Feb. 2, 1954 J. H. CHURCH ET AL 2,667,836

APPARATUS FOR THE USE OF SHAPED EXPLOSIVE CHARGES

Filed March 28, 1950 2 Sheets-Sheet 1

Fig. 1.

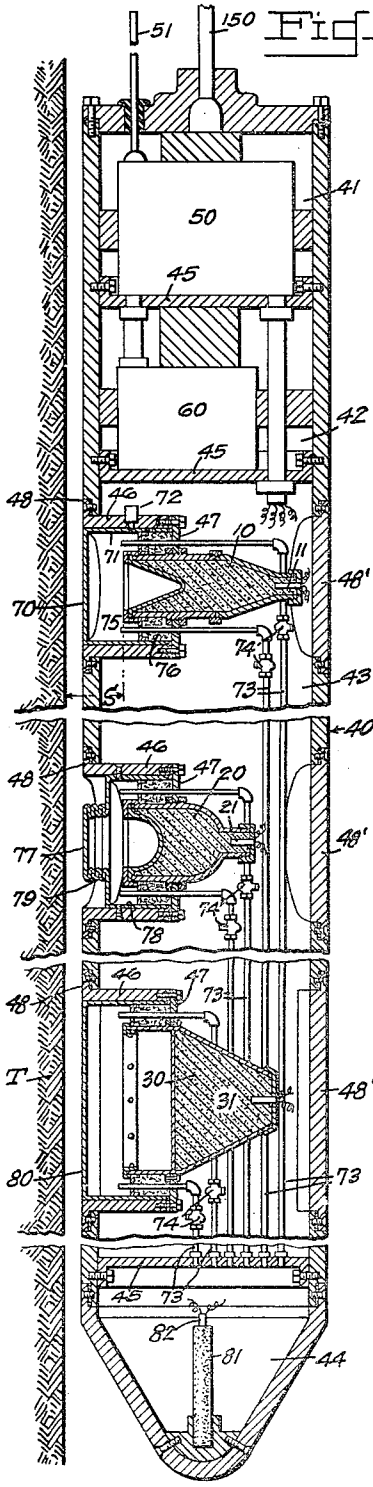


Fig. 2.

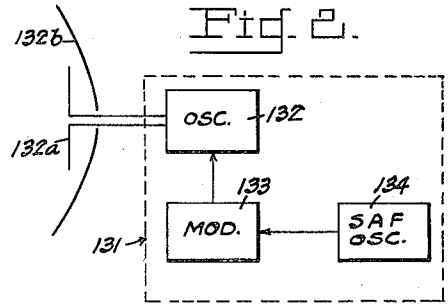


Fig. 3.

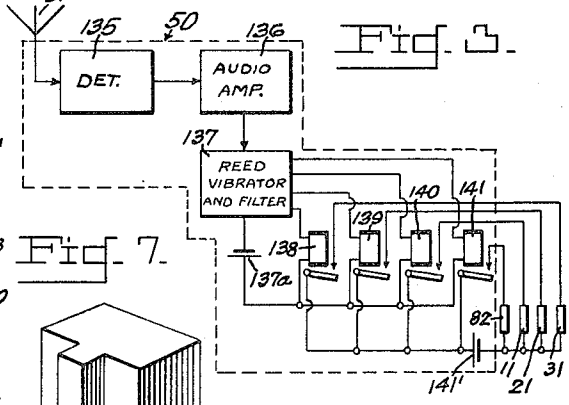


Fig. 7.

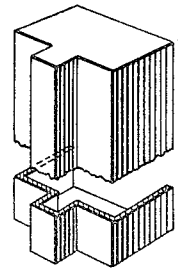
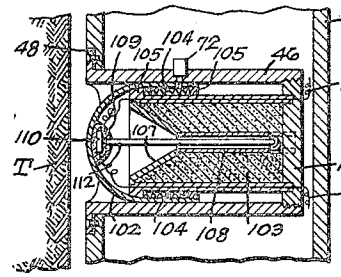


Fig. 9.



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Fig. 4.

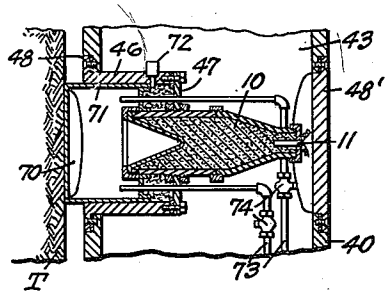


Fig. 5.

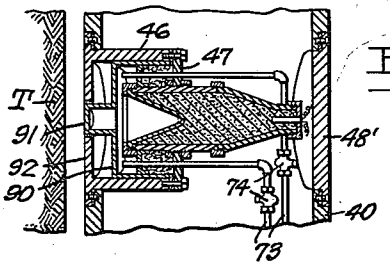


Fig. 6.

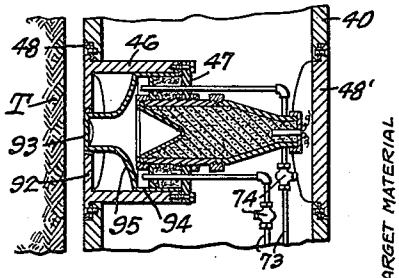


Fig. 8.

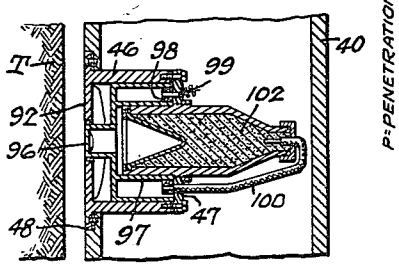
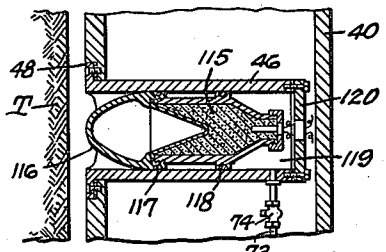


Fig. 10.



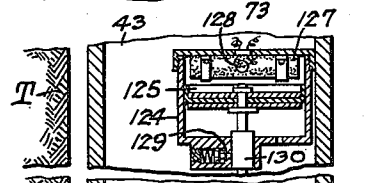


Fig. 11.

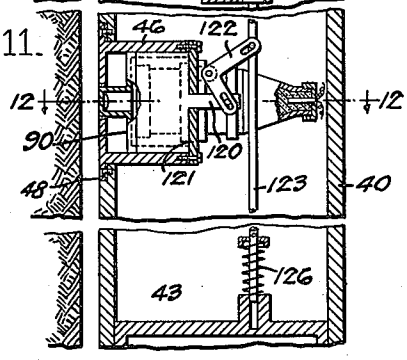


Fig. 12.

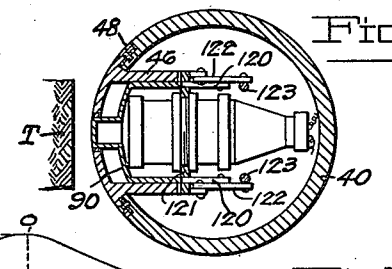
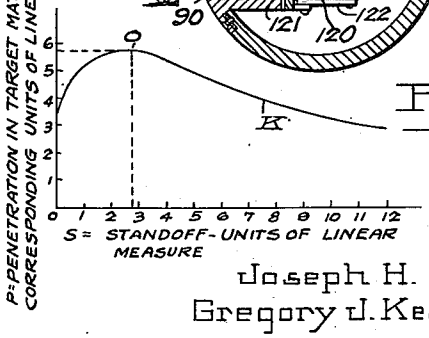


Fig. 13.



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UNITED STATES PATENT OFFICE

2,667,836

APPARATUS FOR THE USE OF SHAPED EXPLOSIVE CHARGES

Joseph H. Church, Austin, Minn., and Gregory J. Kessenich, Madison, Wis.

Application March 28, 1950, Serial No. 152,438

12 Claims. (Cl. 102—20)

(Granted under Title 35, U. S. Code (1952), sec. 266)

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The invention described herein may be manufactured and used by the Government for governmental purposes without payment of any royalty thereon.

This invention pertains to the use of explosive charges of the type frequently referred to as lined hollow or shaped charges, and more particularly to methods and apparatus for employing one or more such shaped charges in a manner so as to utilize the optimum directed force released thereby when detonated, against a target which may be submerged in either a gaseous and/or liquid fluid medium, for the purpose of producing a number of holes of desired geometrical configuration in the target corresponding to the number and arrangement of the charges.

A principal object of our invention is to provide apparatus for chambering a lined shaped charge which may be utilized to position the chambered charge with respect to a target located remotely relative to a station for controlling the apparatus at a standoff distance to effect optimum penetration of the target by the jet formed through detonation of the charge and in a manner to permit the charge to function independently of the characteristics of the fluid medium in which the target may be located.

Another object of our invention is to provide a system for initiating detonation of a lined shaped charge which may, if desired, be controlled through suitable radio circuits.

With the above, and other objects which will be hereinafter made apparent from a description of the invention with reference to the accompanying drawings, in which:

Fig. 1 is a broken longitudinal sectional view through one form of carrier apparatus of this invention showing several different forms of lined shaped charges chambered therein, each of which is old and typical in the art;

Fig. 2 is a block diagram of a radio transmitter suitable for use to control detonation of the shaped charges chambered in the apparatus shown in Fig. 1 from a station remote from the apparatus;

Fig. 3 is a block diagram of a radio receiver suitable for installation in the apparatus of Fig. 1 and responsive to signals from the transmitter shown in Fig. 2 to initiate detonation of the charges chambered in the carrier apparatus;

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Fig. 4 a fragmentary longitudinal sectional view through carrier apparatus similar to the view of Fig. 1, but showing the uppermost shaped charge only, and the standoff piston in standoff position;

Fig. 5 is a view similar to Fig. 4 showing a modified form of standoff piston with the piston in retracted position relative to the carrier.

Fig. 6 is a view similar to Fig. 5 showing another modified form of standoff piston;

Fig. 7 is a perspective view of a form of standoff piston particularly adapted for use with linear type shaped charges of the type illustrated by the lowermost charge shown in Fig. 1 as chambered in a carrier apparatus of our invention;

Fig. 8 is a view similar to Figs. 4, 5 and 6 illustrating modified means for operating the standoff piston;

Fig. 9 shows a method of mounting a standoff piston of this invention directly upon a charge chambered in the carrier apparatus chambering the charge;

Fig. 10 is a partial sectional view illustrating one method of chambering a lined shaped charge in a carrier apparatus so as to be projectable from the carrier apparatus to engage a target at optimum standoff distance;

Fig. 11 is a partial longitudinal sectional view through a carrier apparatus illustrating a modified form of standoff piston actuating mechanism;

Fig. 12 is a sectional view taken upon the line 12—12 of Fig. 11;

Fig. 13 is a representative form of curve showing penetration of target material, plotted in ordinate units, as a function of standoff plotted in similar units in abscissa in a standoff medium of air.

Our present invention is not directed to the improvement of lined shaped charges as such, but rather to the most effective use of any one of the forms of lined shaped charges which are well known in the art and that have long since entered the public domain, in and against targets that may be submerged in a gaseous and/or liquid fluid rendering them inaccessible, or relatively so, for manual placement of such charges.

For the purpose of disclosing our invention we have shown in Fig. 1 three typical forms of lined shaped charges as illustrated by the lined conical

shaped charge indicated at 10, the lined hemispherical shaped charge indicated at 20, and the lined linear shaped charge indicated at 30, each fuzed by an electric detonator 11, 21 and 31, respectively. Although we have only shown three forms of lined shaped charges to obviate unnecessary disclosure of many forms of such shapes which are old in the art, we actually contemplate, under any given conditions where one shape form may be preferable to another, to use any of the shape forms shown in any or all of the following representative publications as well as others which are not here cited:

(1) Max von Foerster: "Versuche mit comprimirter Schiessbaunwolle," Berlin, 1883, Mittler & Sohn, published in Van Nostrand's Engineering Magazine, vol. 31, July-December 1884, pps. 113–119 as translated by Lieut. John P. Wisser, U. S. Army, under the title "Experiments with Compressed Gun Cotton."

(2) Gustav Bloem: United States Patent 342,-423, filed January 20, 1886, and issued on May 25, 1886.

(3) Charles E. Munroe: On Certain Phenomema Produced by the Detonation of Gun Cotton. Newport Natural History Society. Proceedings 1883–88, Report No. 6.

(4) Charles E. Munroe: The Application of Explosives. Popular Science Monthly, 1900, vol. 56, pps. 444–455.

(5) Egon Neumann: Neuartige Hohlkörper aus Brisanzstoffen Zeitschrrift für das gesamte Schliess- und Sprengstoffwesen. May 15, 1914, vol. 9, pps. 183–187.

(6) Charles P. Watson: United States Patents 1,534,011 and 1,534,012, filed September 22, 1921, and August 27, 1923, respectively, and both issued on April 14, 1925.

(7) M. Sucharewsky: Article appearing in the Russian Journal, Technicia i Snobschenie krasnoi Armii, 1925; 170, pps. 13–18 and 177, pps. 13–18.

(8) M. Sucharewsky: Article appearing in the Russian Journal, Woina i Technicia, 1926; 253 pps. 18–24.

(9) Leslie E. Simon: German Research in World War II, published by John Wiley & Sons, Inc., 1947, pps. 118–120.

(10) Leslie E. Simon: German Scientific Establishments PB Report 19849, published by Mapleton House, January 1947, line 2, p. 68.

(11) D. Lodati: Una Spiegazione del Comportomento esplosivo di blocchi cavi di tritolo compresso. Giornale di Chemica Industriale ed. Applicata (1932), vol. XIV, No. 3, pps. 130–132.

As understood by those skilled in this art all shape forms shown or described in the above cited publications are for the purpose which is quite aptly stated by Bloem (cited as (2) above) where in lines 38 to 40 of his patent he recites—"By these constructions the concentration of the effect of the explosion in an axial direction of the exploder is increased."

The various forms of shapes disclosed in the above cited publications may be lined with suitable liners to take advantage of the relatively greater target penetrating ability of the jet of liner material formed by collapse of the liner through detonation of the lined shaped charge as compared to the jet formed by the products of detonation of the unlined shaped charge; such as, the advantage inherent in the lined shaped charge of Fig. 6 of Bloem (cited as (2) above), and as was recognized by Dr. Allerton S. Cushman in the last paragraph of page 2 of his affidavit and Colonel George Montgomery in the

paragraph entitled "Results" occurring on page 4 of his affidavit, both of which were filed on August 29, 1923, and form part of the record of the application for patent which eventuated into reference Patent 1,534,012 cited as (6) above, also as pointed out by R. W. Wood (see especially penultimate paragraph of p. 251 of a paper by R. W. Wood entitled "Optical and Physical Effects of High Explosives" published in Proceedings Royal Society, A vol. 157, pp. 249–253 (1936)), and recently hypothesized as to jet formation from liner (special case of the conical liner) collapse of the theory of hydrodynamics; see the article, "Explosives with Lined Cavities" by Birkhoff, MacDougall, Pugh and Taylor published in the Journal of Applied Physics, vol. 19, No. 6, pp. 563–582, June 1948.

The liner material may be either metallic or non-metallic, some of the materials that have been found suitable as liner material both in this country and abroad are mentioned in the following publications for convenience of illustration:

Publication	Liner Material
R. W. Wood (cited above)	Copper.
Chas. E. Munroe (cited as (4) above)	Tin plate.
British Patent 28,030 (1911)	Sheet metal or other suitable material.
German Patent 419,514, Oct. 9, 1925	Aluminum or like material.
William Payman and D. W. Woodhead: Explosion Waves and Shock Waves, Part II, The Shock Wave and Explosion Products Sent Out by Blasting Detonators, Published in Proc. Roy. Soc. A Vol. 148 pp. 604–622 (1935).	Copper or Aluminum.
Chas. P. Watson (cited as (6) above)	Any material of sufficient strength.
Leslie E. Simon (cited as (9) above) pp. 119–120.	Germans considered steel, sintered iron, copper, aluminum and zinc for World War II.
U. S. Patent 2,416,814, filed Nov. 15, 1943, and issued Feb. 18, 1947.	Copper, brass, cadmium, steel, aluminum, or a nonferrous metal backed by steel.
U. S. Patent 2,441,388, filed Aug. 19, 1942, issued May 11, 1948.	Pressed sheet metal.
U. S. Patent 2,419,414, filed Oct. 3, 1941, and issued April 22, 1947.	Various materials but preferably mild carbon steel.
British Patent 577,531, accepted 1946	Steel or other metal.
British Patnet 578,771, accepted 1946	Metal, synthetic resin or other material.
British Patent 578,995, accepted 1946	Mild steel.

From the data disclosed in the publications hereinabove cited it is quite apparent to anyone skilled in the art that optimum penetration performance of a particularly dimensioned and constituted lined shaped charge as functions of such parameters as shape of the charge cavity, angle of the apex of a conical or similar liner, if such specific form of liner is employed in the particular charge, specific material from which the liner is made, thickness of the liner material, specific explosive employed, volumetric and linear ratios of explosive as proportioned to corresponding ratios of the charge cavity, system of detonation and standoff will change with changes in certain changes in the parameters. It is quite obvious that selection of optimum parameters for optimum penetration performance in a specifically dimensioned and constituted charge will be by empirical methods, using the accumulation of data in the referenced publications as a guide which because of the comprehensiveness thereof greatly simplifies the empiric processes necessary in selecting the optimum parameters in a given case. In the book entitled "Elements of Ammunition" published by John Wiley & Sons, Inc., copyrighted 1946, Major J. C. Ohart has on page 43 recapitulated optimum values of certain of

these parameters having in case a specific purpose charge, however, we prefer to recapitulate the data of these publications in terms of the most important parameters generally as follows:

Parameter	Optimum Value	Remarks
S=	1 to 4c	Where S=standoff from base of liner to target and c=diameter of the charge. This parameter varies with form of shape, liner material and thickness of liner.
l=	1 to 4c	Where l=length of explosive charge and c=charge diameter.
a=	30° to 90°	Where a=the included apex angle of the conical or similar liners, in the special cases of the conical, helmet or similar liners.
t=		Penetration of a mild steel plate target by static test values.
t=	less than 1c	Where c=charge diameter and no liner is used.
t=	approximately 1c	Where non-metallic liner is used.
t=	3c to 5c	Where a metallic or suitable non-metallic liner of comparatively dense material such as copper or steel is used.
$T1$=	1 to 12% of c	Where $T1$=average thickness of liner and c=charge diameter. Will vary with liner material, cavity shape, and amount of slug desired.

Prior to a description of the details of our invention and in order to better illustrate the manner in which the apparatus of our invention is intended to accomplish our stated objects we now refer to Fig. 13, which those skilled in this art will immediately recognize as a curve K generally representative of the average penetration P of any given target material for any lined shaped charge of a specific design and composition when plotted as ordinate values to a linear scale as a function of the standoff distance of the base of the charge liner from the target plotted to a like linear abscissa scale. The observation of importance to a full appreciation of our invention that should be made is that for a lined shaped charge of specific design there is always some real positive value of standoff S for using the charge which will give maximum pentration P of the specific target material, as indicated by the point O on the curve. It is our purpose to provide apparatus which facilitates obtaining and assures the use of this optimum standoff value of S against targets inaccessible for manual placement of the charge.

One form of our charge carrying and chambering apparatus, which is hereinafter simply referred to as a frame or casing is shown diagrammatically in Fig. 1, as indicated at **40**, and may be constructed generally after the fashion of those devices referred to in the oil well completion art as gun perforators; as for example, of the types illustrated in United States Patents 2,154,859, 2,157,729, and 2,307,729, which are used in physical environments that are similar in all respects to the conditions of use which we have stated our apparatus to be particularly adapted.

The charge carrier **40** is comprised of a slender generally cylindrical tubular construction which may be optionally formed of seamless tubing of any appropriate material or of composite longitudinal sections assembled in any fluid sealed manner suitable to the uses to which the charge carrier are to subserve. As indicated in Fig. 1 the charge carrier **40** is internally subdivided into a plurality of chambers consisting of a control chamber **41**, which preferably is located in the uppermost portion of the carrier as viewed in Fig. 1, but which of course may optionally be relatively located elsewhere in the carrier, a

power supply chamber **42** conveniently located subjacent to the control chamber **41**, an intermediate charge carrying chamber **43**, and a lowermost fluid chamber **44** adapted to confine fluids under high pressure or be used as a fluid pressure generation chamber for a purpose hereinafter made apparent.

The several chambers **41**, **42**, **43** and **44** are formed by subdividing the interior of the charge carrier **40** by means of horizontally disposed partition plates or bulkheads **45** to form fluid sealed chambers as shown in Fig. 1.

Control chamber **41** is designed to chamber a radio receiver and associated equipment **50** arranged to control detonation of the charges **10**, **20** and **30** and the fluid pressure system installed in the charge carrier all in a manner subsequently set forth. The receiver is designed to operate on frequencies that will not cause substantial reflection from any of the media in which it is contemplated that the charge carrier may be submerged and is provided with an antenna **51** extending exteriorly of the charge carrier.

While we have indicated a control device of the radio type for controlling detonation of the charges **10**, **20**, or **30** we desire that it be distinctly understood that our invention is in no way limited to this type of control but may just as effectively use any of the metallic conductor systems or time controlled systems available in the art for controlling charge detonation as well as the fluid pressure system of the charge carrier and/or any other elements of the charge operable through a source of electrical energy.

A suitable source of electrical energy or power supply **60** is chambered in the power supply chamber **42** and arranged to be conductively circuited with any of the elements chambered in the charge carrier as herein subsequently described in detail.

The shaped charges **10**, **20**, and **30**, which may be unlined, but which are preferably of the lined type may each be similar, or of different types, as indicated in Fig. 1; but, are in all cases designed within the internal dimensional limitations of the charge carrier to provide maximum dimensioned charges; that is, maximum l/c, for the combination of other parameters used, including any physical or operational reasons that will impose a limitation upon the spacing of the charge carrier from the target. As the charges chambered in the charge carrier should be retained within the charge carrier profile until the charges are presented to the target to prevent damage thereto it is quite apparent that the maximum dimensioned charge adapted under the specific conditions at hand to produce maximum average penetration of the target which may be entirely chambered within the charge carrier must be so arranged that the standoff distance S, as shown in Fig. 1, will be optimum, or at least the standoff under which the charge was designed to be most effective, if maximum target penetration is to be achieved. Where the carrier can be spaced at will from the target the charge can be the maximum that can be chambered by the charge carrier, however, where the charge carrier may be so confined by the target as to be relatively movable only small distances with respect thereto in a standoff direction it may well be that maximum target penetration will be achieved by a smaller dimensioned charge than one which could be entirely chambered in the charge carrier due to the optimum standoff parameter.

Considering the charges 10, 20, and 30 to be designed in accordance with the conditions at hand, including the conditions of limitation upon spacing of the charge carrier 40 from the target T and with optimum parameters in accordance with the teachings of the cited publications, including the standoff parameter S shown in Fig. 1, within the internal dimensional limitation of the charge carrier as referred to, we chamber the charges in chamber 43 by mounting the charges within sleeves 46 having an internal configuration substantially conforming to the external configuration of the charge cases by means of flanges 47 which are fastened to the external cases of the charges and to the inner ends of the sleeves in any conventional manner that will assure fluid tight seals and center the charges within the sleeves. The sleeves 46 are formed with integral flanges 48 upon the outer end portions thereof which may conveniently be used as a method of securing the sleeves within openings formed in the walls of the charge carrier 40 in fluid sealed relation in the manner illustrated in Fig. 1. The sleeves 46 are of sufficient length and the charges are so mounted therein by the flanges 47 so that when the sleeves with the charges therein are secured to the charge carrier 40 optimum standoff S may be realized under all or no limitations imposed upon spacing the charge carrier from the target in a stand-off direction.

To prevent entrance of fluids external of the charge carrier 40 into the cavities of the shaped charges, which if of sufficient density could interfere with formation of the jet by collapse of the liners or products of detonation of unlined charges, upon detonation thereof we provide what we term standoff pistons, one form of which is shown at 70 in Fig. 1. The standoff piston 70 is formed with an outer surface which conforms to the charge carrier contour and is made of a material of sufficient strength to support any pressures to which the charge carrier may be subjected externally. The piston is reciprocably mounted within the sleeve 46 through the piston skirt 71 which may be provided with an appropriate coating of appropriate grease so as to form a fluid seal between the external surface thereof and the coacting internal surface of sleeve 46. As indicated at 72 in Fig. 1 standoff piston 70 may be retained in the retracted position shown by a detent releasable upon application of predetermined pressure internally of the piston which will permit outward movement of the piston under such pressure. If there are no restrictions upon outward movement of the standoff piston detent 72 may be used to engage a suitable stop on the piston skirt to terminate further outward movement thereof under internal pressure when the piston has been outwardly projected by a distance indicated at S. Upon the other hand as shown in Fig. 4 if standoff piston 70 can be outwardly projected only a limited amount because of confinement of the charge carrier by the target the detent 72 can be arranged to engage the inner end of piston skirt 71 in the outwardly projected position of the piston and retain the piston in engagement of the target to maintain standoff distance S until charge 10 is detonated.

Standoff piston 70 is projected outwardly under fluid pressure from compartment 44 by means of conduits diagrammatically shown at 73 in Fig. 1 provided with one-way valves 74 so as to retain pressure applied to the piston.

The conduits 73 enter the fluid pressure chamber 75 formed by the interior of the piston 70, sleeve 46, flange 47 and that portion of the charge within the sleeve 46, by means of sections thereof which pass through flange 47. A fluid seal is established around the conduits 73, the end of piston skirt 71 and flange 47 by means of a conventional mechanical-grease packing 76 as in high pressure devices such as used in recoil and recuperator packings in the artillery art.

Standoff piston 77 shown in Fig. 1 as used with the hemispherical lined charge 20 is a slightly modified form of standoff piston 70 in that the skirt 78 is fixed to sleeve 46 while the piston proper is of reduced size and carried by a bellows 79 secured to the piston skirt and piston in fluid sealed relation. This arrangement will facilitate obtaining a fluid seal between the piston skirt and sleeve.

The standoff piston 80 used with the linear charge 30 is similar in all essential respects to standoff piston 70 except that it is of rectangular shape to fit and cooperate with the rectangular configuration of sleeve 46 when used with a linear charge.

Although we have disclosed separate pairs of conduits 73 extending from fluid chamber 44 to each charge we have only done so for purposes of illustration as we contemplate the use of but a single pair of conduits suitable T'd into the fluid pressure chamber for each charge if preferred. In this case the T'd section of the pair of conduits leading to the individual charge fluid pressure chambers would be provided with one-way valves actuable to admit fluid pressure to the charge fluid pressure chambers only.

We contemplate the use of chamber 44 in the charge carrier 40 for storage of any fluid under high pressure in either gaseous or condensed form or in using the chamber as a chamber in which fluids may be generated under high pressures by chemical processes, such as by reaction of appropriate chemical agents which are caused to react at the proper time, or by burning a gas generating cartridge. As illustrated we have shown a gas generating cartridge 81, which may be of the general type shown in United States Patent 2,229,208 designed for application in cases such as this, located in chamber 44 and adapted to be ignited by the igniter 82 through power supply 60 when the circuit from the power supply through the igniter is closed by the control receiver 50 as more particularly hereinafter pointed out. In the case where chamber 44 is charged with a compressed or condensed fluid, igniter 82 may be used to open a valve or initiate the vaporizing process so as to admit the fluid to conduits 73. Where two chemicals are to react to generate the pressure the igniter or detonator 82 may be utilized to rupture a diaphragm in chamber 44 which separates the chemical agents until the reaction is desired.

Upon occurrence of any of the events initiated to generate pressure in or release fluids under pressure from chamber 44 by energizing element 82 the pressurized fluids resulting will be admitted by conduits 73 into the charge fluid pressure chambers thereby forcing the standoff pistons outwardly to engage target T and fix standoff distance S at the optimum for which the charge was designed to perform with maximum average target penetration.

We have shown charges 10, 20 and 30 all facing in the same direction, however, for a target having an arcuate or circular cross-section which is

to be attacked from the concave side it may be found expedient to stagger or space the charges circumferentially of the charge carrier. The charge carrier may be of any desired length for chambering any number of charges 10, 20 or 30.

Diametrically opposed to the charges 10, 20 and 30 hand opening cover plates 48' cover hand holes through which access to the interior of chamber 43 in the vicinity of the charges may be obtained by removing the cover plates. These cover plates and hand holes may be so dimensioned that the sleeve 46 can be interchanged with the cover plate 48'.

Figs. 5, 6, 7 and 8 show modifications of the standoff piston which we have shown at 70 in Figs. 1 and 4. In the modification of Fig. 5 we have provided the standoff piston 90 with an outwardly projecting boss 91 of circular cross-section and sufficient internal diameter to avoid interference with jet formation. Sleeve 46 is formed with a radially inward extending flange 92 which engages the boss 91 in fluid sealed sliding relation to prevent fluids under pressure external to charge carrier 40 from entering the space inwardly of flange 92. By this construction greater differential pressure between the inner and outer surfaces of piston 90 is facilitated because of the reduced piston area subject to external pressure. Flange 92 also serves as a stop for the piston when it has been forced outwardly to establish the proper standoff distance S. The piston may be secured in its standoff position by a detent such as the detent 72 shown in Fig. 1.

The modification shown in Fig. 6 is similar in substantially all aspects to the modification shown in Fig. 5 except that the boss 93 is joined to the standoff piston skirt 94 by a trumpet shaped wall 95 in order to provide greater space for formation of the jet which under certain conditions of design of charge will be desirable.

Fig. 7 is a perspective of a piston similar to the form shown in Fig. 5 for a linear charge of the type shown at 30.

As shown in Fig. 8 the standoff piston 96 is very similar to the piston 90 of Fig. 5 with the addition of a sleeve 97 integrally or otherwise secured thereto in a fluid sealed relation. A gas generating cartridge 98 similar in performance characteristics to cartridge 81 is fixed to flange 47 and ignitable by the igniter 99 in the same manner and through the same control as that employed for igniter 82 of Fig. 1. Ignition of cartridge 98 generates gas which drives the standoff piston 96 outwardly to standoff position where it may be retained by a detent such as the detent 72 shown in Fig. 1. A suitable fuse 100 ignitable by the cartridge 98 will in turn, and after a time delay sufficient for cartridge 98 to generate sufficient fluid pressure to drive piston 96 to standoff position, detonate charge 102 so that formation of the jet will be subsequent to and after piston 96 has moved to standoff position where it cannot adversely affect jet formation.

In the modification disclosed in Fig. 9 the standoff piston 102 is mounted directly upon charge 103 and normally held in retracted position by springs 104 interposed between abutments 105 upon the charge case and piston. The charge 103 is secured to sleeve 46 through the interthreaded relation between the sleeve and base 106 of the charge. A fluid sealed relation is established between the piston and sleeve in any conventional manner. In the case of charge 103 the conical liner 107 is truncated and loosely receives an end portion of the small tubular element 108 which has the base end secured to charge base 106 in any manner that will leave a gap between the base end thereof and the inside surface of base 106. A gas generating cartridge 109 is suitably affixed within standoff piston 102 and ignitable by an electrical igniter 110 through the leads 111 which pass through suitable passages in the charge case as shown. Ignition of the gas cartridge 109 will also ignite fuse 112 which after a predetermined time delay will detonate the charge. Movement of standoff piston 102 and detonation of the charge will be in the same time relation as that explained in connection with the modification of Fig. 8. As in the other modifications shown the piston 102 may be held in standoff position by means such as the detent 72 shown in Fig. 1. If preferred the annular chamber between the sleeve 46 and charge case and extending from abutment 105 on the piston to base 106 of the charge may be used as the fluid pressure chamber in which case gas generating cartridge 109 would be located in this chamber and fuse 112 extended from the base of the charge to the igniter in this chamber for cartridge 110.

As shown in Fig. 10 the charge 115 is provided with a cap 116 of such dimensions that when it engages the target T the standoff distance for the charge will be optimum. Provision is made for slidably mounting the charge is sleeve 46 in fluid sealed relation by the ring 117 on the cap 116 and ring 118 mounted on the charge case. The charge may be releasably retained in the sleeve 46 chambered in charge carrier 40 by any suitable detent, such as the detent 72 of Fig. 1. The charge may be projected outwardly through admission of fluid under pressure by conduits 73 into the fluid pressure chamber 119 formed by the base end of the charge, ring 118 and plate 120 secured to the inner end of sleeve 46 in fluid sealed relation. Control of pressure is by the same means as those heretofore described for Figs. 1, 4, 5 and 6. The detent may also function to limit outward projection of the charge in those cases where this safeguard is necessary.

Figs. 11 and 12 show modified forms of actuating the standoff pistons which can be of the form of standoff piston 90. In this form of the invention the standoff pistons 90 are each provided with one or more arms 120 projecting through suitable apertures therefor in the plate 121 secured to the inner end of sleeve 46 and as shown bell cranks 122 are also mounted upon plate 121 with the lower arms of each thereof operably connected to a corresponding arm 120. One or more longitudinally disposed rods are reciprocably mounted in chamber 43 and operably connected to the cooperating arms of bell cranks 122, as indicated, in such manner that downward movement of the rods from the normal upper position thereof will through bell cranks 122 force standoff pistons 90 to standoff position. A cylinder bearing member 124 is affixed within chamber 43 and provided with a piston 125 which is also attached in any convenient manner to rods 123. As shown the rods when in their normal upper position, in which they are biased by springs 126, position the piston within the cylinder of member 124 in the upper portion of the cylinder. A gas generating cartridge 127 similar to cartridge 81 is positioned in the cylinder above the piston and ignited by an igniter 128 under a control system and in a manner similar to the ignition control utilized and fully ex-

plained in connection with cartridge 61. When piston 125 has been driven to its lowermost position by generation of fluid under pressure by cartridge 127 to force standoff pistons 90 outward from the charge carrier 40 to standoff position it may be retained in this lowermost position by the retractable detent 129 engaging a collar 130 fixed on rod 123.

When we use the radio receiver 50 as a control we then use a modulated radio frequency transmitter 131 comprising a radio frequency oscillator 132, a modulator 133 and a selective audio frequency oscillator 134 actuating the modulator 133. The oscillator 134 is arranged so that any particular audio frequency may be selected or any particular sequence of audio frequencies may be selected at will to cause the modulator 133 to modulate the carrier frequency oscillator. For the purpose of illustration, there is shown a well known radiation system of a dipole antenna 132*a* and parabolic reflector 132*b*. It being understood that any type of radiation system may be employed depending upon the media through which the carrier must pass and the choice radio frequency necessitated thereby. The modulated carrier containing a single or a multiple of audio frequencies excites the antenna 51 of the receiver 50 which feeds the detector 135, the output of which is amplified by the amplifier 136 having a reed vibrator unit 137 in its output circuit. The amplified audio frequency components of the carrier cause the vibrator unit reeds, not shown, having the same period as that of the above mentioned audio frequency components to vibrate and close the circuits of the relays 138, 139, 140 and 141 as desired. The relays are energized by a battery 137*a* of the power supply 60. When the relay or relays are actuated by the reed vibrator in accordance with selected audio frequencies, the contacts of the relays close a circuit or circuits, as shown in Fig. 3, comprising a battery 141', contained in the power supply 60 for the detector and audio amplifier, in series with the paralleled igniters or detonators 82, 11, 21 and 31 of the gas generating cartridge and shaped charges, respectively, to fire said ignitors or detonators individually, simultaneously or in a predetermined sequence.

The method of employing our apparatus will be apparent to those skilled in the art from the above description and hence requires no detailed description but certain observations should be noted to fully appreciate the advantages inherent in our invention as follows:

1. It is to be noted that the elements or barriers or standoff pistons 70, 80, 90 etc., cap 116 of Fig. 10, expandible, extensible or distensible member 77 of Fig. 1 and any similar devices within the scope of the appended claims are all designed for any particular charge to accomplish, when projected or extended to operable position relative to the charge carrier, spacing of the charge at optimum standoff distance S from the target for most effective use of the charge. In addition to accomplishing standoff spacing S these elements, sometimes collectively referred to as means in the claims, also form a gaseous space of substantially uniform density in which the jet may form and pass to impinge upon the target thereby practically providing the ideal media for jet action independently of the media in which the target may be located. This provision of the invention makes it possible to attain results comparable to static test results in atmosphere.

The pistons, barriers or similar elements will be made of any suitable material adapted to withstand the pressures which will be encountered and may be either metallic or non-metallic as after use, replacement will be necessary for subsequent use of the charge carrier. A particular advantage in this arrangement exists in the fact that the jet will impinge upon the portion of the piston, cap or similar element which bears upon the target thus forming any objectionable burring upon the portion of the piston or similar element impinged by the jet and not on the target proper.

These elements if desired, may be made of frangible material such as glass or plastic so that after being projected and upon withdrawal of the charge carrier from the target area, they may be broken by any obstacle encountered in removing the charge carrier thus obviating any danger of blocking withdrawal of the charge carrier from the target area.

2. That the standoff attained by this invention is applicable to either lined or unlined shaped charges which are herein generically referred to simply as shaped charges, linear or otherwise.

3. That where the charge carrier is provided with opposed standoff pistons that such pistons may in the case of a target relatively closely surrounding or partially surrounding the charge carrier be used to perform a third function of engaging the target and relatively fixing the charge carrier with respect thereto. Obviously the charges used in this case would be designed to have optimum standoffs to fit the circumstances. On the other hand if the charge carrier was provided with standoff pistons all facing in the same direction and used against a confining target of this type the standoff pistons could relatively secure the carrier to the target by directly engaging the target and forcing the charge carrier to engage the opposed surface of the target. In this latter case the charges would or could be designed to employ a greater standoff thus permitting use of larger charges.

In either of the above cases the surfaces of the standoff pistons or equivalent elements engageable with the target can be serrated to effect a more secure engagement with the target.

4. That the illustrated methods of actuating the standoff pistons will suggest numerous other systems, fluid pressure, mechanical and electromechanical all of which employ conventional equipment that are within the purview of this invention.

5. That the interference record in Interference No. 52,570 decided by the Examiner of Interferences January 13, 1928, and affirmed on appeal March 11, 1929, which involved Patent No. 1,534,011 reference (6) above should be carefully considered with respect to shaped hollow charges with respect to charge performance and design noting particular the effect of the shape dcharge and effects produced thereby in exhibit "PP" of this interference.

For convenience in handling the charge carrier a handling cable 150 is attached thereto as shown in Fig. 1 which may be controlled by any conventional mechanism for such purpose from the control station used for controlling operation of the apparatus.

For those interested in the use of liquid explosives particularly suited for use with lined shaped charges we make reference to canceled Fig. 15 and the canceled description appertaining thereto as found in the file wrapper of U. S.

Patent 2,402,552 to Nevil Monroe Hopkins, as well as to those applications for patent referred to in this file wrapper and other patents of the same patentee which have since become abandoned and available to public inspection.

In the claims, the terms "axis" or "longitudinal axis" of the shaped charges identifies the central axis along which the jet is propogated by detonation of the charge. In the case of charges 10 and 20, this axis is coincident with the axis of symmetry of the charge, while in the case of charge 30, the axis is in the plane of Figure 1 perpendicular to the end surface of piston 80 and midway between the ends of the cavity.

Having now described our invention in present preferred forms, we claim:

1. A charge carrier adapted for use in a fluid medium comprising in combination, a tubular member forming a charge carrying compartment, a sleeve fixed with said member and opening through an aperture in the wall thereof, means for mounting a shaped explosive charge within the sleeve in fluid tight relation thereto, a standoff piston slidably mounted in the sleeve in fluid tight relation therewith to a position outwardly of said member to form a pressure chamber with said mounting means, whereby fluids under pressure in said fluid pressure chamber may move the piston outwardly from the charge, and means carried by said tubular member for supplying fluids under pressure to said chamber.

2. A charge carrier adapted for use in a fluid medium comprising in combination, a tubular member providing a charge carrying compartment, a sleeve extending into the charge carrying compartment in fluid sealed relation to the tubular member, means for mounting a shaped charge in the sleeve in fluid sealed relation thereto and in a position whereby the directed force effect thereof upon detonation will be outwardly of the sleeve, a flange integral with the outer end of the sleeve in fluid sealed relation and extending inwardly toward the axis of the sleeve to provide an opening of desired configuration, a standoff piston mounted in the sleeve between said flange and a charge mounted aforesaid in fluid sealed relation to the sleeve and coacting with the charge to form a fluid pressure chamber, said piston being formed with a boss of substantially the same configuration as said flange opening, said boss moving through said opening upon outward movement of the piston, means forming a fluid seal between the boss and opening, and means for supplying fluid under pressure to said fluid pressure chamber.

3. A charge carrier adapted for use in a fluid medium comprising in combination, a tubular member sealed at both ends to provide a charge carrying compartment, a sleeve extending into the charge carrying compartment in fluid sealed relation to the tubular member, means for mounting a shaped charge in the sleeve in fluid sealed relation thereto and in a position whereby the directed force effect thereof upon detonation will be outwardly of the sleeve, an element provided with an extensible portion secured in the sleeve in fluid sealed relation to the sleeve outwardly of the charge mounted aforesaid to prevent fluids external to the tubular member from gaining access to a mounted charge, and means operable to extend said extensible portion to provide a gaseous passage from the sleeve to the target for the jet formed upon detonation of the charge.

4. A charge carrier comprising in combination a tubular member having both ends thereof closed in fluid sealed relation to provide a charge carrying chamber, a sleeve extending into said chamber secured to the tubular member in fluid sealed relation, means for mounting a shaped charge in said sleeve in a position whereby the directed force effect thereof upon detonation of the charge will be outwardly of the sleeve, a standoff piston movably mounted in the sleeve in fluid sealed relation thereto outwardly of a charge mounted aforesaid and forming a barrier to passage of fluids externally of the tubular member to the charge, a linkage connected to the piston biased to hold the piston in normally retracted position relative to the tubular member, and means for actuating the linkage to project the piston outwardly relative to the sleeve.

5. A shaped charge unit comprising a frame, a shaped explosive charge carried by said frame, said frame being adapted to be positioned adjacent a target with the cavity of said charge facing the same, abutment means forming with said charge a gas-tight chamber and including a part movably mounted on said frame from a first position within the confines thereof, to a second position with one end externally of said frame forwardly of and adjacent said charge to contact the target and space the charge a predetermined stand-off distance therefrom and provide a gas-filled path between charge and target, remotely controlled means operable to positively move said abutment means from first to second position and means to hold said abutment means in second position when moved thereto.

6. In a shaped charge unit, a casing adapted to be positioned adjacent the surface of a target, a shaped explosive charge fixed within said casing in position to face the target, abutment means associated with said casing and movable relatively thereto from a retracted position to an extended position forwardly of said charge, and remotely controlled power means operable to positively move said abutment means into and to hold the same in extended position, said abutment means when in extended position engaging the target and spacing said charge a predetermined stand-off distance therefrom.

7. In a shaped charge explosive unit, a casing having an aperture in its wall, a shaped explosive charge mounted in said casing with its cavity facing said aperture, abutment means within said casing movable through said opening and forming with said charge an expansible gas-tight chamber, and means carried within said casing for introducing a gas under pressure into said chamber to project said abutment into contact with the target.

8. In a shaped charge explosive unit, a casing having an aperture in the wall thereof, a shaped explosive charge mounted in said casing with its cavity facing and directed into said opening, means fitting said opening and forming with the cavity end of said charge a sealed expansible chamber, said means including an abutment extendable from said casing in response to pressure within said chamber to contact the target space said charge therefrom and provide a gaseous path only between charge and target, a second sealed chamber in said casing, a conduit connecting said chambers, and means in said second chamber to effect increased pressure therein.

9. A shaped charge explosive unit as recited in claim 8, said last named means comprising a sec-

ond explosive charge, and remotely controlled means for initiating said second explosive charge.

10. A shaped charge unit as recited in claim 8, said last-named means comprising a second explosive charge, and remotely controlled means operable to initiate said second explosive charge and said shaped explosive charge in sequence in the order mentioned.

11. In a shaped charge explosive unit, a casing adapted to be positioned adjacent a target with an aperture in the wall thereof facing the target, a shaped explosive charge fixed in said casing with its cavity facing and directed toward said aperture, a piston slidably mounted in said aperture in fluid-tight relation therewith and forming with the cavity end of said charge, an expansible pressure-tight chamber, and remotely controlled means for pressurizing said chamber to move said piston into engagement with the target and to initiate said charge, in timed sequence.

12. In a shaped charge explosive unit, a casing adapted to be positioned with an aperture in the wall thereof facing a target, a shaped explosive charge mounted in said casing with its cavity facing said aperture, abutment means carried by said

casing within said aperture and forming with said charge, a gas-tight expansible chamber whereby in response to rise of pressure within said chamber, a portion of said abutment means at least is projected exteriorly of the casing to engage the target and space said charge a predetermined distance therefrom, power means carried by said casing to pressurize said chamber, and means controllable remotely from said casing to energize said power means.

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