

March 5, 1968

R. E. ECKELS

3,371,605

SHAPED EXPLOSIVE CHARGE

Filed July 5, 1966

3 Sheets-Sheet 1

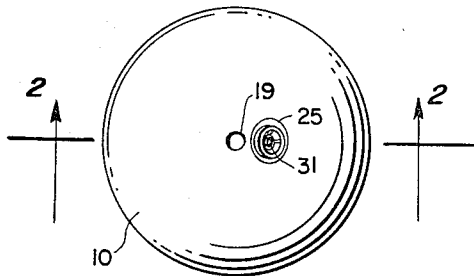


FIG. 1

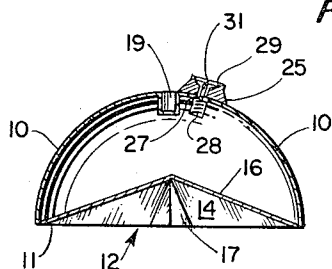


FIG. 2

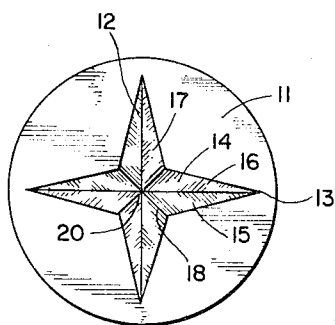


FIG. 3

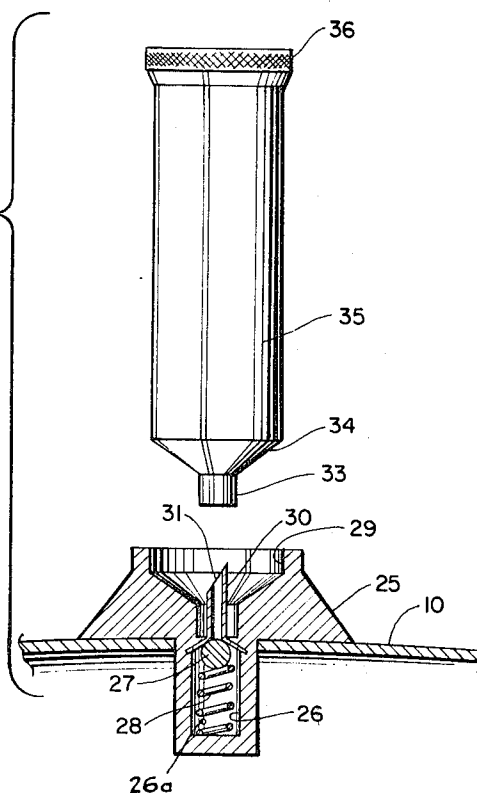


FIG. 4

INVENTOR.
ROBERT E. ECKELS
BY
Richard D. Law
ATTORNEY

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R. E. ECKELS

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3 Sheets-Sheet 2

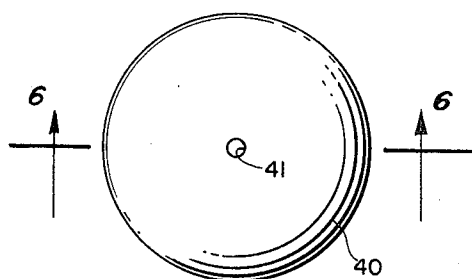


FIG. 5

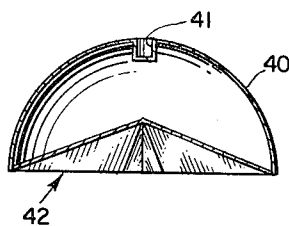


FIG. 6

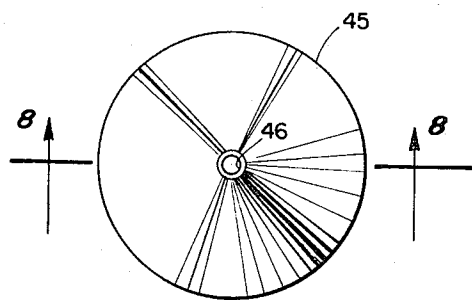


FIG. 7

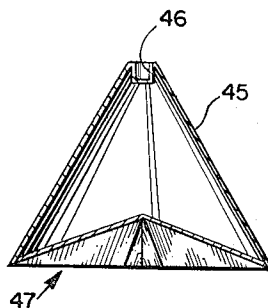


FIG. 8

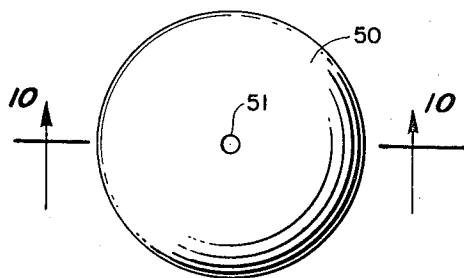


FIG. 9

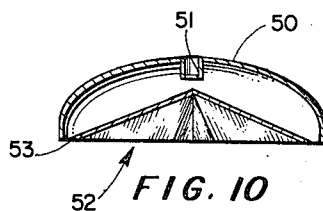


FIG. 10

INVENTOR.
ROBERT E. ECKELS
BY
Richard D. Law
ATTORNEY

March 5, 1968

R. E. ECKELS

3,371,605

SHAPED EXPLOSIVE CHARGE

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3 Sheets-Sheet 3

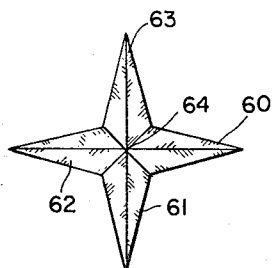


FIG. 11

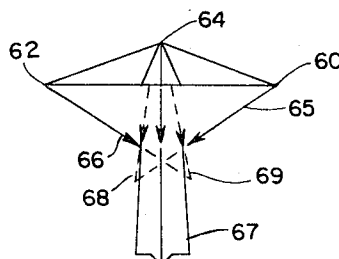


FIG. 14

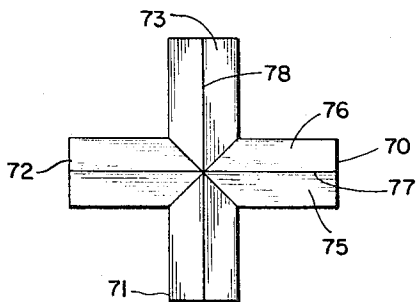


FIG. 12

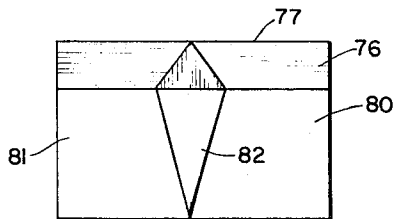


FIG. 15

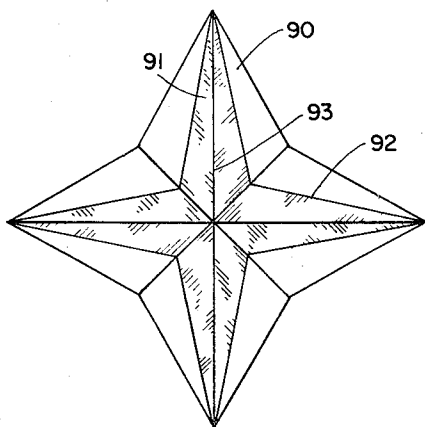


FIG. 13

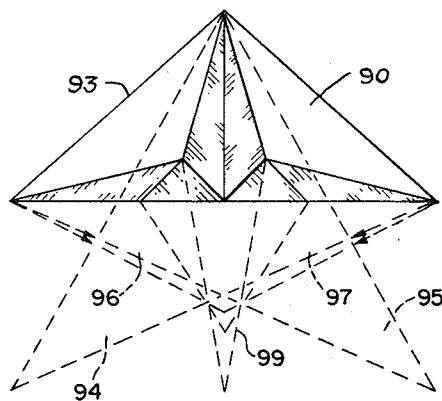


FIG. 16

INVENTOR.
ROBERT E. ECKELS

BY

Richard D. Law

ATTORNEY

1

3,371,605

SHAPED EXPLOSIVE CHARGE

Robert E. Eckels, 2101 Youngfield, Golden, Colo. 80401

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7 Claims. (Cl. 102—24)

ABSTRACT OF THE DISCLOSURE

A shaped explosive charge having a cup-shaped body is provided with a shaped recess therein produced by four intersecting V-shaped depressions, each such depression being formed of two intersecting planar surfaces, and the recess extending over about two-thirds of the diameter of the charge. The resultant jet pattern from detonation is a central maximum jet with four radially extending linear jets.

This invention relates to shaped explosive charges and particularly to a free body breaker and high energy source of an explosive nature.

Shaped explosive charges have been heretofore used to produce a small diameter, high velocity jet to provide high penetration power into a body. The shaped charges heretofore used included a conically shaped recess in a body of explosive to produce a small, generally circular cross-section, high velocity jet. Such small cross-section jets have high penetrating power but only over a relatively small cross-sectional area.

According to the present invention I have provided an explosive device, nominally referred to as a rock breaker, which is a shaped explosive charge having a flat underside with a recess incorporated therein, and the shaped recess providing a series of intersecting planar surfaces to produce a series of linear jets and with a series of such intersecting axis lines joined together there is produced a maximum concentration at a central point or the line of intersection with radially extending linear jets. In general, a series of V-shaped recesses are provided in a body of an explosive, preferably with a number of such V-shaped recesses intersecting at a central point. Detonation of a charge with such a shape produces a maximum jet concentration at the point of the intersection with fracture lines produced by linear jets or line jets extending radially outwardly from the central point toward the edge of the charge to score and spall the object being broken. The charge, also, initiates reflected tensile shock waves from the far side of the object being broken to give an added breakup from the coincident of the approaching compressive waves and the returning tensile waves to exceed the critical normal fracture stress of material. In one form of the invention a hollow, thin-shelled body is provided with the V-shaped recesses formed in the flat bottom thereof. An explosive material fills the shell. The explosive for filling the shell may be a particulate explosive, or a fluid explosive, including liquid explosives and the like. In one aspect of the invention means are provided for field introduction of a sensitizer into the explosive filling the shell, to reduce hazards of transportation of sensitized explosive material.

Included among the objects and advantages of the present invention is to provide a shaped explosive charge for producing high energy linear jets for producing breaking and spalling energy for rocks and similar material.

Another object of the invention is to provide a shaped charge in which the energy of the explosive is concentrated along linear jets to produce a series of high energy linear jets having high fracture energy and spalling energy for rock and the like.

Another object of the invention is to provide means for charging a shell filled with a deactivated body of ex-

2

plosive material with a sensitizer for activating the body into a high explosive.

These and other objects and advantages of the invention may be readily ascertained by referring to the following description and appended illustrations in which:

FIG. 1 is a top plan view of a shaped charge body according to the invention;

FIG. 2 is a cross-sectional view of the shaped charge body of FIG. 1, taken along section line 2—2;

FIG. 3 is a bottom plan view of the body of FIG. 1;

FIG. 4 is an enlarged detail of a sensitizer charging device according to the invention;

FIGS. 5 and 6 are a top plan and cross-section, respectively, of one form of a shaped charge body according to the invention;

FIGS. 7 and 8 are the plan view and cross-section of a modified form for a shaped charge body for an explosive according to the invention;

FIGS. 9 and 10 are the plan and cross-section of a still further modified form of a shell for containing explosives according to the invention;

FIG. 11 is a schematic representation of a plan view of one form of a recess configuration for a shaped charge according to the invention;

FIG. 12 is a modified schematic representation of a modified form of a recess configuration for a charge according to the invention;

FIG. 13 is a schematic representation of a still further modified form of a recess configuration for a charge according to the invention;

FIG. 14 schematically represents a pattern of the cumulative jet action from a recess configuration such as that of FIG. 11;

FIG. 15 schematically illustrates a pattern of the cumulative jet action of a configuration recess such as shown in FIG. 12; and

FIG. 16 illustrates schematically the jet pattern configurations, both primary and secondary, of a form recess such as that shown in FIG. 13.

The shaped charge, which is a hollow shell filled with an explosive, shown in FIGS. 1—4, may be made of such materials as steel, aluminum, glass, and the like. Fiberglass molded to the form shown, also, provides a shell which performs well, and other types of plastics may also be used. The shell includes a hemispherical section 10 (or a major portion of a hemisphere) with a planar closure 11 across the opening of the hemispherical shell, and a recess formed in the closure includes a four-legged, star-shaped recess 12. The shaped recess 12 includes a series of planar surfaces each adjoining pair of which intersect along an apex line, for example, a leg, terminating at apex 13, includes a planar surface 14 which intersects a planar surface 15 along a sloped apex line 16, and each plane intersects the plane of adjacent legs to form additional intersecting lines 17 and 18, all of which intersect and terminate a center apex point 20. The surfaces 14 and 15 are sloped so that the apex line 16 extends from a level recessed below the surface 11 at point 20 along the apex line to point 13. Each of the legs of the star-shaped recess are arranged in this manner. The shell is provided with a detonator or booster well 19 which extends into the space of the shell.

For many applications it is desired to be able to apply an activator or sensitizer to the explosive material contained in the shell so as to sensitize normally non-explosive material into an explosive. It is, also, particularly advantageous to fill the shell with a material which is not sensitized, and then sensitize the material in situ in the shell at the point of use, which provides for safety in transportation and handling up to the point immediately prior to detonation. For adding an activator or sensitizer to the material in the shell, a loading port 25 is provided in the

shell which includes a recess 26 in which a ball check valve 27 controlled by a spring 28 provides a closure for inlet needle port 30 having passage 31 connected to recess 26, and one or more lateral outlets 26a for high velocity release of material into the shell. The port 25 has an enlarged outlet 29 on the exterior of the shell. The debouching outlet 29 is arranged to fit a spout 33 and neck 34 of a collapsible tube 35. The collapsible container 35 may be made of a suitable material for holding the activator or sensitizer. The container may be prepared with a closed, pierceable nozzle 33, and loading of the container is through the open bottom which is sealed at 36 when filled. The container 35 is impaled on the needle 30 which penetrates the nozzle 33 and, by collapsing the walls of the container, the contained material is forced through the needle and the outlet 26a into the interior of the shell. By squeezing the container or rolling it vigorously, the contained material is injected with considerable force into the shell so that it is dispersed quite generally throughout the interior of the shell. It is, furthermore, observed that the correct amount of sensitizer may be provided for the material in each shell so that measuring equipment and skilled personnel are not needed in the field for the completion of the charge preparatory to the detonation.

In place of the system described above using the penetrating needle, it is, of course, obvious that different types of valves and containers may be used, for example, a collapsible wall container may be provided so that its end or nozzle may be partially removed or otherwise opened, inserted into the recess in the port as by pressure or threaded connection, and the sensitizer being exuded from the container to move the ball check or similar type of valve to permit entry of the sensitizer. A pressurized container could also be used to inject sensitizer into the shell. The penetrating needle is an advantageous system for field work since it is simple and conditions and available tools are not always ideal. Where the shell is substantially full with little air space, a pressure relief may be required for the shell, such as a capillary opening with a removable cover, ball check relief valve or the like may be necessary to permit easy entry of the fluid activator or sensitizer. Also, where it is not completely filled and some space remains internally of the shell, the shell may be placed under reduced pressure to permit easy entry of the additional amount of liquid activator or sensitizer.

The actual shape of the upper body of the shell is not critical. A hemispherical shell provides a slightly greater volume for an equivalent surface area, and, also, a spherical segment exerts a greater shock plane front. However, different shapes of bodies have been found to have value for different applications. Some useful shapes are described as follows:

In FIG. 5 a shell is made of a spherical segment 40, which may be a hemisphere or other spherical segment, depending on the volume of explosive desired. The shell body 40 is provided with a booster or detonator well 41 and a star-shaped recessed bottom 42. The recessed bottom may be any shape, as explained below, which provides a series of intersecting planes to form intersecting apex lines for producing linear jets.

In the modified form of FIGS. 7 and 8 a conical shell body 45 is provided with an apex well for a detonator or booster 46 and the shaped bottom 47. As with the other shells, the shaped bottom may be of various configurations and the dimensions of the height of the cone and the diameter of its base will be determined by the requirement of the particular explosive.

A further modified form of a shell is shown in FIGS. 9 and 10 where a flattened, arcuate body 50 is provided with a booster or detonating well 51 and a shaped bottom 52 recessed in a star-shaped covering 53, so that the legs of the star extend completely across the bottom. The recess covers less than the total bottom of the shaped charge, however, due to the islands between the legs.

In actual tests it has been found that a hemispherical shell body, having a four-legged star configuration such as FIGS. 1 through 3 provides excellent rock breaking characteristics. Various sizes of shells were produced with different volumes for explosives, and by using a nitro-alkane explosive with diethanolamine sensitizer having about a 22,000 feet per second detonation rate, the following results were shown with the various sizes of hemisphere volume.

Table 1

- A. 180 cc. of explosive in a hemisphere produces a clean breaking of 0.75 cubic yard of solid unweathered granite sitting on the ground.
- B. 450 cc. in a hemisphere shell produces a quick, clean break and spall of one cubic yard of unweathered solid granite sitting on the ground with unencumbered sides.
- C. 1300 cc. of the explosive in a hemisphere produced excellent fracture and spall of 6 cubic yards of solid granite sitting on the ground with unencumbered side walls.

One excellent configuration of recess is the four-sided star, for example as shown in FIG. 11, which is a star having four legs 60, 61, 62 and 63, all of which intersect at a central point 64, which is the point farthest away from the bottom and is depressed below all apex lines of the intersecting surfaces. In FIG. 14 the schematic diagram of the explosion shows that a thin, linear jet from the coincidence of the two surfaces of the arm 60 produces a linear jet action 65 which extends downwardly somewhat normal to the apex line of the intersecting surfaces, and the other arm 62 of the star has a similar jet 66 which extends somewhat normally to the apex line. The primary jets, such as 65 and 66, and of course similar jets from the other two arms 61 and 63 coincide generally centrally and form an expanding high-velocity penetrating jet 67, with the remaining portion of the jets not forming the central jet 67 spreading outwardly along linear jet radials, such as along dashed lines 68 and 69. The central jet initiates fracture and penetrates the object being broken, and the spreading linear jets fracture along radial linear lines from the point of maximum concentration jet 67. In the fracture of a rock, for example, the compressive shock waves from the explosion pass through the rock to the edge and are reflected as compressive shock waves from the sides back toward the center, which gives an added breakup from the tensile coincidence of approaching compression waves. The returning compressive waves from all sides combine to exceed the critical normal fracture stress of the rock being broken.

A recess according to the configuration of FIG. 12 is a cross instead of a star, and the cross includes arms 70, 71, 72 and 73. Each arm is composed of a pair of intersecting surfaces having an apex line which is parallel to the bottom, for example, arm 70 includes intersecting surfaces 75 and 76, producing an apex line 77 which coincides with the apex line of arm 72 and intersects the apex line 78 of arms 73 and 71. The central apex point is not recessed deeper than the apex lines. An explosion using this type of recessed explosive is schematically shown in FIG. 15 where the surfaces intersecting to form apex line 77 produce primary linear jets 80 and 81 which coincide centrally to produce a maximum concentration jet 82. This jet produces an initial penetration of an object being broken, and the linear jets produce radial fracture and spall lines extending outwardly from the penetration jet.

A compound depression, such as shown in FIG. 13, includes an outer star member 90 and an inner star 91 superimposed therein to form therebetween an apex line 92 which extends around the inside of the outer star 90 and a central apex line 93 which is the intersection of the surfaces of the inner star 91. Detonation of a charge so shaped produces a compound series of linear jets which includes primary jets 94 and 95 which are normal to the apex lines 93 and secondary linear jets 96 and 97, all of

which produce a coincident jet 99 centrally of the depression. The central jet 99 forms an initial penetration jet, which is compounded from the addition of all the intersecting linear jets. The multiple primary and secondary linear jets extending radially from the central coincident jet produce excellent fracture and spalling of such materials as weathered rock, softer rock, both of which tend to absorb shock and are difficultly broken with conventional dynamite-type explosives.

It is not necessary that the depression extend across the full width of the bottom of the explosive; it has been found by actual test that from two-thirds of the distance to the bottom to the full bottom produces valuable shaped charge. Additionally, the shell does not have to be of a round cross-sectional configuration, a four-sided pyramid with the depression star (for example) running from corner to corner has also been found excellent in producing fracture in certain types of rock. Also, a membrane may be placed across the recess of the charge with relatively little difference in performance for air detonations. In water, however, the membrane has the advantage of higher performance since the jets are started initially in an atmosphere different from the surrounding water. Furthermore, the atmosphere in the membrane-covered depression may be changed, as by increased pressure or a reduced pressure, to increase the performance where a reduced pressure is used or slow down the jet velocity where a greater pressure than the atmosphere is used. It has, also, been found that a higher velocity compound jet may be produced by use of lower angle of V in the apex area of the intersecting surfaces to give a greater penetration in a narrower plane, which fractures less from jet compressive shock waves, but with a proportionately greater direct jet penetration into the material. Where the surfaces of the depression intersect to provide a uniform depth of the apex, the resulting linear jet produces maximum concentration along the lines of the intersection and the primary linear jets produce maximum fracture force substantially parallel with the coincident penetrating jet centrally of the arms of the depression.

A valuable side effect from the shaped charge of the invention occurs when fired into solid masses as it produces as a seismic energy source. This source utilizes the vertical compressive shock wave which is translated throughout an area under the compressive effects of the immediately preceding jet. This produces very sharp shock waves which are reflected from the substrata layers as sharp return waves for easier resolution and identification.

While the invention has been illustrated by reference to a particular embodiment, there is no intent to limit the spirit or the scope of the invention to the precise details so set forth except as defined in the following claims.

I claim:

1. An explosive rock breaker or the like comprising a hollow, cup-shaped shell for filling with an explosive, said shell including a concave body forming a major wall of said shell and having an enlarged opening; a planar covering over said enlarged opening enclosing said body forming a non-foraminous hollow shell; there being a small depression in said body spaced from said covering for accommodating a detonator; said covering having a recess therein extending into the volume of said hollow shell, said recess formed of a series of four V-shaped depressions intersecting each other at about right angles forming a central apex, said V-shaped depressions intersecting each other at a low angle at said apex area; said recess extending at least about two-thirds of the width of the covering leaving small planar lands between each pair of adjacent V-shaped depressions, said V-shaped depressions formed by two intersecting planar surfaces and each depression producing a linear jet on detonation of contained explosive thereby producing intersecting linear jets from each said V-shaped depression.

2. An explosive rock breaker according to claim 1 wherein said recess in said covering is star-shaped with the points thereof flush with said covering and the central apex point depressed therebelow.

3. An explosive rock breaker according to claim 1 wherein said body is a portion of a sphere.

4. An explosive rock breaker according to claim 1 wherein said recessed covering has a membrane enclosing said recess and arranged for changing pressure in said covered recess.

5. An explosive rock breaker according to claim 1 wherein said body is a hollow hemisphere.

6. An explosive rock breaker according to claim 1 wherein said recess is in effect a pair of four-legged stars, one superimposed on the other, forming a plurality of intersecting planar surfaces including intersecting surfaces of star on star.

7. An explosive rock breaker according to claim 6 wherein said superimposed stars are four-legged stars.

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BENJAMIN A. BORCHELT, *Primary Examiner.*

V. R. PENDEGRASS, *Assistant Examiner.*