges were constructed in the form of relatively high density bodies composed 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 or arcuate 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 upon the penetrating power of the gaseous jet to effect the desired degree of perforation.

In a hollow charge, the most efficient jet formation for developing maximum power is developed by detonating the charge from the end opposite the hollow and on the axis of the charge. The detonation waves created by this arrangement will then travel generally axially of the charge from the locus of detonation, increasing in power as they travel through the body of the charge until they reach the hollowed end which will then effectively focus and intensify the explosive force into a high powered penetrating jet. The power developed by such a charge is dependent, therefore, in part, at least, upon the length of the charge, which, in turn, has an optimum relation to the diameter of the charge at the hollowed end. This optimum length is generally from one to two times the diameter of the charge at the hollowed end. Due to the space limitations in the ordinary well bore, both the diameter and length of the charges which may be used are necessarily limited. In order, therefore, to obtain maximum penetrating power, applicant has employed charges of maximum length within the optimum limits and to detonate them from the end opposite the hollow to assure high-order detonation of the charges and proper jet formation under all conditions.

Moreover, in well perforating, it is generally desirable to make a plurality of perforations through the well bore linings along the face of the fluid-containing earth formation, in order to provide a plurality of fluid passages from the formation into the well bore to assure access of the formation fluids from the several parts of the formations to the well bore. For the purposes of

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economy and efficiency, it is desirable to effect the desired plurality of perforations in a single operation, and applicant's practice has been to mount a plurality of perforating charges in a single carrier or "gun" and set them off at one time.

Due to the space limitations in the usual relatively narrow well bore it is desirable to provide a series of perforating charges arranged in axially spaced relation along a carrier and to orient them angularly about the longitudinal axis of the carrier. Since, as noted, it is desirable to employ perforating charges of maximum length and diameter to produce perforations of maximum area and depth of penetration, such charges will generally be of a size to extend for substantial lengths transversely of the carrier, with the hollow at one end from which the perforating jet will emerge to strike the well wall. Moreover, since, as noted, in order to produce optimum jet formation to effect maximum penetration, it has been applicant's practice to detonate such charges from the ends opposite the hollowed ends, it has been found difficult to provide a relatively simple, trouble-free fuzing arrangement for a string of such charges which may be fired from one end of the string and which will effectively detonate successively all of the charges in the string at high-order detonation rates and with proper jet formation necessary to produce maximum penetrating power. In firing a string of charges so arranged, it becomes highly desirable to provide a relatively simple fuzing arrangement which will detonate all of the charges in rapid succession and at the high order detonation rates and with proper jet formation necessary to produce maximum penetration power.

One of the objects of this invention, therefore, is to improve the perforating device in order to secure a more effective operation.

Accordingly, this invention includes the provision of a perforating device comprising a plurality of hollow detonating charges, arranged in an elongated string, and employing a relatively simple and novel form of fuzing arrangement for successively detonating the charges at high-order detonation rates from a single firing element connected to one end of the string; and in which the several charges are of optimum sizes to produce relatively large perforations through the well bore and its linings extending to considerable depth into the surrounding formations.

Applicant provides a perforating unit of standardized form and dimensions containing a single hollow charge, each of said units being adapted for connection to other similar units to form a string of charges of any desired length and in any relative orientations; each of said units having its individual fuzing element for detonating its charge; and each of said fuzing elements being arranged in a novel manner relative to said charge to provide for simple and automatic connections to the fuzing elements of the adjacent units to thereby provide a continuous detonatable fuzing train for effectively detonating the successive charges forming said string from a single firing element connected to the upper end of such a string.

Generally stated and in accordance with an illustrative embodiment of this invention the perforating device embodies a firing head and a carrier comprising a series of separable perforating units. The perforating units are of substantially identical construction and are adapted to be coupled together in any desired spacing and orientation arrangement. Each of the units includes a generally tubular casing, designed to be disposed transversely of the longitudinal axis of the device, and is provided with a pair of hollow coupling members extending from opposite sides of the casing generally along said axis for connection to the coupling members of adjacent units forming the series. A detonatable chemical charge having one

end hollowed is arranged in the casing of each unit and each unit is provided with a length of cord-type detonating fuze, which extends through the casing generally from one side to the other, the ends of the fuze having knots formed therein which are seated in the respective coupling members to contact similar knots on the ends of the fuzes in adjacent units when several units are connected together. The portion of the fuze which passes through the interior of the casing is arranged to extend from one coupling member along one side of the charge toward the end opposite the hollowed end and into detonating contact with this opposite end of the charge, and thence back along the opposite side of the charge to the opposite coupling member. Detonation-absorbing or cushioning means, such as strips of a suitable shock-absorbing material, are interposed between the portions of the fuze extending along the sides of the charge to thereby permit only the portion of the fuze passing over the end of the charge to be in effective detonating contact with this end of the charge. By this arrangement each charge in a string thereof will, in effect, be fuzed from the axis of string, thus permitting any desired orientation of the charges, while, at the same time, each of the charges will be effectively detonated from the end thereof opposite the hollowed end, thereby permitting use of charges of maximum dimensions relative to a particular well bore diameter, whereby to produce optimum jet formation and maximum penetration effectiveness.

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 embodiments in accordance with this invention.

Figs. 1 and 1A together comprise a longitudinal sectional view of a perforating device in accordance with an embodiment of this invention;

Fig. 2 is an enlarged longitudinal sectional view of one of the perforating units;

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

Fig. 4 is a view showing the perforating device suspended in a well in position to perforate the wall thereof;

Fig. 5 is a longitudinal sectional view of a spacer element for use between pairs of perforating units;

Fig. 6 is a detail of another embodiment of a fuze connection between units;

Fig. 7 is a view similar to Fig. 3 of another embodiment of a perforating unit in accordance with this invention; and Fig. 8 is a fragmentary sectional view taken along line 8—8 of Fig. 7.

Referring to the drawings, the perforating device (Fig. 1) comprises a firing head 10 to the lower end of which is connected a carrier composed of a plurality of perforating units, each designated generally by the numeral 11. Firing head 10 is preferably constructed in the form of a generally cylindrical solid steel body primarily to provide substantial weight to assure ready sinking of the perforating device through any fluid in the well bore in which it is to be run. Head 10 has a threaded pin 12 at its upper end for connection of a cable connector 13, such as a conventional so-called "rope socket," which is carried on the end of a lowering cable 14 through which is threaded an electrical conductor 15 for transmitting firing current to the firing head from a suitable source (not shown) of such current located at the surface. Head 10 may be equipped with a plurality of angularly spaced, upwardly and outwardly sloping flexible wire fingers 16 of generally conventional form (Figs. 1 and 4) which may be employed in the well known manner for locating or positioning the perforating device in a well, viz., with reference to the joints of a casing.

Pin 12 is provided with a tapered bore 17 which is adapted to receive a correspondingly tapered contact plug 18 having an axially disposed electrode 19 which is adapted to make electrical connection in the usual man-

ner to conductor 15 when the rope socket is screwed down on pin 12. An explosive cap 20, of any suitable or conventional type, is supported in a tubular sleeve 21 attached to the lower end of plug 18, and is arranged in electrical contact with the lower end of electrode 19 so that it may be fired by electric current supplied through the electrode. A passageway 22 extends axially through head 10 in registration with cap 20 and provides communication between the lower end of bore 17 and an internally threaded socket 23 in the lower end of head 10. A connector sub 24 having a threaded pin 25 at its upper end is adapted to be screwed into socket 23 and carries an external packing ring 26, such as a conventional O-ring, below its threaded portion to form a fluid-tight seal between the pin and the surrounding wall of socket 23. The lower end of connector sub 24 is provided with a generally tubular box 27 internally threaded at 28. An axial passage 29 extends through sub 24 in registration with passageway 22 and communicates with box 27. An explosive booster fuze 30, generally comprising a pellet of a suitable detonating explosive, is aligned with passage 29 and held in position in box 27 by means of a suitable centralizing bushing 31, which may be constructed of a suitable insulating material. Fuze 30 is of sufficient length to extend downwardly below the lower face of bushing 31 into box 27 as shown.

Connected into box 27 is the first of the series of perforating units 11, which are all identical in construction, and the subsequent description of one of these units will, therefore, be equally applicable to all of them.

Perforating unit 11 includes a generally tubular casing 32 having integrally formed pin and box connections 33 and 34, respectively, extending axially from the opposite sides of the casing at approximately the mid-point thereof, which will correspond generally to the longitudinal axis of the perforating device as a whole. Pin member 33 is externally threaded and box member 34 is internally threaded. Pin and box members 33 and 34 are provided with internal sockets 35 and 36, respectively, each of which communicates with the interior of casing 32 by means of an axial passageway 37. The base portion of pin member 33 has a packing ring 38, also of the conventional O-ring form, mounted in the periphery thereof to provide a fluid-tight seal between the pin member and the adjacent wall of a box member in which it may be inserted, as will be described hereinafter.

One end of casing 32 is closed by an outwardly extending, integrally formed wall 39. The opposite end of casing 32 is open and provided adjacent the open end with an internal annular shoulder 40 adapted to form a seat for a dome-shaped, circular closure cap 41, which is slidably insertible into the open end of casing 32 and provided with an outwardly curving inner cavity 42. The periphery of cap 41 has a compressible packing ring 43, also of the O-ring form, suitably mounted therein to form a fluid-tight interior seal with the inner wall of the open outer end of casing 32 when the cap is inserted therein and seated against shoulder 40.

Disposed within the interior of casing 32 is an explosive charge 44, composed of any suitable high-brisance type of detonating explosive material, having a mass and shape to substantially fill the interior of the casing to a point substantially flush with shoulder 40. Charge 44 may be premolded to the desired size, shape and density, or may be composed of plastic type explosive which may be packed or pressed into the interior of casing 32 to conform to the internal shape thereof. The end of the charge facing the open end of the casing is provided with a suitably shaped cavity or hollow 45 which may be generally conical, spherical or other suitable arcuate form. Hollow 45 is lined with a thin liner 46 of corresponding shape, constructed preferably of a suitable metal, such as copper, aluminum, various alloys thereof, or of other suitable material. When cap 41 is put in place, it will be seen that cavity 42 forms a sealed hollow chamber ex-

tending forwardly from the hollowed-end of the charge and this chamber defines the so-called "stand-off" space within which the explosive forces are permitted to converge and form into the desired jet conformation without interference from extraneous materials.

A length of a suitable flexible fuze cord 47 extends through the interior of casing 32 generally transversely thereof. The free ends of the cord extend into the opposite passageways 37 and are provided with knots 48 formed in the ends which are seated in sockets 35 and 36 of the pin and box members 33 and 34, respectively, forming enlarged masses of detonatable material therein which serve as detonation boosters. Portions of the cord extend from the knotted ends rearwardly along opposite sides of charge 44, the intermediate portion of the cord being thus arranged to pass over and be placed in contact with the end of the charge opposite the hollowed end. The portion of cord 47 inside casing 32 is thus held closely confined between the exterior surface of charge 44 and the inner wall of the casing including end wall 39. Strips 49 of a suitable shock-absorbing material, which is preferably a non-metallic material, such as rubber, fibrous material or other suitable composition, are inserted between the portions of cord 47 extending along the opposite sides of charge 44 and the adjacent portions of the charge. Two of the strips 49 are preferably employed, each extending lengthwise from a point inside passageway 37 slightly in advance of the point where the cord begins to bend as it passes into the interior of the casing to a point slightly spaced from the apex of the rear end of charge 44, to thereby provide a gap 50 in the shock-absorbing material adjacent the apex of the charge, as illustrated particularly in Figs. 2 and 3. Instead of the strips 49, a continuous sleeve of shock-absorbing material may be employed to surround the charge to thereby hold the side portions of the fuze cord out of detonating contact with the sides of the charge. About $\frac{1}{16}$ inch to $\frac{1}{8}$ inch of shock-absorbing material will ordinarily be sufficient for this purpose. With the described arrangement only that portion of cord 47 which passes over the apex portion of the rear end of charge 44 is in effective detonating contact with the latter. Charge 44 may be provided with an arcuate recess 51 in which the cord or at least the curved inner surface thereof and the interposed shock-absorbing strips are embedded, as shown. Recess 51 may be preformed in the charge during molding, or when charge material of plastic form is pressed or packed into casing 32 with cord 47 in place therein, the pressure employed in packing the charge will extrude it about the cord and strips to produce the desired embedded arrangement. The sides of passageways 37 adjacent the points where the cord bends in entering and leaving the interior of casing 32 are smoothly rounded, as at 52, to eliminate sharp corners about which the cord would otherwise be forced to bend more sharply than is desirable when using flexible detonating cord of the general type described.

Fuze cord 47 may be of any suitable or conventional type and is preferably the material commonly known in the art as "Prima Cord," which is a cord-type material consisting essentially of a flexible tubular casing, the interior of which is packed with a suitable and conventional detonating explosive, which is adapted when detonated from one end thereof to transmit a high-powered detonating wave throughout its length, and may be employed to serially detonate a string of inter-connected explosive charges such as are employed in the perforating device herein described.

As previously noted, charge 44 may be composed of one or more of the well-known high-brisance types of chemical detonating explosives, which include such materials as 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. Booster fuze 30 may be composed of similar material.

The several parts of casing 32 and cap 41 are preferably constructed of material which will shatter into relatively small pieces upon explosion of the charge. Such materials include metallic materials such as fragile cast iron, cast aluminum or one of its fragile alloys or other metal which will withstand high pressures but will also shatter readily. Special types of glass which are adapted to withstand high pressures but which will shatter completely upon explosion of the charge have been found suitable. Various readily shatterable plastic materials may also be used, particularly under relatively low pressure conditions. The material selected will, in all cases, be such as to produce as little so-called "junk" as possible in the well which would tend to interfere with the flow of fluid into and from the well.

In assembling the perforating device, any desired number of the perforating units 11 will be connected together, pin member 33 of one unit being screwed into box 34 of the adjacent unit, thereby forming a string of units of the desired length. The units may be angularly oriented with respect to each other to produce any desired pattern of perforations in the wall of the well. As the units are screwed together knots 48 in the adjacent ends of the respective fuze cords will be brought into compressive contact forming effective connections between the fuze cords of the several units throughout the string of units. Box member 34 of the lowermost unit in the string will be closed by means of a threaded closure plug 53 (Fig. 1) which carries a sealing ring 38 of the O-ring type to thereby form a fluid-tight seal for the lowermost end of the string of charges. Booster fuze 30 will be inserted in the bore of centralizing bushing 31 and sub 24 will be screwed down over pin member 33 of the uppermost unit in the string, thereby inserting fuze 30 into detonating contact with knot 48 seated in socket 35. Packing ring 38 carried by the base of pin member 33 will compressively engage the inner wall of box 27 of the sub to form a fluid-tight seal between the pin member and the socket. Pin 25 will then be screwed into socket 23 to connect the string of perforating units to head 10. Firing plug 18 carrying firing cap 20 will then be inserted into bore 17 and rope socket 13 will then be connected to pin 12 and the entire device will thus be assembled preparatory to lowering into a well bore.

Operation of the device is as follows: The device, assembled as above described, will be lowered into a well bore 55 (Fig. 4). Merely by way of illustration, the latter is shown to be partially lined with the usual well casing 56, leaving a section of open hole below the lower end of the casing liner. In this case the device will be lowered until fingers 16 are below the end of the casing, whereupon the string will be raised sufficiently to cause the upper ends of the fingers to engage the lower end of the casing which thus forms a stop in order to fix the position of the perforating units opposite the unlined portion of the well bore. It will be understood that the device may be positioned within the casing, in cases when it is desired to produce perforations through the casing into the surrounding formations. In such case flexible fingers 16 will be employed in the well known manner to engage in a collar space between adjacent sections of the well casing in order to position the perforating string at the selected point in the well.

When the device is in the desired position in the well bore, current will be applied to conductor 15 to set off cap 20. The jet of hot, high-pressure gases released by firing of the cap will travel downwardly through passageways 22 and 29 and will strike booster fuze 30 which will be detonated thereby to release a high-velocity detonating wave which will strike the adjacent knot 48 of the fuze cord extending through the uppermost one of the perforating units 11, and start detonation of this first

section of the fuze cord. The resulting shock wave will travel at a high velocity throughout the length of this first section of fuze cord. However, the interposition of shock-absorbing strips 49 between the fuze cord and charge 44 will effectively prevent detonation of the latter from the side portions of the cord until the shock wave reaches gap 50 where the cord is in direct contact with the charge and where the full force of the detonation of the fuze cord will be applied to the end of the charge. Detonation will thus be effected at the point on the charge which will produce maximum high-order detonation thereof and most effective jet formation of the explosive forces. The detonation wave will then continue through the lower side portion of the fuze cord to lower knot 48 which is in contact with knot 48 of the next succeeding perforating unit. The increased mass of detonating material thus interposed in the path of the detonating wave serves to boost or increase the velocity of the detonating wave as it enters the fuze cord of the next unit to such a degree as to maintain the velocity of the detonating wave through the next unit at the same order of magnitude as in the preceding unit and thereby assure equally high-order detonation and jet formation of maximum efficiency of the second unit. The process is repeated throughout the string of perforating units thereby assuring high-order detonation and maximum efficiency of jet formation of all of the units irrespective of the length of the string.

When the charges have thus been set off, the several perforating units 11 will be completely shattered. However, head 10 and the cable connections will normally be uninjured and may be withdrawn from the well for re-use. Ordinarily only cap 20 and sub 24 will need to be replaced, in addition, of course, to a new string of the perforating units.

With the described arrangement it will be seen that all of the charges are, in effect, fuzed from the common axis of the string thus permitting orientation of the charges about the axis in any desired manner, while at the same time permitting use of the full length of each charge to give maximum depth of penetration. With such an arrangement the length of each charge may be made a maximum for the particular well bore diameter in which it is run and thereby permit use of charges which will produce perforations of maximum size and depth of penetration.

By making the individual units of identical form and dimensions, a string of any desired length and number of charges can be readily assembled, in which all of the charges will be uniformly spaced and may be effectively detonated from one end in a manner to produce maximum penetration for each unit. It will be understood that if greater spacing is desired than that which will be produced by connecting one unit directly to the other, spacer sleeves of any desired length may be inserted between pairs of the perforating units and a length of fuze cord installed therein to form a fuzing connection between the fuze cords of the connected units. Fig. 5 illustrates an embodiment of a spacing member for effecting such spacing and comprises a tubular sleeve 60 of the desired length provided at one end with a hollow threaded pin member 61 and at the other with a hollow internally threaded box member 62, pin member 61 and box member 62 corresponding in dimensions with pin members 33 and box members 34 of the units 11. An axial passageway 63 extends through sleeve 60 communicating with the interiors of pin and box members 61 and 62. A length of fuze cord, similar to cord 47, is extended through passageway 63 and is provided with knots 48 at each end seated in the bores of pin and box members 61 and 62.

When such a spacing member is interposed between two of the units 11, the detonation wave will pass from the fuze of one unit to the other though the section of cord 47 mounted in sleeve 60 in the same manner as described for the directly connected units.

Fig. 6 illustrates another embodiment for boosting the detonation wave passing from one unit to the next. In this embodiment the ends of cord 47 are left unknotted and extend into the respective sockets 35 and 36. A pellet 65 of a suitable detonating explosive is inserted between the adjacent ends of the fuze cords of successive perforating units, as shown, and will serve to boost the detonating wave as it passes from one cord section to the other with substantially the same effect as that produced by the contacting knots 48.

Figs. 7 and 8 illustrate a somewhat modified embodiment of the perforating units, employing pre-molded explosive charges of somewhat modified form, adapted particularly for use in relatively narrow well bores necessitating the use of charges of relatively small dimensions but which will function with maximum penetrative effectiveness.

The explosive charge in this modified embodiment is similar to that disclosed in my copending U. S. application, Serial No. 88,740, filed April 21, 1949. In this embodiment, explosive charge 44 is shaped into a generally conical form by molding or pressing the explosive material into a generally conical container 70. Hollow 45 is formed in the larger diameter end of the charge and is lined with liner 46, as in the previously described embodiment. The apex portion of the container is provided with a transverse notch 71 through which the intermediate portion of fuze cord 47 is threaded. Notch 71 has a relatively thin bottom wall 72 which is curved transversely to conform to the radius of the fuze cord and to extend into the interior of the container, so that when the explosive material is pressed into the container it will be extruded around the curved inner surface of bottom wall 72 into the space between the sides thereof and the adjacent side wall 73 of the container, thereby, in effect, producing a partially embedded relation of the fuze cord to the apex end of the charge (see Fig. 8). Bottom wall 72 is also curved outwardly about a relatively large radius longitudinally of the notch (Fig. 7) to increase the length of the surface of bottom wall 72 which is in contact with the fuze cord. The tapered side wall 73 of the container is made substantially thicker throughout its circumference than bottom wall 72 and serves the same function as strips 49 of the previous embodiment for preventing pre-detonation of the charge from the portions of fuze cord 47 extending along the sides thereof toward notch 71. Bottom wall 72 is made to a thickness as small as possible so as to readily transmit detonating shock from cord 47 to the apex portion of the charge and will ordinarily be from about 5 to 15 one-thousandths of an inch as compared to an average thickness of wall 73 of about one-eighth inch. The latter dimension will be such as to interpose a layer of material between the explosive charge and the adjacent portions of the fuze cord which extend along the side wall toward the apex portion of the charge, which will be sufficient to effectively prevent detonation of the charge by the side portions of the fuze cord. Container 70 may be constructed of various materials such as one of the numerous synthetic plastics which possess sufficient mechanical strength to support and hold the explosive in the desired shape and which will permit safe and effective handling of the charge and container as a unit for shipping and loading. Such materials will also be readily destroyed by the explosion of the charge. Due to the conical conformation of container 70 some air space, indicated at 74, may also be provided between the sides of the container and the adjacent portions of the fuze cord to thereby additionally protect the side portions of the charge from the detonating wave traversing cord 47.

I have discovered that the diameter of the perforation made by a perforating unit, of any given size, in accordance with this invention, may be controlled to an important degree, merely by the selection of the material from which cap 41 is constructed. For example, if cap 41 is constructed of cast iron, a substantially larger per-

foration will be produced than when the cap is made of aluminum alloys, using identical explosive charges, and without any other changes in the size, form, material, and fuzing arrangement of the unit as a whole. Thus, standard perforating units of a given size may be employed to make various sized perforations, as desired, merely by supplying caps 41 constructed of different materials, thereby avoiding the necessity, in many cases, of providing a different size perforating unit for each particular size of perforation which is desired.

It will be understood that the perforating gun may be run on a wire line or string of tubing and firing head modified in accordance with conventional practice to permit firing of cap 20 by well-known mechanical percussion methods, as the electrical firing arrangement illustrated and described herein is presented merely by way of example.

Numerous other alterations and modifications may be made in the details of the illustrative embodiments without departing from the scope of the appended claims but within the spirit of this invention.

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

1. An explosive unit for a well perforating device, comprising, a detonatable chemical charge having one end hollowed, a casing enclosing said charge, a continuous detonating fuze extending generally transversely through said casing and having an intermediate portion extending transversely across and in detonating contact with the opposite end of said charge and having its other portions extending from said intermediate portion along opposite sides of said charge between the charge and the wall of said casing to points intermediate said ends, detonation-absorbing means comprising strips of a shock-absorbing material interposed between said other portions and adjacent portions of said charge, and detonation-boosting elements carried by the opposite free ends of said fuze disposed for detonating engagement with detonating elements of adjacent units.

2. An explosive unit for a well perforating device, comprising, a detonatable chemical charge having one end hollowed, a casing enclosing said charge, a continuous cord-type detonating fuze extending generally transversely through said casing and having an intermediate portion extending transversely across and in detonating contact with the opposite end of said charge and having its other portions extending from said intermediate portion along opposite sides of said charge between the charge and the wall of said casing to points intermediate said ends, detonation-absorbing means interposed between said other portions and adjacent portions of said charge, and detonation-boosting elements comprising knots formed in the opposite free ends of said fuze disposed for detonating engagement with detonating elements of adjacent units.

3. A well perforating device, comprising, a carrier designed for placement in a well and embodying a firing head and a series of substantially identical separable

perforating units connected at one end to said head, each of said perforating units comprising a generally tubular casing arranged transversely of the longitudinal axis of said carrier and having hollow coupling elements extending from opposite sides thereof along said axis, a detonatable chemical charge having one end hollowed co-axially disposed in said casing, a continuous length of detonating fuze extending generally transversely through said casing having an intermediate portion thereof extending transversely across and in detonating contact with the opposite end of said charge and its other portions extending along opposite sides of said charge and terminating within said coupling elements, detonation-absorbing elements interposed between said other portions and adjacent portions of said charge, and detonation-boosting elements carried by the free ends of said fuze extending into said coupling elements and into contact with the boosting elements on the fuzes of adjacent units.

4. An explosive unit for a well perforating device, comprising, a generally cylindrical detonatable chemical charge having one end hollowed, a generally tubular casing concentrically enclosing said charge, hollow connection members extending laterally from opposite sides of said casing intermediate the ends thereof and communicating with the interior thereof, a single length of a cord-type detonating fuze extending generally transversely through said casing, said fuze having an intermediate portion extending transversely across and in detonating contact with the end of said charge opposite said hollowed end and having its opposite ends extending into and terminating within said connection members, and knots formed in both the opposite free ends of said fuze.

5. An explosive unit according to claim 4 having detonation-absorbing means interposed between said charge and the portions of said fuze extending from the opposite ends of said intermediate portion of said fuze.

6. An explosive unit according to claim 4, wherein said connection members are provided with threaded sections for threaded connection to similar adjacent units.

7. An explosive unit according to claim 4 having a removable closure for the end of said casing adjacent the hollowed end of said charge.

References Cited in the file of this patent

UNITED STATES PATENTS

1,968,565	Mallet	July 31, 1934
2,026,061	Prikel	Dec. 31, 1935
2,139,104	Wells	Dec. 6, 1938
2,391,932	Turechek	Jan. 1, 1946
2,402,153	Elliott	June 18, 1946
2,414,349	Alexander	Jan. 14, 1947
2,418,486	Smylie	Apr. 8, 1947
2,446,235	Markham	Aug. 3, 1948
2,494,256	Muskat	Jan. 10, 1950