Oct. 24, 1967 R. W. KEENER ETAL 3,348,482

EXCAVATING APPARATUS AND METHOD FOR EXCAVATING MATERIALS

Filed Jan. 3, 1966 3 Sheets-Sheet 1

Fig. 1

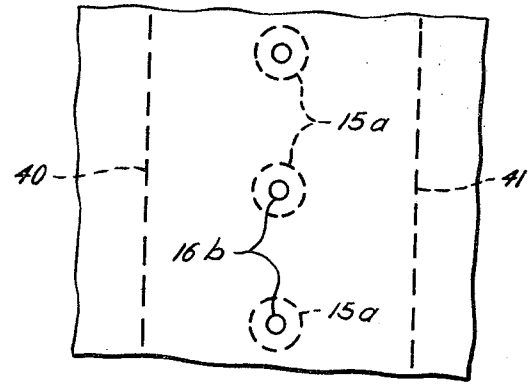
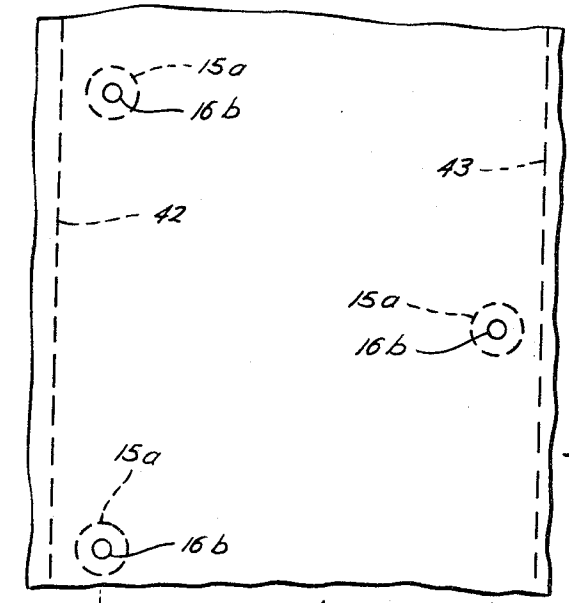


Fig. 2



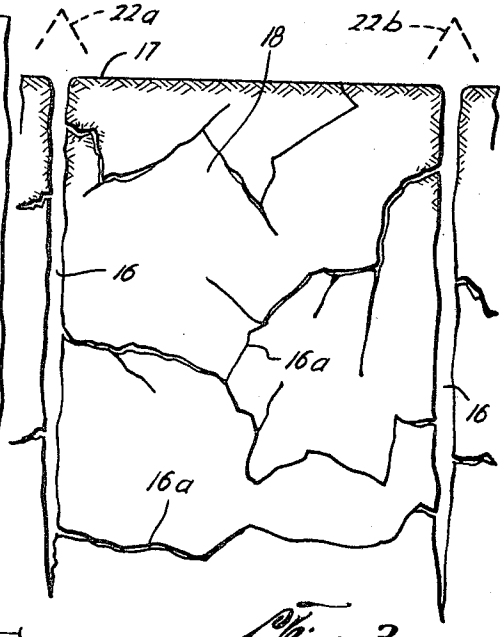


Fig. 3

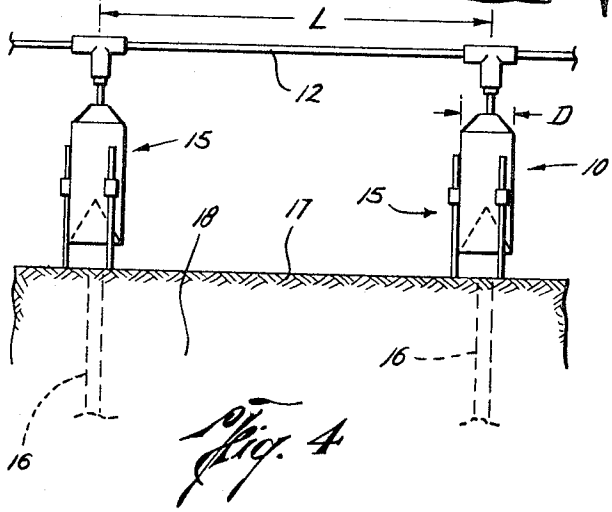


Fig. 4

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EXCAVATING APPARATUS AND METHOD FOR EXCAVATING MATERIALS

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Fig. 5

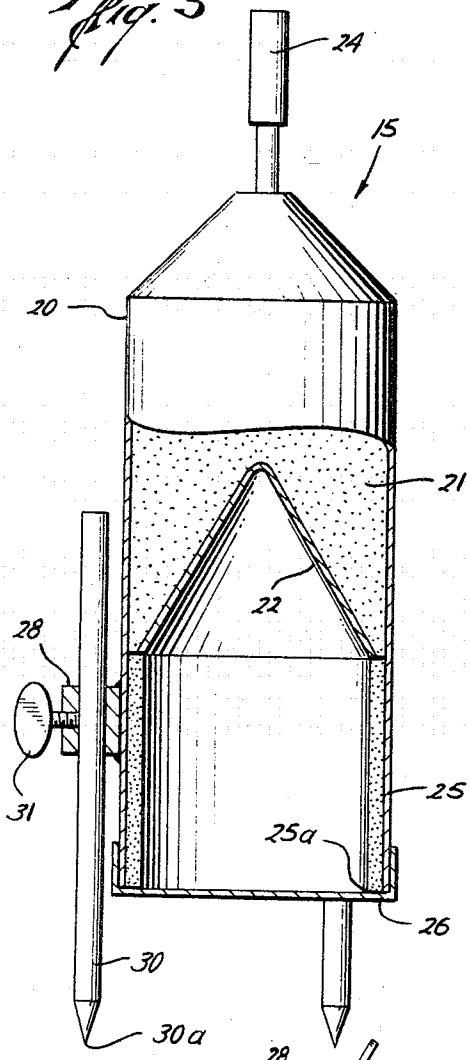


Fig. 7

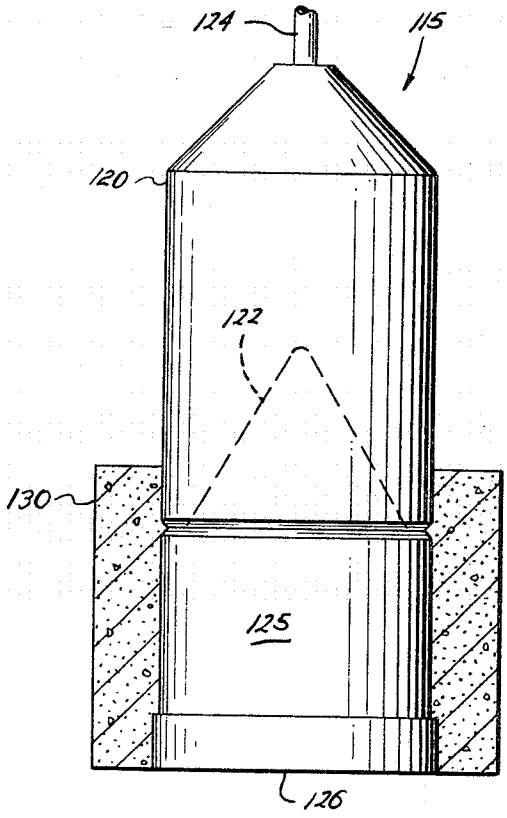


Fig. 8

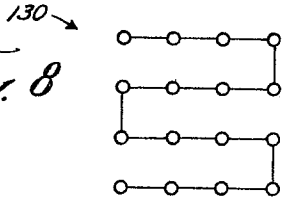
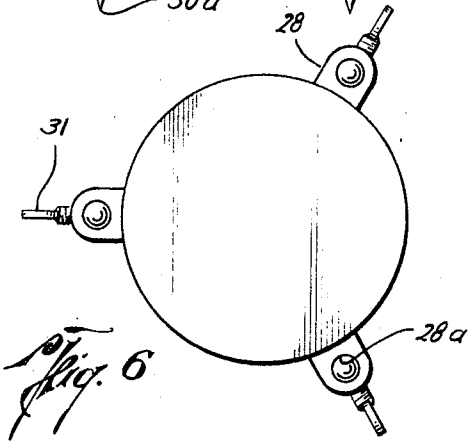


Fig. 6



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EXCAVATING APPARATUS AND METHOD FOR EXCAVATING MATERIALS

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Fig. 9

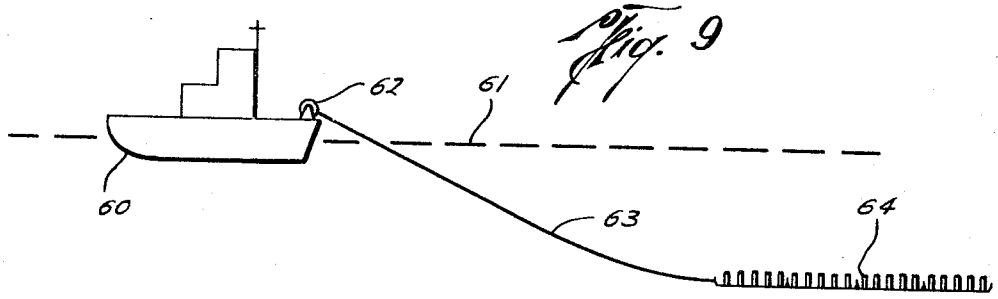
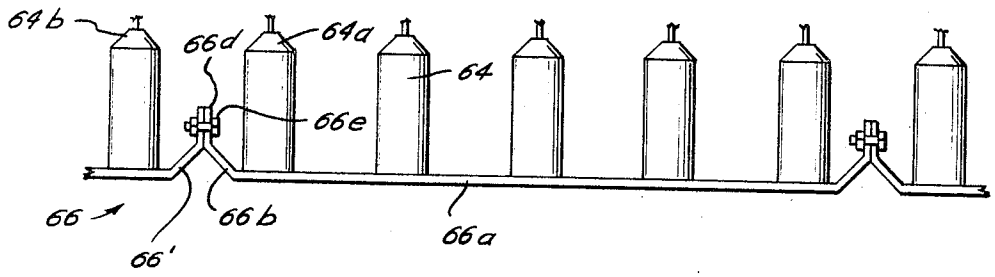


Fig. 10



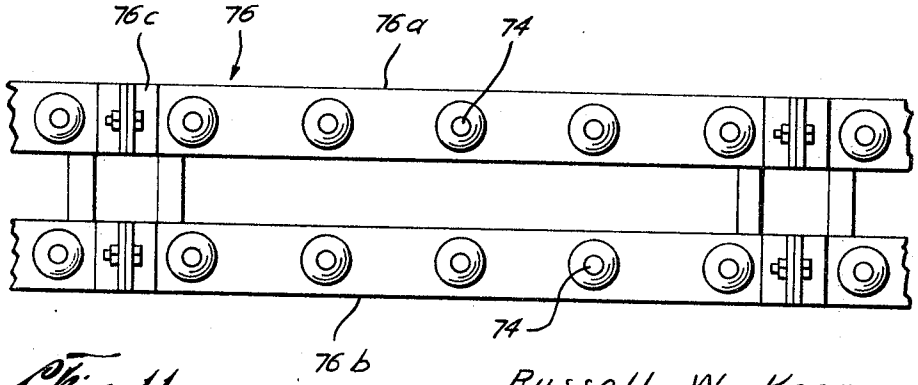


Fig. 11

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United States Patent Office

3,348,482

Patented Oct. 24, 1967

3,348,482

EXCAVATING APPARATUS AND METHOD FOR EXCAVATING MATERIALS

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Filed Jan. 3, 1966, Ser. No. 518,368

11 Claims. (Cl. 102—23)

ABSTRACT OF THE DISCLOSURE

An apparatus for and a method of fracturing materials, and more particularly a technique for fracturing material of any description at a desired volume, whether at the surface of the earth or beneath a body of water. This energy may be directed into a material to break up same, such as in forming an excavation, ditch, trench, or the like, or in breaking materials for ease of handling, as in strip mining, or other processes.

BACKGROUND OF THE INVENTION

(1) *Title of the Invention*

It will be appreciated that the breaking up of materials, which is described generally hereinafter as "excavating," is sometimes directed at selected volumes of material. By way of example and not limitation, it might be determined that a strip of overburden of granite above a layer of coal should be removed for ease of strip mining the coal. The present invention provides an arrangement of shaped charges to form ditches, trenches, or remove overburden to expose an area for mining.

(2) *Description of the prior art*

"Excavations" for other puruposes such as the forming of a trench or ditch to receive conduits, telephone or telegraph conductors, pipelines or the like are conventionally formed by special equipment which removes material from the trench prior to placing the member in the excavation. Excavating equipment is usually tractor propelled and tends to be cumbersome and therefore suffers from limited mobility and lack of speed. Poor mobility and speed limit applicability of conventional excavating equipment as will be recognized by those skilled in the art.

The terrain at an excavation also interposes difficulties in operation of excavation equipment. Thus, the surface may slope, as on the side of a hill or mountain, or the surface may be essentially vertical as adjacent to a river or at the side of a ravine. Moreover, the terrain surrounding an excavation site often interferes with transportation of the excavating equipment to the site without regard to the slope or contour of the site to be excavated. As an example, a ditch across a plateau might be easily dug but for the location of the plateau in mountaineous regions. Therefore, transportation of equipment to the plateau may be well neigh impossible.

Closely akin to conventional trenching equipment, stripping machinery, and other land based excavating equipment is dredging and similar apparatus usually carried on barges or other vessels. Harbors, canals and channels are "excavated," sometimes over a broad area and sometimes along a trench or underwater ditch. As an example, pipelines are placed on the submerged surface beneath a body of water and may extend some distance

beneath the water. The use of barge-mounted equipment to excavate beneath the surface of water is subject to limitations due to inaccessibility of the body of water, wave action routinely occurring, bad or inclement weather, range of the tides, and ease of disposal of dredged materials which is customarily by barge.

A problem encountered in excavating a volume of materials from the earth's surface, above or below water, is the hardness and regularity of the materials. Conventional excavating apparatus is inadequate for excavating granite, above water, or coral below water. Also, multilayered mixtures of materials can interfere with the use of conventional excavating equipment and require more specialized apparatus. And, irregularities such as the occurrence of occasional stones and gravel hamper conventional excavating equipment.

As will be recognized by those skilled in the art, heavy excavating apparatus cannot operate on materials too soft or marshy. Therefore, material hardness, or the lack thereof, and irregularities in firmness or density can interfere with excavating operations, and may even require the use of special apparatus in excavating hard materials.

SUMMARY OF THE INVENTION

The foregoing examples illustrate the scope of problems encountered in excavating materials, it being recalled that "excavation" is generally related herein to the breaking up of materials. With a view of these problems and others, it is an object of the present invention to provide a method of arranging shaped charges in a pattern related to the ratio of charge spacing to diameter to excavate materials.

Another object of this invention is to provide a new and improved apparatus for excavating materials ranging in hardness from granite to clay and ranging in consistency from homogeneous materials to multilayered soil and rock and including randomly located stones of all sizes.

One object of the present invention is to provide an apparatus for excavating which apparatus is readily usable at any location and is not encumbered by the lack of mobility found in the prior art apparatus.

A further object of the present invention is to provide a method of excavating in which terrain irregularities are easily accommodated without resorting to special equipment.

Another object of this invention is to provide a method of excavating materials at a vertical wall, cliff, or other embankment.

Still a further object of the present invention is to provide a new and improved apparatus for excavating materials in which the extent of excavation is known prior to excavation.

An important object of the present invention is to provide a new and improved apparatus for trenching which achieves approximately vertically extending walls which are spaced from one another to enable placement of a pipeline, electrical cable, or the like therein.

Another object of the present invention is to provide a new and improved apparatus having a flexible member connected to a plurality of shaped charges to eliminate the need for preliminary spacing measurements in placing each shaped charge.

An additional object of the present invention is to provide a new and improved excavating apparatus including a plurality of shaped charges which can be arranged in a straight line to excavate a trench, or which can be arranged in any other pattern to excavate material to whatever extent desired.

Still a further object of the present invention is to provide a new and improved method of excavating materials utilizing shaped charges arranged relative to one another dependent on the ratio of the center line spacing to the diameter of the charges.

Other objects and advantages of the present invention will become more readily apparent after an examination of the following specification and drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of the surface of material to be excavated in forming a trench in accordance with one use of the present invention;

FIG. 2 is a view similar to FIG. 1 in which shaped charges are arranged in a pattern for excavating a trench;

FIG. 3 is a sectional view taken through the earth and perpendicular to the surface thereof in the plane of primary openings formed by shaped charges arranged in accordance with the teachings of this invention for illustrating the use of the present invention to break up the web of material located between adjacent shaped charges;

FIG. 4 is an elevational view of the apparatus of this invention illustrating connection of adjacent shaped charges to an elongated member wherein the center line spacing of the adjacent shaped charges is related to the diameter;

FIG. 5 is an elevational view of a shaped charge, partly broken away to disclose a partial sectional view of the shaped charge;

FIG. 6 is an elevational view of the structure shown in FIG. 5 which illustrates adjustable standoff means;

FIG. 7 is a view similar to FIG. 5 which illustrates a shaped charge having negative buoyancy for use in excavating trenches under water;

FIG. 8 represents a pattern of shaped charges which can be extended indefinitely to excavate over a large area;

FIG. 9 illustrates a method for positioning shaped charges in the water;

FIG. 10 illustrates a plurality of shaped charges connected together for use under water in accordance with the method of the present invention; and

FIG. 11 is a top elevational view of a plurality of shaped charges for excavating under water in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Considering the invention broadly, attention is directed to the apparatus as illustrated in FIG. 4 indicated generally by the numeral **10** and which is illustrated as including an elongated flexible member **12** and two shaped charges **15**. The shaped charges **15** have generally a circular cross-section with a nominal diameter D, and they are spaced at a distance L measured from center line to center line along the elongated member **12**. Because the ratio of L to D is limited to not exceed a ratio of seven to one, initiation of the shaped charge **15** forms a plurality of primary openings indicated in dotted line at **16** which extends into the earth **17** and also achieves fracturing of the web **18** of material between the primary opening **16**. Thus, excavation is accomplished on initiation of the charges **15** wherein the material **17** is broken, and even the web **18** is fractured.

Considering the invention more in detail, attention is directed to FIG. 5 which illustrates the preferred embodiment of the shaped charge **15** in greater detail. The shaped charge **15** shown in FIG. 5 includes a container **20** of right cylindrical construction which is filled with a mass of explosives **21** which is shaped into a conical surface at **22** having a circular base of diameter D to provide portions of surface at least partially opposed to one another for directing energy in a given direction. The explosives **21** are initiated by a detonator indicated generally at **24**. It will be appreciated by those skilled in the art that various detonation means may be provided such as Primacord, electrical detonators or similar means. The detonator **24** initiates chemical conversion which travels as a wave front radiating from the detonator **24** into the explosive mass **21**. Rapid initiation is a measure of the quality of the explosives, which are described as high or low velocity explosive material, as the case may be. For purposes of an indication of approximate low and high velocities, low velocity explosives are considered as those having a speed of about 10,000 feet per second, while high velocity explosives have a rate of propogation of about 20,000 feet per second. Those knowledgeable in the art are familiar with both high and low velocity explosive materials and may supply same for fabrication of shaped charges such as the shaped charge **15**.

The conical surface **22** located interiorly of the shaped charge **15** is aligned with a standoff **25** which is a cylindrical extension on the container **20** and which is shown with a cover plate **26** placed across the lower end **25***a* of the standoff **25**. Guide collars **28** are welded or otherwise atatched to the exterior of the container **20**, and FIG. 6 illustrates three guide collars **28** in the preferred embodiment. The collars **28** have small axial openings parallel to the axis or center line of the shaped charge **15**. The openings **28***a* are adapted to receive stand members **30** having pointed lower ends at **30***a* which are pressed or otherwise urged into the surface, if possible, in positioning the shaped charge **15** of this invention. The stand members **30** are individually adjusted to a desired length by rotation of a thumb screw **31** extending through the guide collar **28** mounted on the container **20** for locking the stand member **30** relative to the opening **28***a*.

The shaped charge **15** is positioned by the above described means to propagate a shock wave into materials from the conical surface **22**. The energy released on initiation of the explosive mass **21** creates the shock wave at the conical surface **22** which is focused by the construction of the shaped charge **15** ino the jet of energy. The shock wave is conducted axially through the standoff **25**. The shock wave passes through the cover plate **26** attached across the open end **25***a* of the standoff and punctures or penetrates the earth **17** therebelow to form a primary opening such as the opening **16** shown in FIG. 4. By way of example, the primary opening for a nine inch diameter shaped charge is about three inches in diameter and may extend several feet into the material therebelow. Of course, the diameter, depth and even the existence of the primary opening **16** depends in part on the quantity and quality of the explosive material **21**, the geometry and dimensions of the conical surface **22**, and the materials penetrated by the energy. For purposes of description, it will be assumed that the shaped charge does form a primary opening such as that shown in the drawings.

Attention is directed to the shaped charge **115** shown in FIG. 7. The shaped charge **115**, which is similar to shaped charge **15** shown in FIG. 5, includes a container **120** filled with explosives formed to the desired shape. The shaped charge **115** includes a conical surface indicated in dotted line at **122** for directing the shock wave of the shaped charge through the standoff **125** connected therebelow. Means for initiation of the shaped charge is provided at **124**. A seal member or plate **126** is attached to the bottom of the standoff **125** and provides leakproof protection for the shaped charge **115**. A jacket of cementitious material **130** surrounds the standoff **125**, and can extend along the outer surface of the container **120** any desired distance. The material **130** serves as weight means providing a negative buoyancy to the shaped charge **115** to offset the buoyancy of the standoff **125** which is sealed against leakage of water. The negative buoyancy of the shaped charge **115** enables same to be positioned beneath water at the bottom, and it may be appreciated that little labor is required to handle and manipulate the shaped charge **115** under water. With a view of this, frogmen or divers can position the shaped

charge **115** with little effort preliminary to excavating under water.

The thickness and length of cement of the weight means **130** can be varied to achieve various degrees of negative buoyancy of the shaped charge. Of course, connective means may be provided for securing the shaped charge **115** to the bottom surface and may be, by way of example, adhesives, projecting members for penetration of material, or other suitable means.

The relative spacing of the shaped charges shown in FIG. 3 accomplishes the fracturing beneath and between adjacent shaped charges which are positioned before firing at the locations **22***a* and **22***b*. The positions **22***a* and **22***b* represent shaped charges and are provided as a reference to aid in understanding fracturing of the subsurface web **18** which is shown between the primary openings **16** beneath the position of each of the shaped charges. The jets of ultrasonic energy created by the shaped charges **22***a* and **22***b* form the primary openings **16** in the material and develop cracks and fractures extending between the primary openings **16** which completely break the web **18**. While the fractures **16***a* are shown in the plane of FIG. 3, it may be appreciated that they extend in several directions about the primary openings **16** and interact at various points not coinciding with the plane defined by the primary openings **16** so that a volume of materials in the vicinity of the plane of FIG. 3 is fractured and completely broken for convenient removal. Those skilled in the art will appreciate that some materials do not fracture as such, but are dispersed in form of particles such as in the case of sand. For the present purposes, all materials will be considered to fracture.

As mentioned hereinbefore, the shaped charges causing the fractures and primary openings shown in FIG. 3 are spaced to define a ratio of seven to one or less between the center line spacing L of the shaped charges **15** and the diameter D of the shaped charges.

FIG. 1 represents the earth wherein a trench to be excavated is defined by a pair of dotted lines **40** and **41**. Centered between the sides **40** and **41** is a plurality of shaped charges **15** which are indicated in FIG. 1 to the extent of showing their locations at **15***a*. The shaped charges are positioned and aligned relative to one another to define a ratio of seven to one or less between the center line displacements and the diameter of the shaped charges **15**. The shaped charges are initiated and puncture the above described primary openings in the material at the locations **16***b* shown in FIG. 1 and also develop a multiplicity of fractures and fissures extending to intersect one another between the edges **40** and **41**. The interaction of the fractures and fissures about the locations **16***b* of the primary openings fully fractures the material for ease of removal, leaving the trench with essentially vertical walls which are approximately parallel. Of course, characterization of the walls as vertical and parallel includes reasonable variations dependent on the character of the material in which the trench is excavated.

FIG. 2 illustrates a somewhat wider trench to be excavated between the edges **42** and **43** by use of shaped charges positioned at **115***a* in a pattern, as contrasted with the straight line arrangement shown in FIG. 1. The center lines of the shaped charges **15** are coincident with the corners of an equilateral triangle. The shaped charges, on initiation, form fissures extending through the material and intersecting one another to break the material. The cracks in the material are between the edges **42** and **43** and enable the broken material to be easily removed thereafter to define approximately vertical and parallel walls of the trench. The spacing of the shaped charges in the equilateral triangular arrangement shown in FIG. 2 achieves approximately parallel walls at both sides of the ditch at the indicated edges **42** and **43** and, of course, such equilateral triangular arrangement may be repeated along the length of the ditch indefinitely to extend the approximately parallel walls to any desired length. Patterns other than the equilateral triangular arrangement shown in FIG. 2 may be used to provide an even wider ditch or trench upon maintaining the spacing within the seven to one ratio previously mentioned.

Attention is directed to the pattern of shaped charges shown generally at **130** in FIG. 8. As previously noted, the term "excavation" used herein is generic in sense of describing the breaking of materials, without regard to the extent or volume of materials involved. Thus, excavating may be involved in forming a trench such as illustrated in FIGS. 1 and 2 or in breaking material extending over an area to any desired extent. As examples of excavating over a wide area, it may be desired to remove material in cutting a highway through a hill, in removing a rock burden at a gravel pit or stone quarry, or the like. Thus, the pattern of shaped charges shown in FIG. 8 having an L or D ratio of less than seven to one can be extended to any desired limits to achieve excavation of materials to be removed.

In using the method and apparatus of the present invention to excavate materials, it should be observed that the present invention sometimes, depending on conditions, cleans out the excavation and removes the broken debris from the excavation. At other times, the excavation may contain broken pieces of material which can be easily removed by conventional means and in little time. As an example, if the present invention is used to break and fracture a layer of granite on a formation of coal prior to strip mining and the pattern of FIG. 8 is extended to encompass several acres, it will be appreciated that some broken stone will remain over the coal. However, the broken material can be removed with ease to lay open the coal therebelow for strip mining.

In use of the present method, the shaped charges **15** are positioned on the surface of the material to be excavated. Placement may make use of the stand members **30** shown in FIG. 5 which are urged into the surface material to align the shaped charge **15** with the cone **22** directed downwardly to form the primary opening **16** approximately perpendicularly in the material **17**. Of course, if the surface is hard, rocky, or otherwise difficult to penetrate with the pointed ends **30***a* of the stand members, legs of the shaped charge are rested on the surface after arranging the pointed members to level and align the shaped charge. The shaped charges are not only positioned and leveled, but they are also arranged in a pattern such as the straight line arrangement shown in FIG. 1 or the indefinitely extending pattern of FIG. 2. Dependent on the dimensions of the excavation and other factors such as the type of material, the shaped charges **15** are arranged adjacent to one another with the ratio of L to D less than seven to one.

Positioning of the shaped charges may be achieved relatively simply. For instance, a string or other elongated flexible member such as a surveyor's chain having spaced indicators or markers along the length of the string at distances calculated to maintain the desired L to D ratio may be laid on the surface of the earth. The string may be very easily and quickly stretched parallel to the edges **40** and **41** (FIG. 1) of the trench to be excavated and the shaped charges are thereafter positioned above the markers on the string. The same string may be used repetitively in spacing shaped charges to form a long trench and excavation of portions of the trench may be, if desired, accomplished at various times.

As an alternative step in the method of this invention, two or more strings may be utilized to position any number of shaped charges in a pattern (see FIG. 8). After positioning the shaped charges **15** in a pattern having the desired L to D ratio, the charges are then prepared for connection to means for initiating same, and which may be electrically operated detonators on each of the shaped charges, or commonly-shared means such as Primacord connected to several of the shaped charges. Interference patterns between adjacent shaped charges may aid in fracturing the material in the web **18**.

By way of example and not limitation, one nominal size of shaped charges has a diameter D of nine inches. The spacing L for shaped charges having a diameter of nine inches can be up to about five feet, center line measurement, wherein the L to D ratio is slightly less than seven to one. Shaped charges of this size have been effective in fracturing material in the web **18** between the shaped charges shown in FIG. 4 to excavate in various and sundry kinds of materials. It may be appreciated that the depth of the primary opening **16** is partially dependent on the geometry of the shaped charge and standoff and other factors. However, these factors are well known to those skilled in the art.

In considering the character of material to be penetrated, it will be appreciated that shaped charges may be used to excavate in all sorts of materials including stone, clay, coral, and others. Of course, if the material is very homogeneous or "smooth," delivery of the high energy may be more rapidly effected on initiation of the shaped charge and may extend to a greater depth. On the other hand, materials interspersed with rocks and other debris may tend to diffuse the energy in the shock wave and may alter the fracturing of the material to some extent. Shaped charges having a nine inch diameter and located on five foot spacing between center lines have been found effective for excavating diverse materials, including mud and coral. Certain materials may permit slight alteration in the *L/D* ratio to a value less than seven to one which is considered the upper limit in view of the shaped charges now available. The lower limit of the *L/D* ratio is material to the extent that economical use of shaped charges is material when they are crowded too close together. The lower limit of the *L/D* ratio should preferably be not less than two for economical and efficient excavation. More generally, the shaped charges should be spaced in a nonabutting manner on one hand, but the spacing should not exceed an *L/D* ratio of seven to one, on the other hand.

Of course, the type of excavated material is also dependent on the location of the excavation. The materials in mountainous areas are generally filled with rocks and are sometimes homogeneous rock, such as sandstone or granite. In addition to the use of the present invention on land, it is available for use under water, even at the bottom of a body of water. Various bodies of water have bottom surfaces ranging from relatively deep silt or mud to sandy bottoms, rocky bottoms, and even coral formations. Such materials, and many more, are within purview of the present invention.

The apparatus of this invention provides the shaped charge **115** with negative buoyancy for use beneath the surface of the water. The positioning of the shaped charges is achieved in the foregoing described manner except for the fact that it is accomplished under water. Initiation of shaped charges under water sometimes creates a "water hammer" which appears to surge into the excavation and clean broken materials from the excavation.

In operation of the apparatus of this invention, the flexible member **12** shown in FIG. 4 is connected to the shaped charges **15** with an *L/D* ratio of less than seven to one. When using the apparatus to excavate, the structure can be, if desired, extended indefinitely to include any number of shaped charges **15** placed in a pattern (see FIG. 1 or 8).

The apparatus **10** of this invention preferably includes the elongated member **12** and co-extensive means for the shaped charge **15** by actuation of the detonators of the shaped charges. The extensible member **12** may itself be means communicated with the shaped charges, such as Primacord, or the member **12** may carry and support a means connected to the shaped charges to initiate same. Of course, use of the shaped charges **115** shown in FIG. 7 requires waterproofing of the detonation means to provide a device operable under water and also waterproofing of the elongated member connected to a plurality of shaped charges, should the elongated member be used to conduct electrical initiation signals or provide a Primacord communicating with the shaped charges.

Should the present invention be needed at remote locations or in difficult terrain, it may be appreciated that the present invention is quite portable and is easily moved to any desired location. It may be used to open any sort of excavation in irregular terrain, even to the extent of being used on vertical walls or the like. If a cut through a vertical wall or cliff is desired, whether above or under water, shaped charges can be positioned against the sloping surface to excavate into the face of the slope. If desired to cut a pipeline trench through a ravine wtih vertical walls, for example, the present invention can provide a trench excavated with ease and facility where conventional excavating apparatus is not free to travel. Moreover, the present invention may be used a second time in the excavation for providing a deeper cut or excavation. Those skilled in the art will appreciate the significance of repeated usage.

Attention is next directed to FIG. 9 of the drawings which illustrates one method of placing shaped charges in the water prior to excavating at the bottom of the water covered area. In FIG. 9, a tug **60** sailing on the water **61** is equipped with towing apparatus **62**. The tug **60** travels along a line intended to position a plurality of shaped charges **64** as they travel behind the tow line **63**. The tug **60** can be maneuvered to position the charges **64** in a desired position on the bottom to excavate at a predetermined location.

As an example, if it is desired to lay a pipeline across a body of water, the charges **64** are aligned at the shore and towed off the shore and into the water with the tug **60** providing impetus in the desired direction. As the charges **64** are moved to the desired locations, the tug **60** is halted to position the charges **64** on the bottom and the tow line **63** is freed of the charges, if desired. Thereafter, excavation will be directed to form the trench in line with the pipeline at the shore.

FIG. 10 illustrates a plurality of charges **64** preassembled on a sled **66** as one means expediting use of shaped charges in accordance with the discovery of the present invention. As previously noted, the spacing of shaped charges to obtain an L to D ratio of seven to one or less will excavate on initiation. The charges **64** are assembled on the sled **66** within the limits of the seven to one ratio.

The sled **66** is preferably formed of an elongate member **66***a* on which is mounted a number of shaped charges **64**. The charges are joined to the elongate member **66***a* by any suitable means and are spaced to conform with the preferred ratio while also being directed as a group in the same direction. The elongate member **66***a* is sufficiently heavy to keep the shaped charges **64** in an upright position under water.

The elongate member **66***a* shown in FIG. 10 is provided with a connective means indicated at **66***b*. The means **66***b* on the member **66** is only one-half the length of member **66** found between charges **64** so as to provide proper spacing when joined to an identical connective member such as the means **66'**. The total span of the connective means **66'** and **66***b* is calculated to position the charges **64***a* and **64***b* within the seven to one ratio previously referred to.

Mechanically, the connective means includes an upturned flange **66***d* through which a bolt **66***e* or other joinder means is secured. Of course, any number of bolts **66***e* may be used.

Referring again to FIG. 9, it will be appreciated from FIG. 10 that any number of shaped charges **64** may be joined together for excavation and towed into the water by the ship **60**. For instance, if fifty shaped charges are needed, the structure of FIG. 10 provides an exemplary structure wherein ten sleds **66** are joined together to provide fifty shaped charges **64**. If fifty-two charges are needed, eleven sleds **66** connected together with three

charges **64** omitted from the last sled **66** will suffice. Of course, the sled **66** may be of any length and accommodate any number of charges.

FIG. 11 illustrates a sled **76** for excavating a wide trench as suggested by the charge placement shown in FIG. 2. The sled **76** provides a pair of runners **76***a* and **76***b* on which shaped charges **74** are located within the seven to one spacing pattern previously described. The sled runners **76***a* and **76***b* are similar or even identical to the runners **66***a* shown in FIG. 10. In addition, connective means **76***c* are provided at the end of the sled **76** to enable connection with additional sleds **76** to form an excavation of any desired length utilizing the means of the present invention. Again, FIG. 11 shows five charges **74** on the means **76**, but those skilled in the art will appreciate that the means **76** may be of any desired length and will therefore accommodate any number of shaped charges **74**.

In FIGS. 10 and 11, the detonator means has been omitted for purposes of clarity although it will be appreciated that the means for initiating the charges **64** and **74** may be easily attached to the shaped charges prior to placing same in the water for ease of fabrication.

Briefly, the present invention relates to an apparatus for excavating materials and relates to a method of utilizing shaped charges to excavate, above or below water, in any type of materials.

What is claimed is:

1. A method of excavating comprising the steps of:
(a) positioning a plurality of circular shaped charges to direct energy generated on initiation into a material to be excavated;
(b) nonabuttingly arranging said shaped charges in a pattern relative to one another in which the center line spacing between adjacent shaped charges to diameter of shaped charges does not exceed seven to one;
(c) initiating said shaped charges to direct energy into the material to be excavated; and
(d) said energy excavating material adjacent to said shaped charges and also between adjacent shaped charges having center line spacing to diameter which does not exceed seven to one.

2. Excavating apparatus comprising a plurality of circular shaped charges adapted to direct energy into a material to be excavated, and means for nonabuttingly positioning said plurality of shaped charges to obtain a center line spacing of not more than seven times the diameter of said shaped charges whereby initiation of said shaped charges excavates material.

3. The structure of claim **2** wherein:
(a) the plurality of charges includes a pair of shaped charges of a given diameter;
(b) means for nonabuttingly positioning said shaped charges relative to material to be excavated;
(c) said means adapted to position said shaped charges with center line spacing not exceeding seven times the diameter of said shaped charges;
(d) means for initiating said shaped charges to direct energy into the material; and
(e) wherein said shaped charges excavate material adjacent thereto and also excavate material between the center lines of said shaped charges.

4. The structure of claim **2** wherein:
(a) the plurality of charges includes a pair of shaped charges of a given diameter;
(b) an elongated member adapted to be extended between said shaped charges; and
(c) said member aiding in nonabuttingly positioning said shaped charges with center line spacing not exceeding seven times the diameter of said shaped charges whereby material is excavated by said shaped charges adjacent thereto and therebetween.

5. The structure of claim **2** wherein:
(a) the plurality of charges includes three shaped charges, each of which includes a given diameter and center line;
(b) means for nonabuttingly positioning said shaped charges in a triangle wherein the center line spacing between shaped charges does not exceed seven times the diameter of said shaped charges; and
(c) means for initiating said shaped charges, said shaped charges excavating material within the triangle defined by the center lines of said shaped charges.

6. The method of claim **1** wherein a trench or ditch is excavated and wherein the shaped charges are arranged in a pattern along the length of the trench to be excavated, and wherein the center line spacing between shaped charges to diameter does not exceed seven to one.

7. A method of excavating over a large area comprising the steps of:
(a) positioning a plurality of substantially circular shaped charges to direct energy generated on initiation into material to be excavated;
(b) nonabuttingly arranging said shaped charges in a pattern relative to the area to be excavated, wherein:
(1) the center line separation between adjacent shaped charges to diameter does not exceed seven to one, and
(2) the plurality of shaped charges is arranged in a pattern over the extent of the large area;
(c) initiating said shaped charges to direct energy into the material; and
(d) wherein the energy generated on initiation excavates the large area.

8. A method of excavating materials beneath a body of water comprising the steps of:
(a) positioning a plurality of substantially circular shaped charges to direct energy generated on initiation into materials to be excavated beneath water;
(b) nonabuttingly arranging said shaped charges:
(1) in a pattern wherein the center line spacing of adjacent shaped charges to diameter does not exceed seven to one, and
(2) wherein the pattern of shaped charges extends over the area to be excavated;
(c) initiating said shaped charges to direct energy into the material; and
(d) said shaped charges excavating material over the area to be excavated.

9. The invention of claim **8** wherein the body of water cleans broken material from the excavation.

10. Excavating apparatus comprising:
(a) a pair of nonabuttingly arranged substantially circular shaped charges, each of which includes:
(1) an explosive mass,
(2) a container,
(3) said container shaping said mass to define at least partially opposed faces for directing energy in a given direction, and
(4) standoff means for focusing energy generated on initiation into material to be excavated,
(b) means for initiating said shaped charges;
(c) an elongated member connected between said shaped charges;
(d) said elongated member communicating with said means for initiating said shaped charges and adapted to operate same for initiation of said shaped charges;
(e) said elongated member communicating along its length at a spacing not exceeding seven times the diameter of said shaped charges with said means for initiating said shaped charges; and
(f) wherein said shaped charges spaced along said elongated member, on initiation, excavate material adjacent to said shaped charges and also excavate material between said shaped charges so as to form one continuous excavation.

11. The structure of claim **2** wherein:

(a) said plurality of shaped charges includes a pair of shaped charges;

(b) means carried on said shaped charges adapted to position same to direct energy generated on initiation approximately perpendicularly into the face of the material to be excavated;

(c) said means being also adapted to position said shaped charges with a center line separation not exceeding seven times the diameter of said shaped charges;

(d) a flexible member connected to said shaped charges;

(e) means for initiating said shaped charges extending along said flexible member; and

(f) said shaped charges, on initiation, excavating material adjacent to and also between said shaped charges.

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