JET TYPE PERFORATING UNIT

Filed May 20, 1950 4 Sheets-Sheet 1

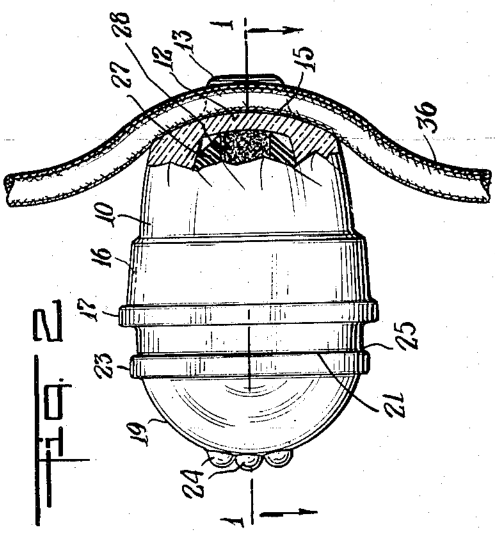


FIG. 2

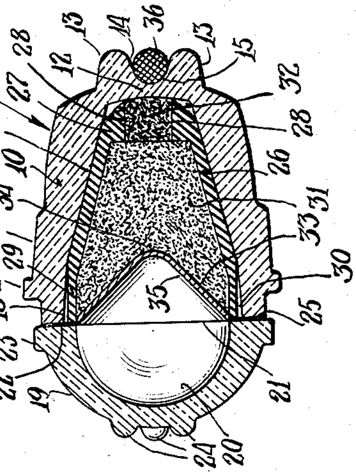


FIG. 1

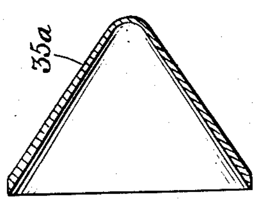


FIG. 11

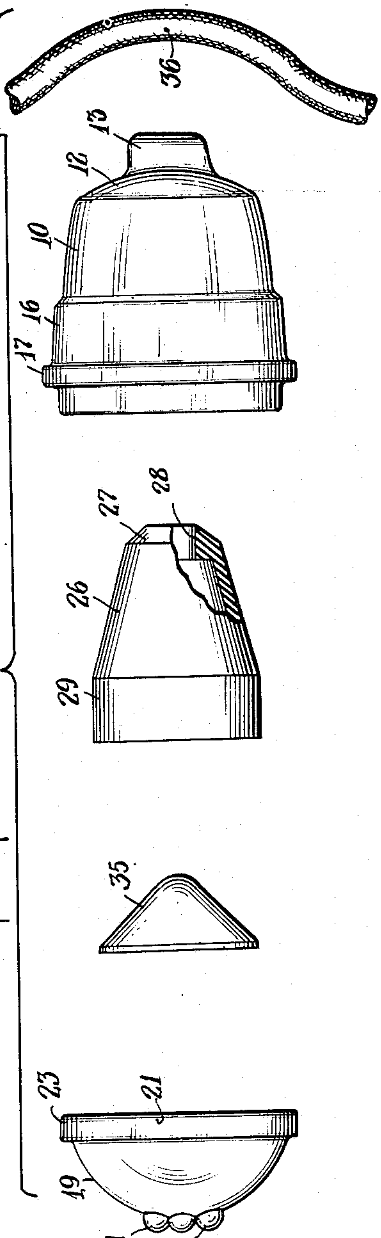


FIG. 3

INVENTOR.
William G. Sweetman
BY
R. Werlin
ATTORNEY

Feb. 24, 1953 W. G. SWEETMAN 2,629,325

JET TYPE PERFORATING UNIT

Filed May 20, 1950 4 Sheets-Sheet 2

Fig. 4

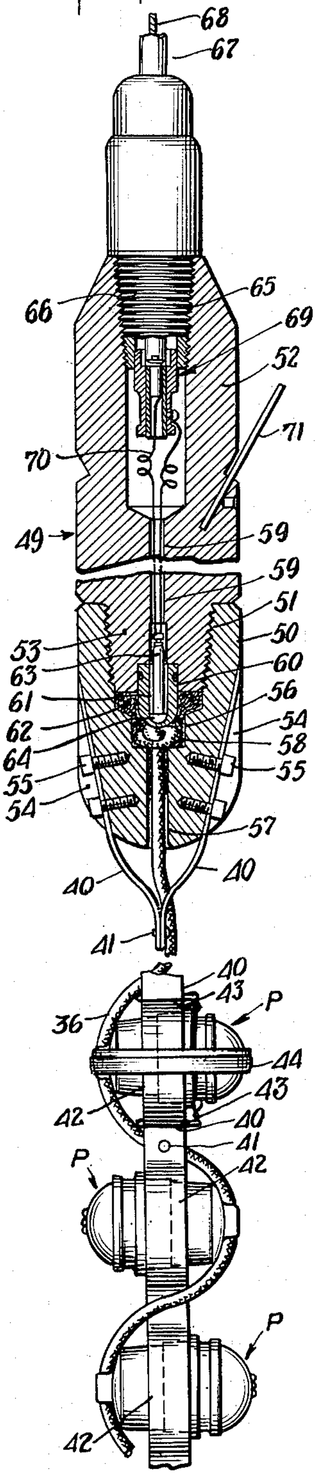


Fig. 5

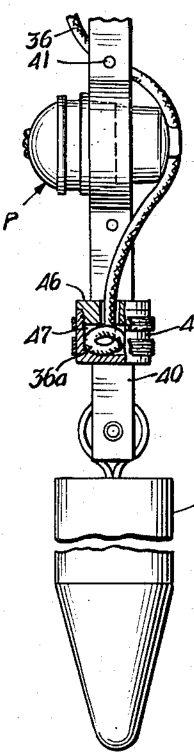


Fig. 6

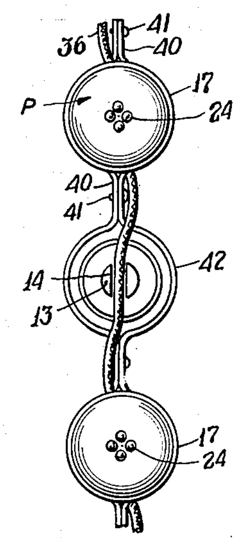


Fig. 9

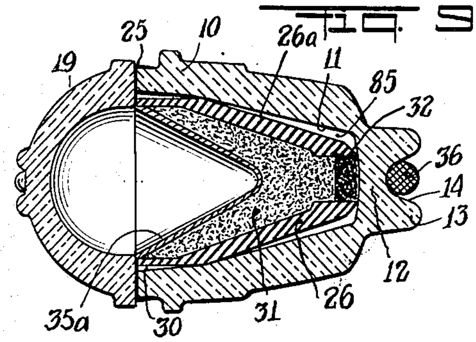
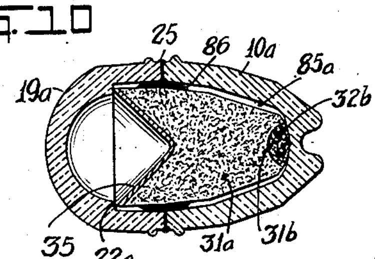


Fig. 10



INVENTOR.
William G. Sweetman
BY
[signature]
ATTORNEY

Feb. 24, 1953 W. G. SWEETMAN 2,629,325

JET TYPE PERFORATING UNIT

Filed May 20, 1950 4 Sheets-Sheet 3

Fig. 8

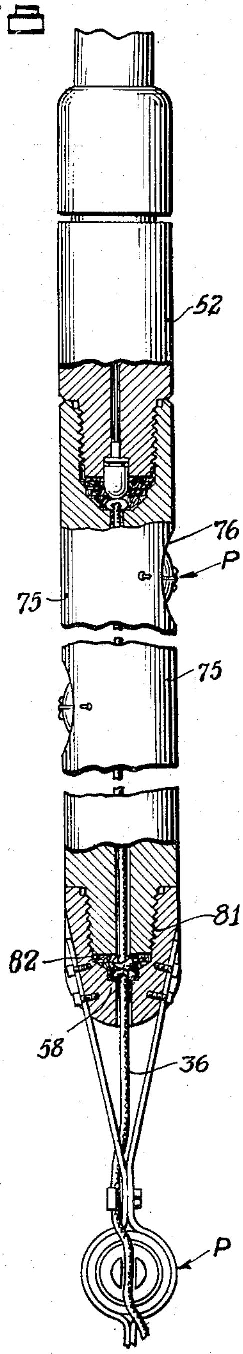
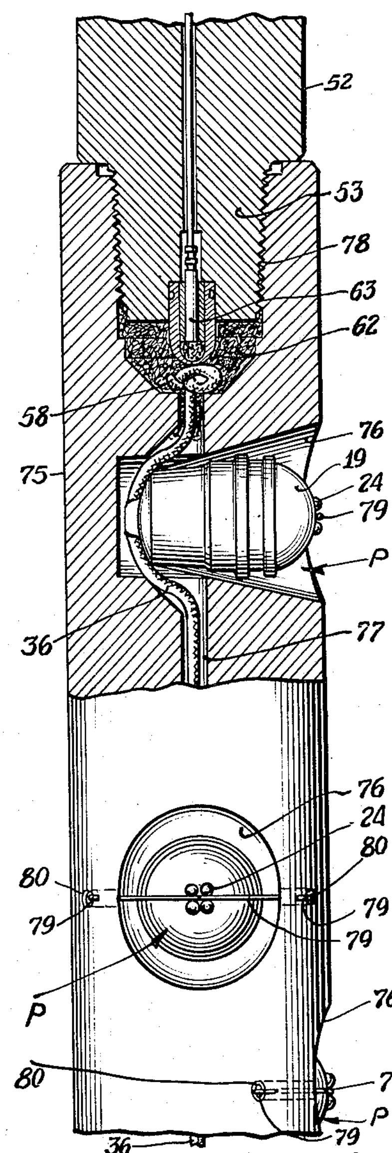


Fig. 7



INVENTOR.
William G. Sweetman

BY

R. Werlin

ATTORNEY

Feb. 24, 1953 W. G. SWEETMAN 2,629,325

JET TYPE PERFORATING UNIT

Filed May 20, 1950 4 Sheets-Sheet 4

Fig. 12

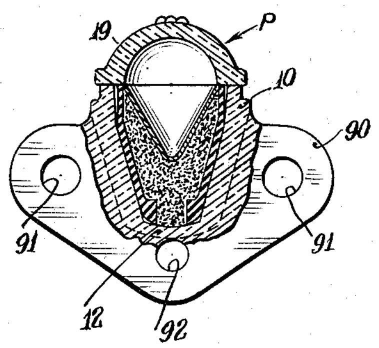


Fig. 13

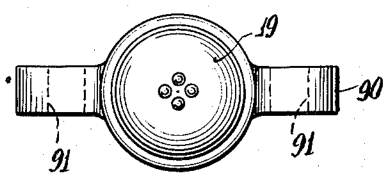


Fig. 14

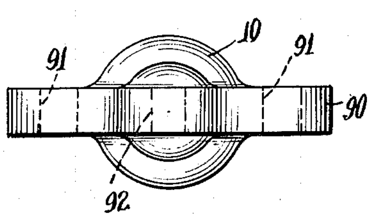
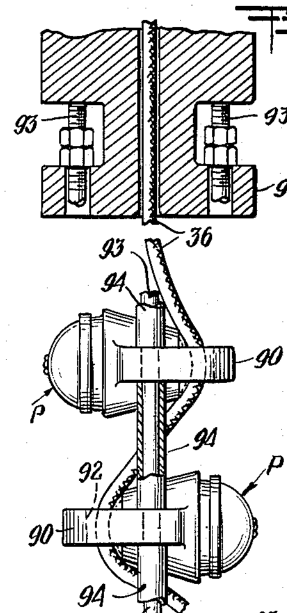


Fig. 15



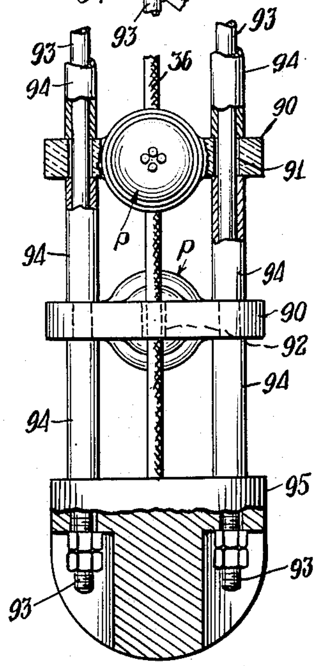


Fig. 16

INVENTOR.
William G. Sweetman

BY

R. Weli

ATTORNEY

Patented Feb. 24, 1953 2,629,325

UNITED STATES PATENT OFFICE

2,629,325

JET TYPE PERFORATING UNIT

William G. Sweetman, Houston, Tex.

Application May 20, 1950, Serial No. 163,146

8 Claims. (Cl. 102—20)

1

This invention relates to well perforating and particularly to improved perforating devices of the so-called "jet" type in which a hollowed explosive charge is employed to effect perforation of a well wall.

Jet perforating as heretofore practiced, has given rise to several troublesome problems resulting from the formation and accumulation in the well of so-called "junk" produced by the disintegration of the casings which enclose the explosive charges and of the carriers employed to support the charges which are normally mounted thereon in groups for insertion in a well and are generally fired simultaneously. The quantities of junk produced with the more conventional types of perforating units and carriers is often sufficient to plug the perforations or otherwise seriously interfere with the free entrance of earth formation fluids into the well bore. In instances where the perforating units may be mounted in a heavy cylindrical steel carrier body which is intended to be withdrawn from the well, the junk formed may become lodged between the carrier body and the well wall and cause the carrier to become stuck in the well bore. Also when employing steel carrier bodies, the forces released upon detonation of the charges may be such as to damage the carrier body to such an extent that it may not be re-used or used only a few times before it must be discarded. As these steel carrier bodies are normally relatively expensive to construct, too frequent replacement thereof may render this type of operation relatively uneconomic.

The present invention has for its principal objects the provision of an improved form of perforating unit which produces a minimum amount of detritus or "junk" when the explosive charge is detonated, and which may be employed with either a disintegrable type of carrier or with one which is to be recovered for re-use.

An important object is the provision of a perforating unit which is completely self-contained and fully sealed against the entrance of extraneous fluids, whereby the units may be mounted in widely varying forms of carriers, without affecting the perforating efficiency thereof.

A more specific object is the provision of a jet type explosive unit which is enclosed in a sealed casing constructed of glass material of a type which will be fully disintegrated, as to a fine powder, by detonation of the contained explosive charge.

In accordance with an illustrative embodiment

2

of this invention, the improved perforating unit comprises the combination of a hollow casing constructed of glass material and having a bore of generally frusto-conical form, a detonating-type explosive charge generally similar in shape to the bore of the casing enclosed within the casing and having a generally conical hollow in the end directed toward the open end of the casing, a thin metallic liner corresponding in shape to the charge hollow and seated therein, and a domed cover of glass material for closing the open end of the casing and sealed thereto with a suitable cement. The glass material employed in the casing and cover may be a special so-called "tempered" type which is adapted to disintegrate into a fine powder when subjected to the detonation of the explosive charge. The explosive charge may be enclosed within a hollow plastic insert before insertion in the casing.

Other and more specific objects and advantages of this invention will become readily 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 a cross-sectional view of a perforating unit in accordance with one embodiment of this invention;

Fig. 2 is an exterior view of the perforating unit turned through 90° from the position illustrated in Fig. 1, and having a portion thereof broken away for purposes of better illustration;

Fig. 3 is an exploded view of the principal portions of the perforating unit;

Figs. 4 and 5, together, comprise a longitudinal side view, partly in section, showing a group of perforating units mounted on an open type of carrier;

Fig. 6 is an end view of a portion of the carrier shown in Figs. 4 and 5;

Fig. 7 is a view, partly in section, of a portion of steel carrier showing the manner in which the perforating units may be mounted therein;

Fig. 8 is a partial, generally elevational, view showing the manner in which carriers of the types shown in Figs. 4 and 7 may be combined for supporting perforating units in accordance with this invention;

Fig. 9 is a longitudinal section view of a perforating unit in accordance with another embodiment of this invention;

Fig. 10 is a sectional view illustrating still another embodiment of the perforating unit according to this invention;

Fig. 11 is a sectional view of another modification of the charge liner;

Fig. 12 is a plan view, partly in section, illustrating still another embodiment of a perforating unit in accordance with this invention;

Figs. 13 and 14 are front and rear end elevations respectively, of the embodiment illustrated in Fig. 12;

Fig. 15 is a longitudinal view, partly in section, of the upper portion of another form of carrier for mounting perforating units of the form shown in Fig. 12; and

Fig. 16 is a longitudinal view, partly in section, of the lower portion of the carrier illustrated in Fig. 15 but turned through 90° with respect to the upper portion shown in Fig. 15.

Referring first to Figs. 1 to 3, inclusive, there is shown a perforating unit P in accordance with one embodiment of this invention which includes a casing 10 constructed of a glass material and formed in a generally frusto-conical shape. The term "glass material" as employed herein, is intended to include not only glass of the ordinary and well known types, but also various ceramic materials, which when baked or fired produce a rigid but highly frangible body. Casing 10 has a bore 11, also of generally frusto-conical shape, which is open at its wider end and closed by means of an end wall 12 at its smaller end. End wall 12 is made slightly concave, having a slight degree of curvature in two directions at right angles to each other, as will be seen in Figs. 1 and 2 particularly. The exterior of end wall 12 has molded therein a pair of spaced-apart projections 13—13 defining a recess 14 extending transversely across the center of the rear end of the container, and provided with an inwardly curved bottom 15 which also has a degree of convex curvature along the longitudinal axis of the recess. The wall of casing 10 is provided with externally thickened portion 16 and an annular flange 17 for reinforcing the container and to provide shoulders for mounting the casing in suitable carriers as will be hereinafter described. The slope of bore 11 is preferably reduced slightly adjacent its forward portion, as at 18.

A dome-shaped cover 19, also of glass material, having a generally hemispherical cavity 20 is provided to close the open end of casing 10 and has its annular end margin 21 made to somewhat thickness than the adjacent end of the casing to thereby provide an internal annular shoulder 22 which extends inwardly toward the axis of the casing, and is also provided with an external annular flange 23 to annularly reinforce the margin of the cover. A plurality of spaced outwardly extending projections 24 may be molded in the forward end of the cover as shown. The engaging margins of casing 10 and cover 19 are preferably ground to provide a very close fit between these members and are adapted to be connected together by means of a thin layer of any suitable strong water proof adhesive material 25 which will serve to effectively seal the joint and hold the cover on the casing under the high pressures to which the unit may be subjected in use.

One material from which container 10 and cover 19 may be constructed is a glass material of the type commonly referred to as "tempered glass" manufactured by Corning Glass Works, Corning, N. Y. This type of glass has very high crushing strength but has the unique property that when subjected to vibrations of pre-determined frequency, it will completely disintegrate to a fine crystalline powder, as contrasted with the relatively large irregular pieces into which ordinary types of glass will break. The disintegration frequency of this type of glass may be varied in accordance with the tempering conditions. The detonation of an explosive is ordinarily a wave or vibratory phenomenon, and the frequency of the vibration will depend upon the character of the particular explosives. Accordingly, it is found to be possible to match the disintegration frequency of the glass to that of the particular explosive material which is to be enclosed in the glass casing, so that the casing will always disintegrate to the desired fine powder upon detonation of the charge and thereby assure the absence of relatively large particles of detritus in the well. Generally speaking, however, it is found that most glass and ceramic materials will disintegrate to a relatively fine state at the vibration frequencies of the shock waves produced by the explosive charges of the kind herein contemplated.

A hollow insert 26, preferably constructed of a rigid synthetic plastic material, is made in a generally frusto-conical shape adapted to fit snugly in bore 11 of the casing. The inner end of insert 26 is provided with an end wall 27 through which an axial opening 28 is provided. Insert 26 is formed with a straight or cylindrical forward end portion 29 which is dimensioned to terminate at a point flush with the forward end of casing 10 so as to be in engagement with shoulder 22 of the cover when the latter is put in place over the end of the casing. Since portion 18 of the casing slopes toward the axis of the unit, while forward end portion 29 of the insert is straight or cylindrical, a narrow air space 30 is thereby provided between these portions which functions to reduce or absorb the radial explosive forces from this end of the unit on the adjacent portions of the carriers in which the perforating unit may be mounted and thereby helps to protect the adjacent portions of the carrier from damage from the explosion of the charge. This is particularly useful in the case where the perforating units are mounted in solid metal type carriers which are to be recovered for re-use.

The interior of insert 26 is filled with a charge of a suitable explosive material 31 which is adapted to extend through opening 28 into contact with the inner surface of end wall 12. The portion 32 of the explosive material which lies within opening 28 and extends into contact with end wall 12 may be of a more sensitive character than the main body of the charge to serve as a booster therefor. Portion 32 may be a different type of explosive material or may be the same explosive material but pressed to a different degree of density than the main body of the charge so as to increase its sensitivity relative to that of the main body of the charge.

Explosive material 31 and booster 32 are high-brisance explosive materials, such as pentaerythritol tetranitrate (PETN), tetryl, pentolite (50% PETN and 50% TNT), trinitrotoluene (TNT), amatol, cyclonite, tetrytol (60% tetryl and 40% TNT), and other well known detonating chemicals.

The end of the explosive material directed toward the open end of the insert is provided with an outwardly opening generally conical hollow 33, the apex of which is preferably rounded, as at 34, and lies on the longitudinal axis of the unit. A conical liner 35, having a generally complementary shape to that of hollow 33, and with its apex portion rounded to complement the shape of apex 34 of the hollow, is seated in the hollow and pressed snugly against the wall thereof. The apex angle of hollow 33 (and of liner 35) will usually be an angle of from about 40° to about 100° depending on the character of the jet desired. Liner 35 is ordinarily constructed of thin metal, preferably copper, having a thickness dimension depending upon the dimensions and character of the explosive and the jet characteristics sought. This thickness dimension will ordinarily range from about 0.015 to about 0.140 inch for various sizes of perforating units and may be uniform throughout the liner or may taper from a somewhat thinner section at the apex to a somewhat thicker section at the base end of the liner, as illustrated at 35a in Fig. 10 and in Fig. 11. This tapered shape is particularly effective for assuring complete disintegration of the liner and more perfect jet formation, resulting in greater penetrative efficiency and superior hole formation. The length of liner 35 is dimensioned so that when snugly inserted in hollow 33 its outer end will be flush with the outer ends of insert 26 and casing 10 and will also be in contact with shoulder 22 when cover 19 is put in place on the end of the casing. Cavity 23 in cover 19 provides the so-called "stand-off" space forming a forward extension of the hollow in the end of the charge in which convergence of the explosive gases into jet or narrow columns formed by the shape of hollow 33 and liner 35 may take place without interference by extraneous materials.

The perforating unit may be assembled in any suitable and convenient manner. If insert 26 is to be employed, the requisite quantity of explosive material, ordinarily in plastic or powder form, may be introduced into the insert, and pressed into place using liner 35 as the pressing die to thereby simultaneously form hollow 33 and insert the liner. Booster explosive 32 may be separately inserted in advance of the main body of explosive material or may be a portion of the main charge itself; this portion being compressed to a somewhat different density than the remainder of the charge to give it a different degree of detonating sensitivity. The insert now containing the explosive and fitted with liner 35 may be inserted as a unit into the casing. A film of sealing adhesive 25 is then applied to the engaging ends of casing 10 and cover 19 and the cover is then applied and kept in place until the adhesive is set, either by air-drying, thermosetting, or the like, depending on the nature of the particular adhesive used. Other known methods of hermetically sealing the casing may be employed.

If desired, insert 26 may be eliminated, in which case the explosive charge may be pre-molded to the desired shape and inserted directly into the casing as illustrated in Fig. 10.

When assembled in the manner described, the perforating unit, constructed in the form set forth, will be completely leak-proof and capable of withstanding external pressures of several thousand pounds, so that it may be installed in a well bore at any desired depth and immersed in fluids under very high hydrostatic pressures without damage prior to being set off. The described construction permits the perforating units to be completely assembled at an appropriate assembly point and handled and shipped to widely distributed points of use without danger and in condition to be installed in whatever type of carrier it is desired to use at a particular location.

Since it is hermetically sealed, the perforating unit may be stored for long periods of time without danger of deterioration of the explosive.

To set-off the perforating unit a strip of flexible detonating cord 36, such as the well-known "Prima Cord," is led through recess 14 and held in close contact against bottom 15 thereof, the detonating force resulting from detonation of cord 36 being transmitted through end wall 12 to the booster explosive 32 and thence to the main explosive charge 31 and being thereby applied on the longitudinal axis of the perforating unit and at its rear end. The detonating cord will normally have a strong water proof covering so that it will withstand any fluid to which it may be exposed in the well without affecting its explosive properties. By means of the described construction whereby the perforating unit is constructed as a fully self-contained, sealed structure, and by providing the external recess 14 on the end of the casing, the detonating cord may be applied externally. This greatly simplifies the final assembly at the well and permits mounting of a plurality of perforating units on any open-type carrier, which may be of extremely simple design, since it is only necessary to provide any convenient form of carrier which will support the units in the desired spacing or orientation arrangement, and since it is unnecessary to protect the exterior of the units or detonating cord against exposure to fluid. The detonating cord is then threaded through or over the supporting carrier frame in any convenient manner as it passes from one unit to another.

As the detonating cord 36 is applied externally to the perforating units, it is important that the thickness dimension of end wall 12 be held within suitable limits which will permit effective transmission of the detonating shock from the detonating cord to the end of the explosive charge. This thickness dimension for glass materials of the types herein described will ordinarily be between about one-eighth of an inch and about one-fourth of an inch for the various sizes of perforating units used in wells.

Figs. 4, 5 and 6 illustrate one form of carrier which may be employed to support a plurality of perforating units and to lower them into a well. In this embodiment the carrier comprises a pair of narrow flat metal strips 40, constructed preferably of any metallic material which is adapted to shatter and disintegrate into relatively small pieces under the forces accompanying detonation of the explosive charges. Various aluminum and magnesium alloys having the desired shattering properties are available. The strips are fastened together at longitudinally spaced points by suitable fastening means 41, such as rivets or screws, and the intervening sections of the strips are spread apart and shaped to form circular sockets 42 into each of which one of the perforating units is inserted, as illustrated particularly in Fig. 4, flange 17 serving as a stop to prevent the unit from slipping entirely through the socket. Each of the units may be held in place in any suitable manner, as by means of a wire 43 which encircles the casing in front of flange 17 and then is wound about strips 40 above and below the socket. A strip of detonating cord 36 is then strung longitudinally of the carrier, being inserted successively into recesses 14 of the several units mounted on the carrier. The portion of the detonating cord lying in the recesses is held firmly in place by winding friction tape 44 lengthwise about each unit, as illustrated in Fig. 4, the tape also encircling the exterior of the sockets to thereby additionally assist in holding the units in place. It will be understood that any other suitable and generally conventional means may be employed to hold the units in place on the carrier. The lower end of the detonating cord is enclosed in a suitable receptacle 45, passing through a screw cover 46 for the receptacle, and terminating in a square knot 36*a* which is embedded in a suitable water-repellant grease 47 or similar plastic material which is insoluble in the fluids which may be present in the well, and which is adapted to seal the free end of the detonating cord against intrusion of such fluids. The receptacle may be fastened to the carrier in any convenient manner. A weighting member 48 may be suspended from the lower end of the carrier, as shown, to apply sufficient weight thereto to assure ready sinking of the carrier through fluids which may be present in the well bore.

The upper end of the carrier is connected to a firing head, designated generally by the numeral 49, which includes a lower member 50, provided with an internally threaded socket 51, and an upper member 52 having an externally threaded pin 53 adapted to be screwed into the socket. Lower member 50 is provided with upwardly extending slots 54 along its opposite sides into which the upper ends of strips 40 are inserted and fastened thereto by means of studs 55. The bottom of socket 51 is bored out to form a receptacle 56 which is connected by an axial passageway 57 which extends to the lower end of lower member 50. The upper end of detonating cord 36 is threaded through passageway 57 and a square knot 58 is formed therein to hold the end of the cord in place in receptacle 56.

Upper member 52 has an axial bore 59 which, at the lower end of pin 53, is enlarged to receive the upper end of a tubular capsule 60 having a bore 61 closed at its lower end. The latter protrudes from pin 53 so that when the pin is screwed into socket 51 the closed lower end of capsule 60 will be placed in compressive contact with knot 48 in the end of the detonating cord. The lower end of socket 51 and receptacle 56 will be packed with a suitable water repellant grease 62, which, when pin 53 is screwed into the socket, will be packed tightly about knot 48 and into passageway 57 about detonating cord 36. This grease forms a plastic seal for the upper end of the detonating cord which will prevent the entrance of fluid into the interior of the firing head and thus protect the open end of the detonating cord from the deleterious effects of such fluid. At the same time, due to its plastic nature, the grease will transmit the external pressure to the knotted end of the detonating cord, thereby increasing its density in accordance with the magnitude of the external pressure. The greater the density of the explosive material forming the core of the detonating cord, the greater will be the velocity of the detonation thereof. Therefore, by providing a plastic seal of the kind described for the end of the detonating cord, the detonating efficiency of the cord will be increased with increasing external pressures, while serving as an efficient flexible seal to prevent entrance of external fluids into the firing head.

An electrically fired explosive initiator cap 63, of suitable and generally conventional type, extends into the bore 61 of capsule 60, and a small pellet of a suitable booster explosive 64 may be inserted in the bottom of bore 61 below the end of cap 63 to increase the intensity of the initiating shock to be transmitted from cap 63 to knot 58 in the end of the detonating cord. The upper end of bore 59 is enlarged and threaded internally at 65 to receive a threaded pin member 66 which is connected to a cable 67 which is employed to lower the perforating device into a well. An electrical conductor 68 is enclosed within cable 67 and is connected in a generally conventional manner to an electrical contact assembly 69 which is mounted in the lower end of pin member 66 and which is connected in a generally conventional manner by means of a pair of current conducting wires 70 to cap 63.

A plurality (only one shown) of upwardly and outwardly extending flexible fingers 71 may be mounted about the exterior of the firing head for use in positioning the perforating device in a well bore in a manner well known in this art.

The perforating device, assembled as illustrated particularly in Figs. 4, 5 and 6, will be lowered into a well bore on cable 67 to the desired position at which the well wall is to be perforated and firing current transmitted through conductor 68 to cap 63 which will be set off, thereby setting off detonating cord 36. The detonating wave will travel through the detonating cord and will successively set-off the explosive charges in the perforating units P. As will be understood, the detonating wave travels at such high velocity, that, for all practical purposes, all of the units will be detonated substantially simultaneously, and each will produce an extremely high-powered gaseous jet which will be directed against the well wall to produce the desired perforations therein. As noted previously, the frequency of the detonating wave produced in each of the perforating units will cause the respective glass material casings to disintegrate completely into a fine powder while the carrier comprising strips 40 will likewise be completely shattered into small pieces. None of this so-called "junk" will be sufficiently bulky to plug the perforations or the well bore and may easily be washed out of the well if found desirable. The firing head will normally not be damaged and may be withdrawn from the well for replacement of the initiating elements and attachment of a new carrier supporting a new set of perforating units.

Fig. 7 illustrates an arrangement wherein the perforating units P may be mounted in another type of carrier which comprises a solid cylindrical steel body 75 provided with a plurality of sockets 76 in which perforating units may be inserted. An axial bore 77 extends through the body and communicates successively with sockets 76. The upper end of body 75 is provided with an internally threaded box 78 to receive pin member 53 of the upper member 52 of firing head 49. In assembling the device, the detonating cord 36, having knot 58 in its upper end, is threaded downwardly through bore 77 passing successively through each of the sockets 76. As each perforating unit is inserted in its socket 76, it is rotated so that recess 14 will register with the portion of the detonating cord passing through the socket, the cord being thereby snugly seated in the recess as the perforating unit is fully inserted. The perforating unit is held in place by any suitable fastening means such as a wire 79 which is stretched transversely across the outer end of cover 19 between projections 24. The opposite ends of wire 79 are extended through lateral openings 80—80 which communicate with opposite sides of the forward end of socket 76 and extend to the exterior of the body, the outer ends of the wire being turned over the edges of the outer ends of openings 80, as illustrated, to thereby hold the perforating unit in place in the socket. Pin 53 is equipped with initiator cap 63 and its associated elements as in the previously described embodiment, and the bottom of socket 78 is packed with grease 62 which seals and protects the end of the detonating cord and the upper end of passageway 77 in the same manner and for the same purposes as described in connection with the previous embodiment.

With the arrangement described, it will be seen that by using the sealed, self-contained perforating units in accordance with this invention, careful machining of the body and close tolerances in the sockets 76 become unnecessary, thereby greatly reducing the cost of manufacture of solid carriers of this type, and permitting their repeated re-use many times.

Fig. 8 illustrates still another carrier arrangement in which the steel bodied carrier of Fig. 7 may be combined with an open type carrier of the type illustrated in Figs. 4, 5 and 6. The connection between the two types of carriers is made by means of a threaded pin member 81 which is adapted to screw into socket 51. The lower end of the section of detonating cord 36 passing through body 75 is provided with a square knot 82 which is adapted to compressively engage knot 58 in the upper end of the cord section extending into socket 52 from the lower carrier. The contacting knots will be packed in grease in the manner previously described. The detonation wave will pass through the section of detonating cord in body 75 and will then pass through the contacting knots 82 and 58 to the perforating units in the lower carrier. All the perforating units in both carriers will thus be set off successively and substantially simultaneously.

It will be understood that numerous other arrangements and carrier designs may be employed to support the perforating units in accordance with this invention.

Fig. 9 illustrates a somewhat modified form of perforating unit in which the cone angle of the conical portion 26a of insert 26 is made somewhat greater than that of the inner portion of bore 11 with the result that an air space 85 is provided between these portions. This modified type of unit is particularly adapted for mounting in solid-type carriers, of the kind illustrated in Fig. 7, as it is found that the provision of air spaces 85 and 30 function to reduce the radial forces emanating from the explosive charge. These air spaces appear to act as shock absorbers and thereby greatly reduce the possibility of damage to the enclosing socket walls and consequently serve to greatly increase the useful life of the solid types of carriers.

Fig. 10 illustrates an embodiment, adverted to previously, in which insert 26 is eliminated. This arrangement is particularly adapted for use with relatively large-sized charges of explosives. In this embodiment, the body 31a of the explosive material is premolded to the desired generally frusto-conical shape and provided at its apex end with a cavity 31b for the reception of a suitably shaped body of a booster explosive 32b. Casing 10a is made somewhat shorter than explosive body 31a so that the hollowed end of the latter protrudes a corresponding amount from

the open end of the casing. Cap 19a is made proportionately longer so as to surround the protruding end of the explosive body and is counterbored to provide an internal shoulder 22a against which the hollowed end of the charge body and inserted liner 35 will abut when the cap is put in place over the end of the charge. Shoulder 22a is spaced from the closed outer end of the cap at the appropriate distance to provide the desired stand-off space inside cap 19a.

The radial dimensions of body 31a are made somewhat smaller throughout its length than the bore af casing 10a and the counterbored portion of cap 19a to provide an annular air-space 85a about the entire length of the explosive body which, as noted previously, will serve to cushion the lateral forces emanating from the explosive. A suitable spacer 86 may be provided about body 31a to maintain it in concentric position within the casing. Spacer 86 may be of any suitable material, such as tape, plastic material, or most conveniently, merely an excess of the adhesive material 25 which is employed to cement the cap to the casing and is allowed to run into the interior of the casing around the explosive body 31a.

Fig. 11 illustrates the previously mentioned tapered liner construction in which the wall thickness is reduced toward the apex. It will be understood that this tapered type liner may be employed in any of the several embodiments of perforating units previously described. It will also be understood that the degree of taper may be varied for various thicknesses and sizes of liner and for various materials of which the liner may be constructed. In general, the reduction in wall thickness in the apex portion of the liner will range from about 10 to 75% of the thickness of the liner at its base end.

Figs. 12, 13 and 14 illustrate still another form of perforating unit in which casing 10 has integrally formed therewith a laterally extending flange 90 which extends about the sides and the rear end of the casing in the central plane of the unit. Perforations 91—91 are provided in flange 90 on opposite sides of casing 10 and a perforation 92 is formed in the rear portion of the flange adjacent the exterior of end wall 12 thereof, being designed to serve the same function as recess 14 of the previously described embodiments, that is, to receive detonating cord 36. The body of the unit and the explosive assembly contained therein is otherwise of exactly the same form as in the previously described embodiments.

Fig. 15 illustrates a form of open-frame type carrier which may be employed for mounting a plurality of perforating units of the form illustrated in Fig. 12. This form of carrier comprises a pair of cylindrical rods 93—93 which are adapted to slip through perforations 91—91 of the perforating units. The desired number of the latter may thus be slipped successively on rods 93 and may be spaced apart on the rods by means of tubular spacer sleeves 94. Spacer sleeves 94 may be made of any desired length to provide the desired degree of spacing between the perforating units. Alternate perforating units may face in opposite directions as illustrated, or may all face in the same direction or may be arranged in any other grouping desired. The lower ends of rods 93—93 are connected to a nose piece 95 and the upper ends are connected to a top head 96 which corresponds generally to lower member 50 of the firing head illustrated in Fig. 4. The detonating cord 36 coming through head 96 is threaded successively through perforations 92 of the several perforating units and its lower end is fastened into nose piece 95 in any suitable manner.

With this carrier construction, when firing of the perforating units occurs, the casings are completely shattered but the carrier frame, including rods 93, spacer sleeves 94, nose piece 95 and head 96, will not be shattered and may be withdrawn as a whole from the well.

It will be understood that numerous other forms of carriers may be employed for mounting the several embodiments of perforating units herein illustrated and described. The carriers may be of the open or solid type and in the latter type, the carrier body may be constructed of solid metal or monolithic cementitious or ceramic or glass material which will be completely disintegrated by detonation of the perforating units. Such a solid, disintegrable carrier body is described in my co-pending application Serial No. 33,062, filed June 15, 1948.

It will be understood that various changes and alterations may be made in the details of this invention 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. An explosive perforating unit, comprising, a hollow casing composed of imperforate glass material and hermetically sealed, a body of a detonating explosive enclosed within said casing, said body having a generally conical hollow in one end thereof spaced from one end wall of said casing and said body having its other end in contact with the opposite end wall of said casing, and a thin metallic liner having a shape corresponding to said hollow seated therein, said glass material transmitting detonating shock at high order from the exterior of said casing through the glass material of said opposite end wall directly to said body to obtain substantially complete high order detonation of said body to produce an effective perforating jet and with substantially complete disintegration of said casing.

2. An explosive perforating unit according to claim 1 wherein the wall thickness of said liner is rdeuced from its base end toward its apex.

3. An explosive perforating unit according to claim 1 wherein said glass material is characterized by a property of substantially complete disintegration at a vibration frequency corresponding to that of the shock wave generated by detonation of said explosive body.

4. An explosive perforating unit as defined by claim 1 in which said body of detonating explosive includes a booster explosive portion in contact with said opposite end wall of said casing.

5. An explosive perforating unit as defined by claim 1 having in combination therewith a detonating means arranged entirely externally of said casing and in contact with the exterior surface of said opposite end wall.

6. An explosive perforating unit, comprising, a hollow two-piece casing composed of imperforate glass material and hermetically sealed, a body of a detonating explosive enclosed within said casing, said body having a generally conical hollow in one end thereof spaced from one end wall of said casing and said body having its other end in contact with the opposite end wall of said casing, a thin metallic liner having a shape corresponding to said hollow seated therein, a container composed of rigid plastic material annularly confining said body, said body being detonatable by detonating shock transmitted from the exterior of said casing through the glass material composing said opposite end wall.

7. An explosive perforating unit, comprising, a hollow two-piece casing composed of imperforate glass material and hermetically sealed, a body of a detonating explosive enclosed within said casing, said body having a generally conical hollow in one end thereof spaced from one end wall of said casing and said body having its other end in contact with the opposite end wall of said casing, a thin metallic liner having a shape corresponding to said hollow seated therein, an annular air space between the sides of said body and the surrounding casing, and a container composed of rigid plastic material annularly confining said body, said body being detonatable by detonating shock transmitted from the exterior of said casing through the glass material composing said opposite end wall.

8. An explosive perforating unit as defined in claim 1 in which said glass casing is composed of two pieces sealingly adhered together.

WILLIAM G. SWEETMAN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
179,077	Swett	June 20, 1876
318,761	Letson et al.	May 26, 1885
2,323,301	Anderson	July 6, 1943
2,455,556	Burch	Dec. 7, 1948
2,494,256	Muskat	Jan. 10, 1950

OTHER REFERENCES

"Formation Penetrating with Shaped Explosive Charges," reprint from "The Oil Weekly," July 8, 1946, by Robert H. McLemore (2 pp.). Copy in Division 70, Patent Office, 102–56.

"Casing Perforating with Shaped Explosive Charges" by R. H. McLemore, reprint from "The Oil and Gas Journal," issue of December 28, 1946; vol. 45, No. 34, pages 268 to 271. Copy in Division 70, 102–56.

"Secrets of the Shaped Charge" by George B. Clark, article published in "Ordnance," July–August 1948, pages 49 to 51; page 51 relied on. Copy in Division 70, 102–56.

Advertisement, p. 77 of Saturday Evening Post, November 12, 1949, by Corning Glass Works, Corning, New York. Copy in Division 70, Patent Office, 102–56.

"The Jet Perforation Process" by W. T. Box and R. F. Meiklejohn, article published in "World Oil," vol. 130, No. 4, March 1950, pages 112, 116, 118, 121 and 122; page 122 is considered most pertinent, containing Fig. 11 and editor's note of article presentation; published January 17, 1950. Copy in Division 70, 102–56.