United States Patent [19]

Eckels

[11] **3,741,119**

[45] **June 26, 1973**

[54] **REMOTE ROCK BREAKING METHOD APPARATUS THEREFOR**

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[22] Filed: **Feb. 22, 1971**

[21] Appl. No.: **117,537**

[52] **U.S. Cl.** ..... **102/23,** 102/24 HC

[51] **Int. Cl.** **F42d 1/02,** F42d 3/00

[58] **Field of Search** ..... 102/22, 18, 23, 24 HC, 102/70.2 A

[56] **References Cited**

UNITED STATES PATENTS

3,012,503	12/1961	Brown et al.	102/19.2 X
3,348,482	10/1967	Keener et al.	102/23
3,408,937	11/1968	Lewis et al.	102/70.2 A

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[57] **ABSTRACT**

A method of remotely breaking rock, or the making of predetermined size holes in the earth, in a precise position, suspends an assembly of prepositioned shaped charges in a pendulum array between a distance line of sight signal generator and receiver for such signal for accuately positioning the charges in a predetermined location. The pendulum array may be precisely laterally aligned along the predetermined line, and longitudinally along the line in accordance with predetermined mappings. The method provides a means of explosively forming trenches along the bottom of bodies of deep water, the precision breaking of underwater rocky barriers, etc., using an optimum spacial arrangement of a plurality of charges. The spacial arrangement being determined by testing on similar rock. The apparatus for such method includes articulated sinking rafts supporting such spacially arranged charges which are arranged for lateral and longitudinal leveling.

12 Claims, 14 Drawing Figures

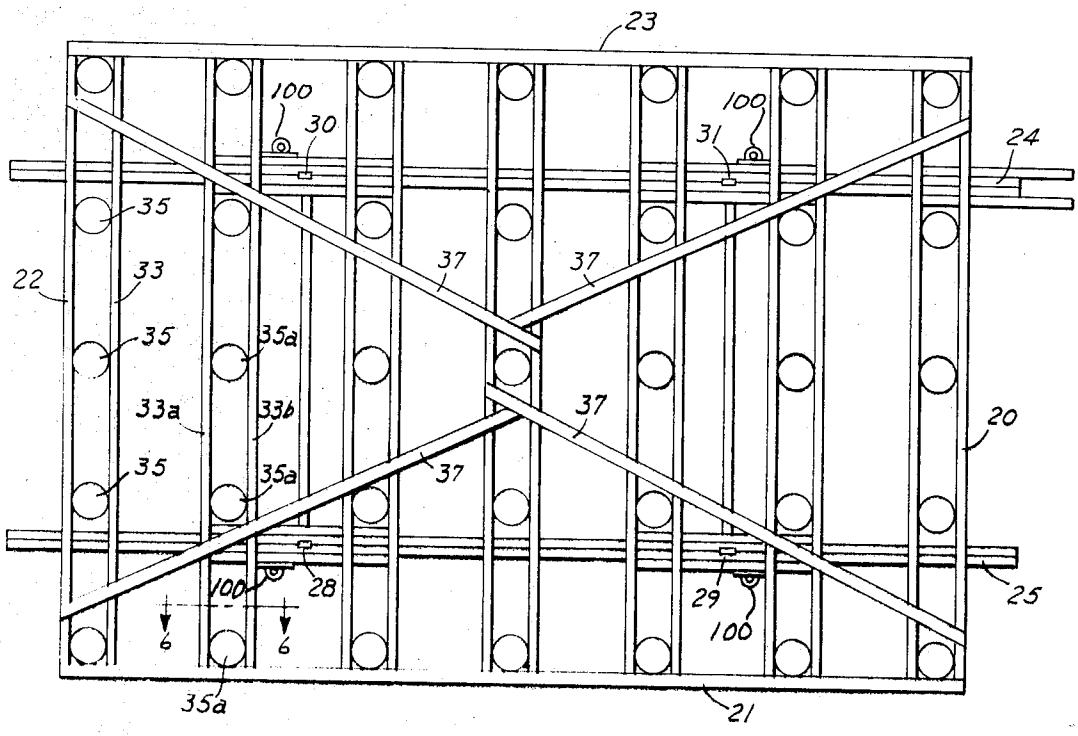
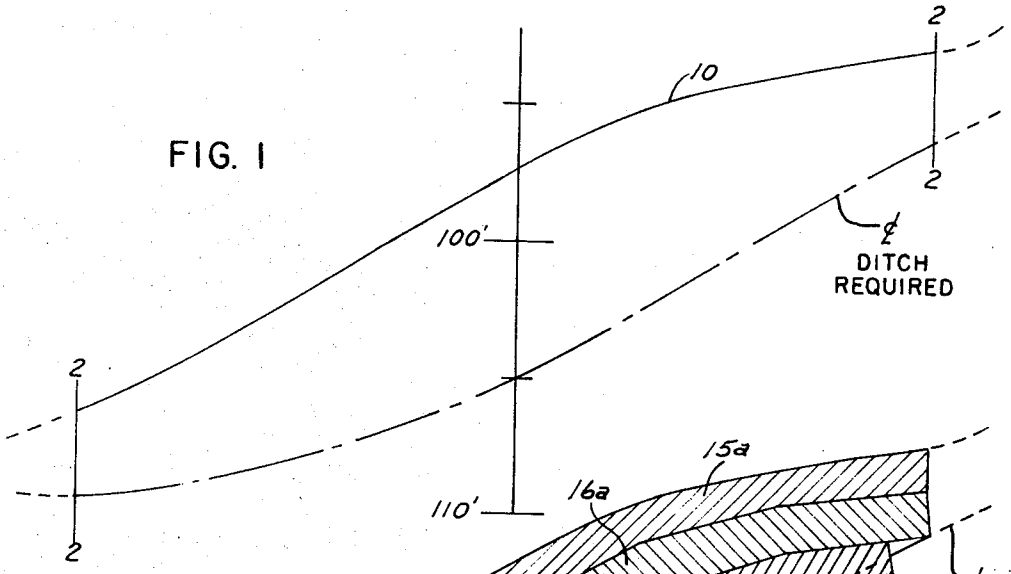


FIG. 1



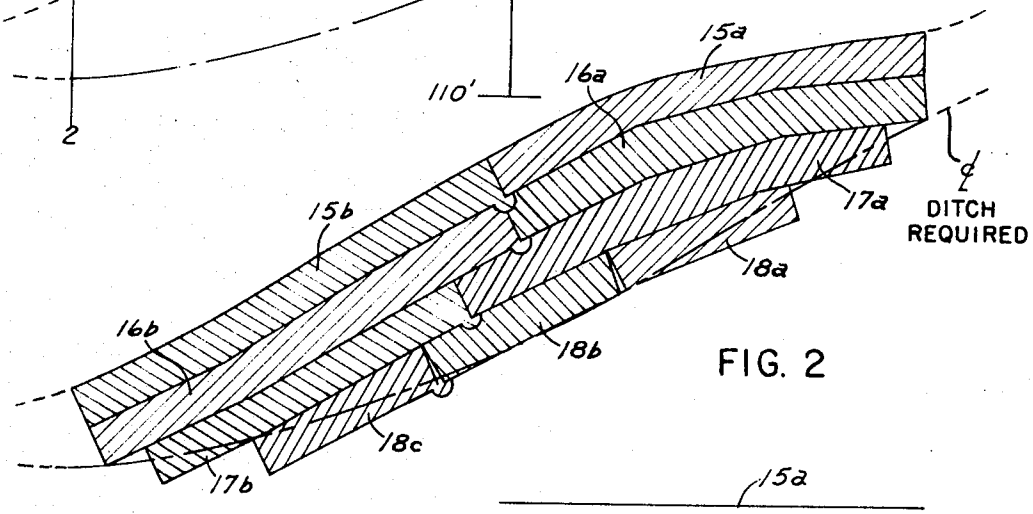


FIG. 2

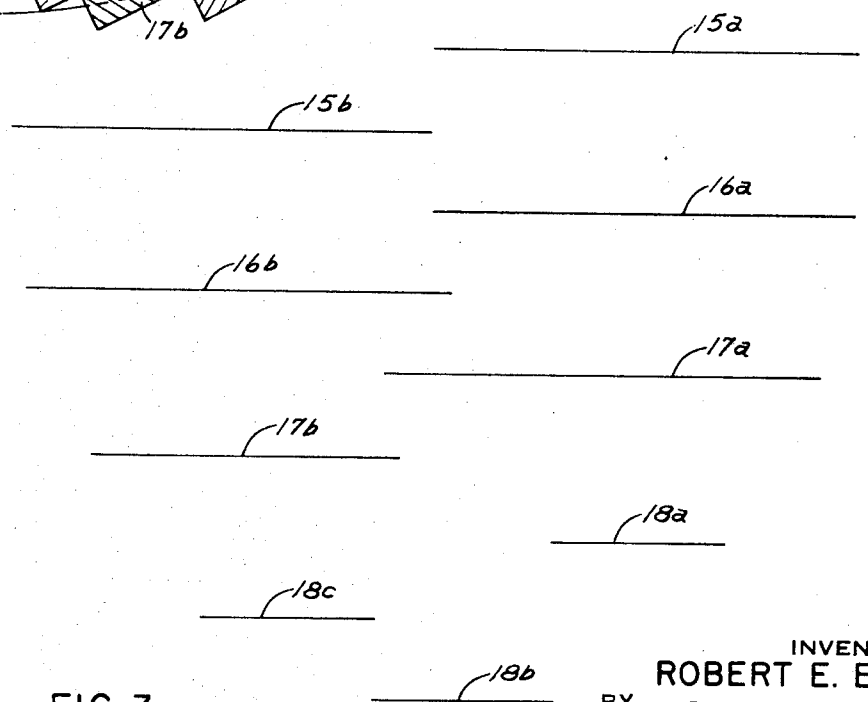


FIG. 3

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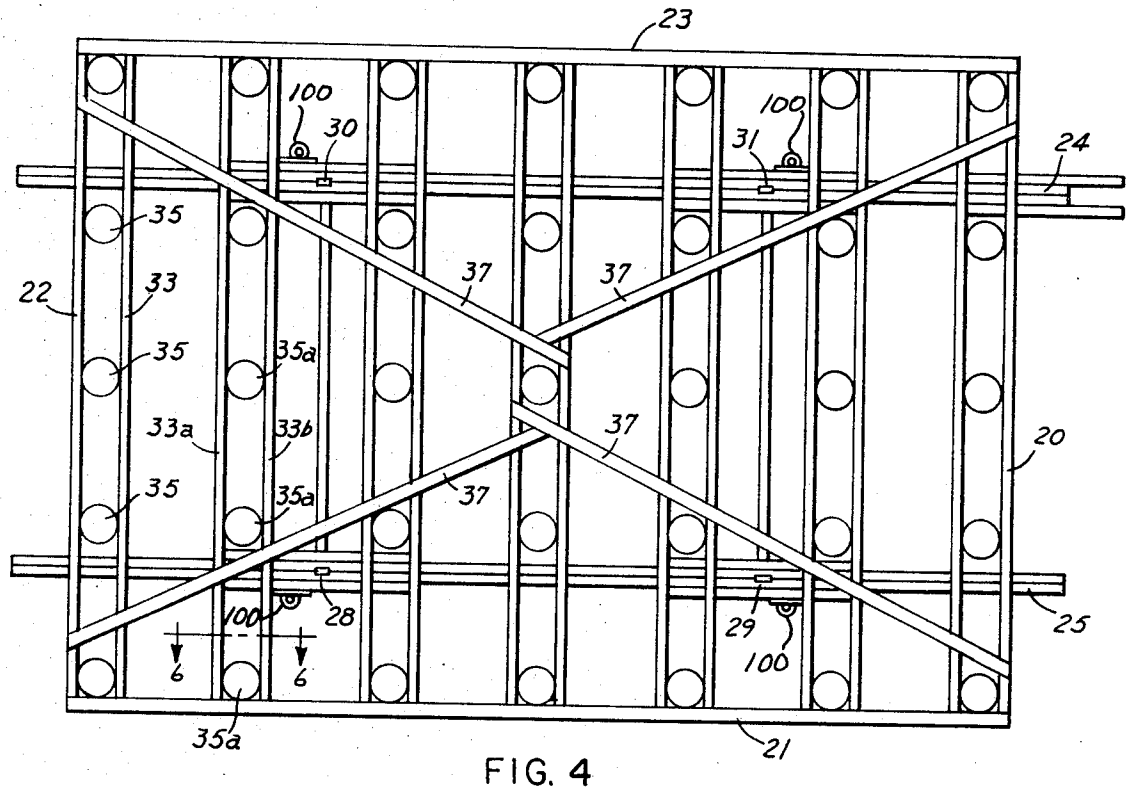


FIG. 4

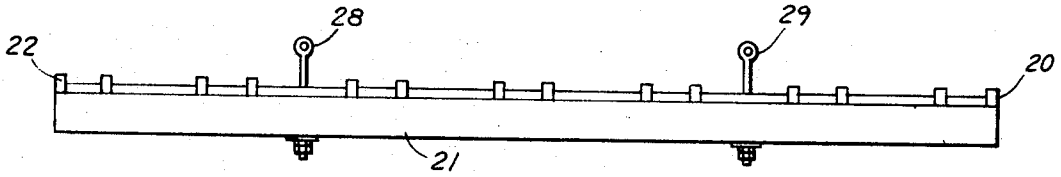


FIG. 5

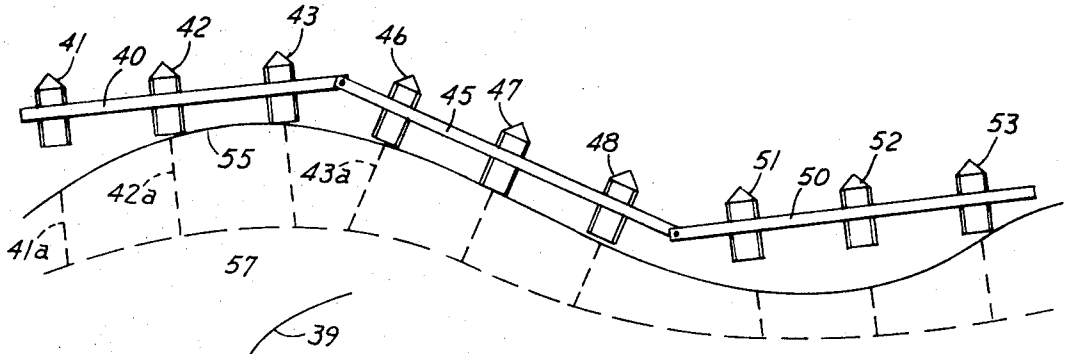


FIG. 7

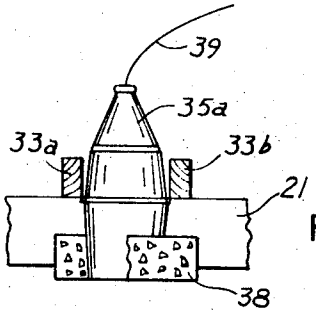


FIG. 6

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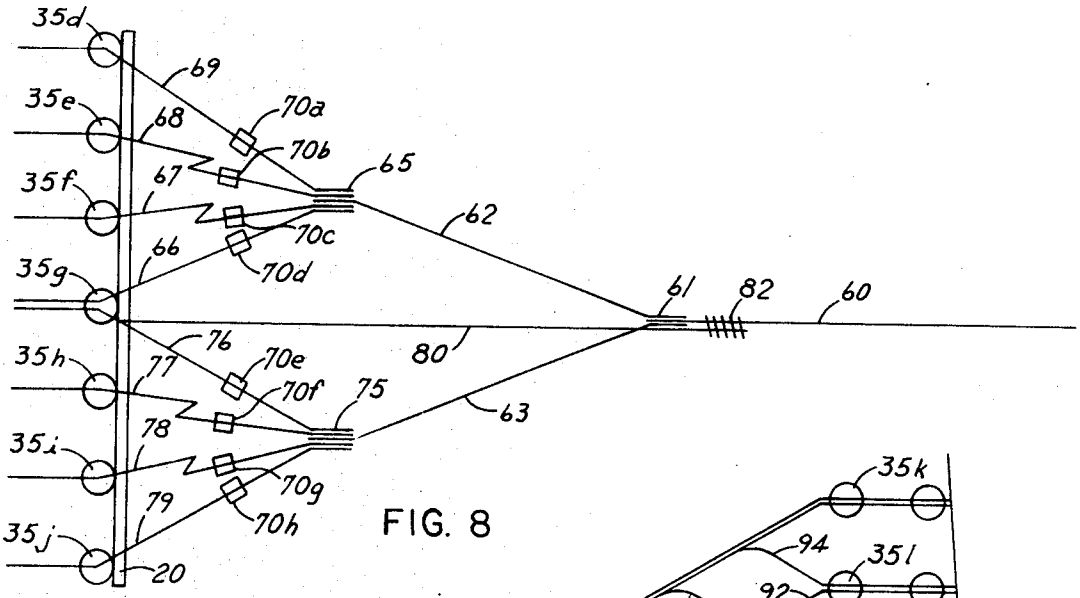


FIG. 8

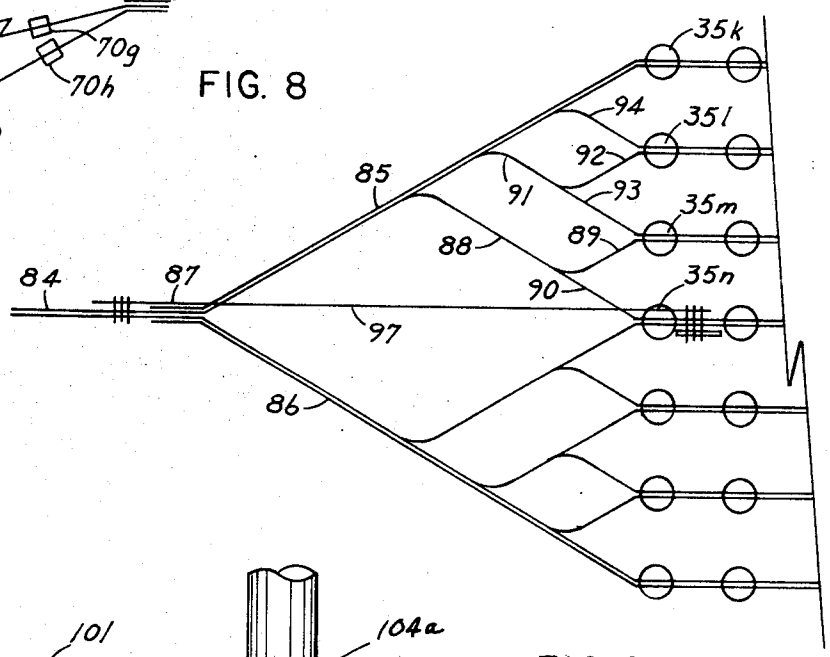


FIG. 9

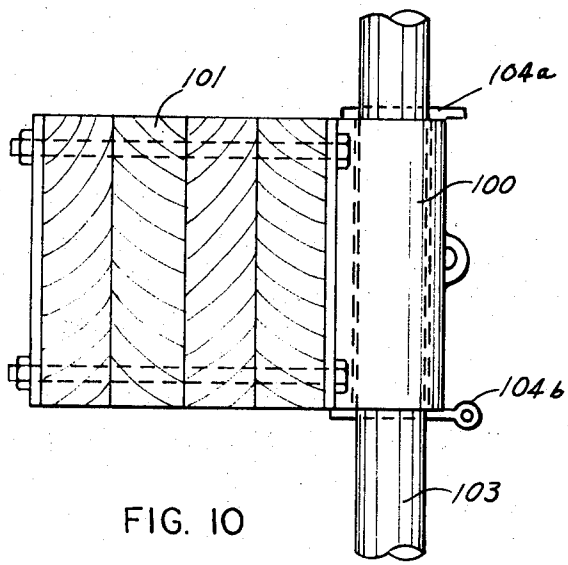


FIG. 10

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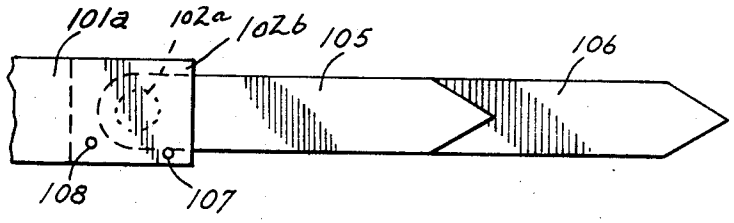


FIG. 11

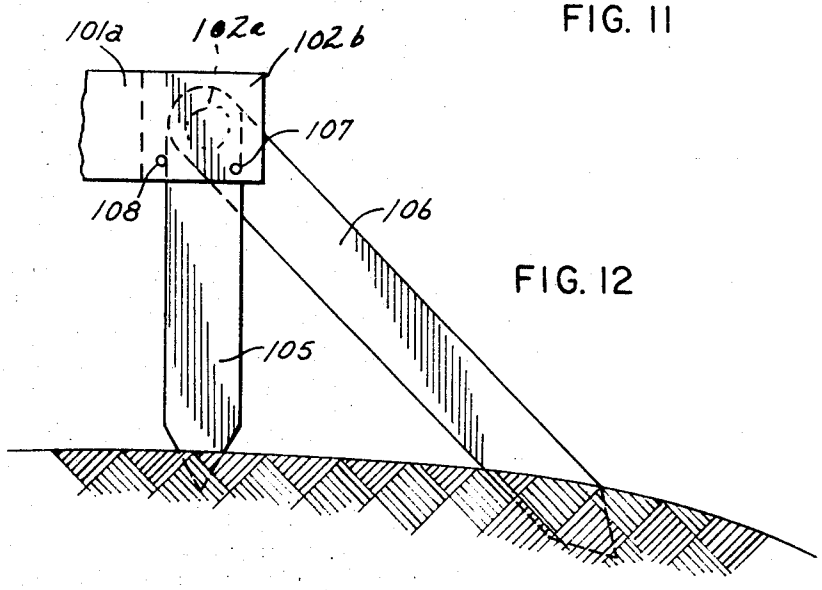


FIG. 12

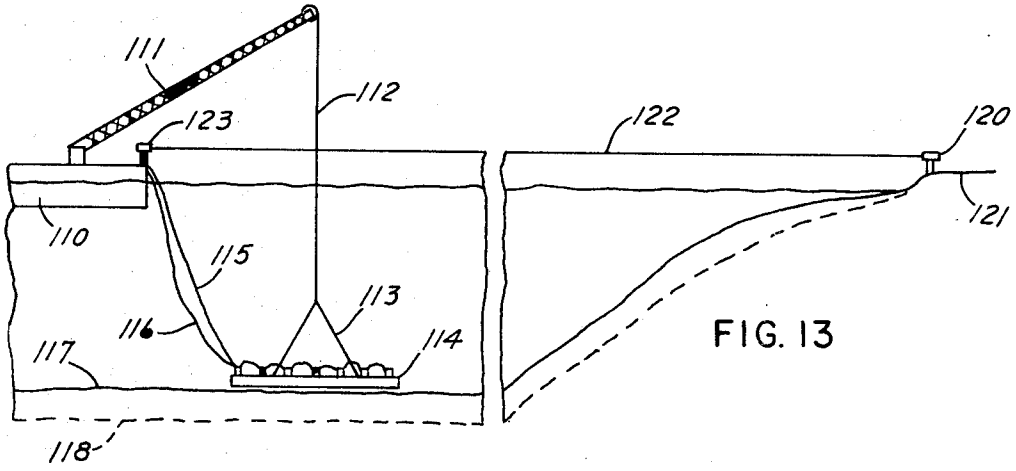


FIG. 13

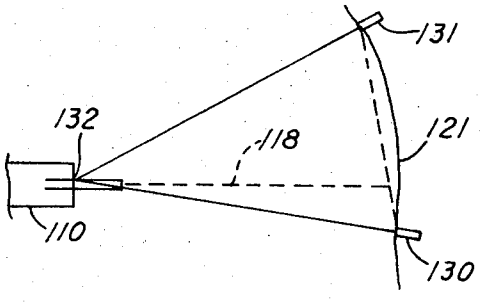


FIG. 14

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REMOTE ROCK BREAKING METHOD APPARATUS THEREFOR

The use of underwater pipe lines for oil, petroleum products, etc., is rapidly expanding due in part to the lack of an oil supply at local areas of use. The requirement of transportation of petroleum products from one location to another has brought about an increase in size of tankers used for the transportation of such products. With the increase of size of the tankers, it has been necessary to make substantial changes in the method and the location of loading and unloading the oil cargo from such tankers. Few ports of the world can adequately berth the new super tankers which are becoming more common on the oceans of the world. One solution to the loading and unloading problems of such large size vessels has been the use of a floating platform, monobuoy, etc. in water sufficiently deep for the super tankers. Pipe lines extending from the platform to storage facilities on the shore are extended along the ocean bottom. These pipe lines are quite large, usually on the order of 2 to 6 feet diameter, and are generally not flexible enough to conform to the rather uneven profile of the ocean bottom. With the pipe line merely lying on the ocean bottom it is vulnerable to currents, tides, hurricanes, dredging equipment and the like, therefore, it has been an increasing practice to excavate ditches or trenches along the ocean bottom to form a smooth bed for the pipes and to provide a means for protecing the pipe in the watery environment. In many instances, the ocean bottom approaching a shore is extremely rocky, is quite rugged and the water may run quite deep.

The forming of underwater trenches has, in the past, been more or less a haphazard operation, particularly in murky water or in water having relatively high currents. The trenching operations in deep murky waters have been particularly haphazard where the services of divers with visual observation of the location of charges has not been feasible. In many areas adjacent shores where storage facilities are located, the ocean currents are quite high, and the tide maximum and minimum levels are quite extensive. In some bay areas, where such trenches have been found desirable, currents as high as 4–8 knots have been encountered thus greatly increasing the problem of forming a trench in the ocean bottom.

It is, therefore, an important object of the invention to provide a means for a controlled, remote breaking of rock or like hard substances.

A particular object of the invention is to provide a means for remotely breaking rock in precision locations on ocean bottoms.

Another objet to the invention is to provide a programming means and location means for the target to be broken in an effective and efficient manner.

Still another object to the invention is to provide a plurality of spaced charges, accurately positioned spacially for remotely breaking of rock on an ocean bottom.

Yet another object of the invention is to provide a system of firing a plurality of spaced explosives which are precisely aligned in an optimum explosive pattern on an ocean bottom, in a timing sequence which will provide optimum breaking of the target rock on the ocean bottom.

A still further object of the invention is to provide detonating means to a plurality of prepositioned charges so as to provide a selected sequential detonation of the charges for optimum breaking of target rock.

An additional object of the invention is to provide an assembly of explosive charges prepositioned with respect to one another according to their center lines, the basis of the spacing determination being by test to be optimum for the target rock.

A still further object of the invention is to provide modular sinking raft arrangements, designed for supporting a plurality of explosive charges at predetermined spaced intervals, which modulars may be assembled as rigid, articulated or semiarticulated assemblies which may be lifted through the air and placed in the water for sinking to position on a target area while maintaining the integrity of the entire assembly.

Another object of the invention is to provide sinking raft apparatus for supporting spaced explosive charges, which raft is arranged for lateral leveling at the target area for optimum use of the explosive charges on the raft.

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 schematic profile of a section of ocean bottom showing the center line of a proposed trench along the ocean bottom;

FIG. 2 is a schematic profile of a series of proposed explosive trenching shots to form a proposed trench;

FIG. 3 is a time-space, schematic diagram of the sequence of explosive shots for forming a trench on the bottom shown in FIG. 1;

FIG. 4 is a top plan view of one form of a sinkable raft in modular construction for positioning shaped charges for underwater trenching;

FIG. 5 is a side elevational view of the raft of FIG. 4;

FIG. 6 is an enlarged detail view of the setting of a concrete encased, shaped charge in a sinkable structure such as shown in FIG. 4;

FIG. 7 illustrates the positioning of an articulated, modular sinkable structure assembly for forming a trench along the center line of a rock target;

FIG. 8 is a top plan view of a detonating cord assembly for the precise timing of the detonation of spaced charges;

FIG. 9 is a top plan view of a redundant detonating cord bridle assembly for multiple explosive charges, prepositioned on a target;

FIG. 10 is an enlarged detail view of one form of a leveling leg useful for a raft according to the invention;

FIG. 11 is an enlarged detail view of a modified form of leveling leg assembly for a sinkable raft assembly according to the invention;

FIG. 12 is an enlarged detail view of the leg system of FIG. 11 in a down or leveling position;

FIG. 13 is a schematic elevational view of a barge positioning means for a shape charge assembly utilizing a laser beam from a shore generator for accurately positioning a pendulum suspended explosive array from the barge; and

FIG. 14 is a top plan view, in distorted detail, of a triangulation measuring system for accurately positioning a shaped charge array along a proposed trench line.

The method of the invention, in general, provides for suspending multiple explosive charges prepositioned in

a frame work in a pendulum array in a precise location in which it is desired to break rock in the target area. Generaly, the explosive charge assembly is suspended by one or two cables from a crane on a floating barge or the like which has been anchored in position by triangulation or other survey methods. By prepositioning a plurality of charges in a modular essentially rigid frame work, the charges may be accurately positioned to produce an optimum breaking which will result in an essentially laterally levelled trench, and the explosives produce optimum rock breaking with the charges used.

While the major part of the following description is applied to forming underwater trenches it is not intended that this should limit the scope of the invention to only underwater breaking of rocks. It is intended that the word rock shall include other hard materials which may be frozen earth, ice, frost, etc., as well as usual rocks and whether the rocks are under the water or above the water.

The optimum breaking of target rock requires that the explosive charges be spaced in accordance with the character and the type of material being broken in relation to the charges. In general, the space is best determined by actual testing on the particular material to be broken. A number of variables inevitably occur in providing optimum break for the number and the size of charges used in any particular operation. Due to many of these variables, some spacings of the explosive charges produce ineffective results in one target material where effective results are produced in a different type of material with the same spacing and the same amount of charge.

The break between the jets of spaced, shaped charges is in one area a function penetration of the jet. The penetration in turn resolves into a particular configuration of hole. i.e., a depth and approximate radius. The depth of the hole is largely related to the density of the jet divided by the density of the target to the one-half power plus lesser items. The configuration of the cone of the shaped charge and the construction material for the shaped charge is, also, a variable which must be taken into consideration in determining the optimum break. The character of the shaped charge, eg., the size, the type of cone, the material of the cone, etc. determines the standoff, distance of cone from target, for maximum jet penetration. This is conveniently stated in diameters of the charge or cone. In one size, using a 9 inch diameter charge and a steel lined cone, the distance of standoff is generally one–three diameters. This distance is determinable from available data. After the charge size and standoff distance is chosen, it is necessary to determine the optimum spacing of multiple charges for producing optimum breaking. The distance apart of the shaped charges is conveniently stated in terms of diameters, (of the charges) from center line to center line of adjacent charges. Since subtle changes in the same or similar rock may cause substantial changes in breakage of the rock, testing on the particular rock is desirable to determine optimum charge spacing. As an example of changes found in breakage, shown by testing granitic rock requires a spacing which ranges from 2.4 to four diameters depending on the particular granite. It is suggested that similar rock material on shore will be approximately the same as the rock material underwater along a proposed trench line extending outwardly from the shore, and testing on the shore rock approximately testing the underwater rock.

A preferred test method includes detonating a series of charges on target rock or equivalent rock near the target. The charges are spaced at predetermined different distances apart and sequentially or simultaneously detonated. For granitic rock four charges should provide an adequate test. The charges are placed in a line so that the second charge is two diameters from the first, the third is three diameters from the second and the fourth is four diameters from the third. The charges are detonated and the breakage is visually observed. This shows which spacing produces optimum breaking, considering the economics of the number of charges. In some types of material five charges may be necessary, placing the fifth charge five diameters from the fourth. Visual inspection and digging in the breakage area determines the optimum spacing.

The type of target material determines the test spacing necessary to make the determination of the spacing for the charges. Epidote requires a spacing of from 2.4 to 3.5 diameter, therefore, spacing of the test charges of 2.5, 3, 3.5 and 4 diameters should provide an adequate test. Cinnabar on the other hand, requires a spacing of 1.2 to 3 and charges spaced to span these distances should provide a representative test. Some materials break very easily and greater distances are involved. Ice, for example, breaks easily and the spacing may be as great as twelve diameters, and the test spacing must be sufficient to span such distances.

In the testing method, a spacing between charges which is greater than the optimum spacing will aid in showing the optimum spacing. Where the rock type is not accurately known, or where no test data is available, several such tests may be necessary. Generally, however, in granitic rock tests which span four diameters will provide the necessary information. As the density of the rock increases, the distance apart of the charges normally reduces, and conversely as the density decreases the distance apart of the charges increases.

One acceptable concept of what takes place in the action on an explosion of a shaped charge, is that the jet hits and enters the rock mostly by compressive means. The compressive shock waves produced, travel away from and normal to the entry axis of the jet itself. These compressive waves are followed by alternate tensile or rarefaction waves. By the superpositioning of these waves on like waves from other nearby sources, important areas of tensile and shear stress occur. Generally, rock has a much lower tensile and shear strength than compressive strength, and the most effective use of energy in breaking is against the tensile strength. Each rock has a critical normal fracture stress character in each of its three planes and in the stress and environment conditions involved. It is, therefore, necessary to overcome this tensile strength value as a first condition of economic rock failure. Further, it is not unusual to find that the compressive strength of a rock upwards to 50 times or more the tensile strength of the rock.

Compressive waves approaching each other from spaced sources will have a multiplicity of areas of coincidence where tensile or shear conditions are possible. Compression waves which radially displace particles beyond the compressive strength of the rock will cause failure of that part of the rock and a break in very small pieces, and just beyond this area the displacement will be such that the resilient particle return causes areas in tensile stress. The tensile, or return wave, when either

traveling parallel or opposite directions to the radii from such multiple sources can have coincidential tensile or shear areas. Radially displaced particles develop stresses under optimum design conditions when simultaneously firing two or more explosive devices to exceed the critical fracture stresses of the rock to give breakage.

The shock waves from the multiple source areas may be reflected producing superposition of waves to produce stresses which exceed the compressive, tensile, and shear stresses and cause breaking of the rock. The overall effect is that an exact placement of simultaneously fired explosive devices will superposition stress waves which results in a high percentage of relatively small rocks broken in place. "Simultaneous" may be a very close sequence.

In FIG. 1, the ocean bottom profile 10 is shown with a proposed ditch or trench line, illustrating the extent of excavation necessary in one section of the ditch. This illustrates that a trench may be required along the crown of a underwater mound or on the slope of the mound itself. To form a trench on such a slope, FIG. 2, illustrates the shots necessary to ditch into the sea mound, using a plurality of superimposed charges. A first series of shots, 15*a* and 15*b* are made stepwise along the profile of the sea mound in a sequence, for example, as shown in FIG. 3. This indicates a time sequence from top to bottom. After each series excavation may be necessary to remove broken rock. A second series of explosives are set along a pattern as shown in 16*a* and 16*b* which are superimposed over the initial blast area of the 15 series. The first series breaks the cap rock and the second series provides an initial leveling of the area. A third series of shots 17*a* and 17*b* provides additional breakage. The broken rock may be removed, as by a clam-shell digger on a barge. The final series of shots 18*a*, 18*b* and 18*c* produces the final breakage for the trench. As can be seen, the number of shots in a single location requires precise location of the charges in order to form the desired trench. The number of charges required for each of the series of shots is determined by the length and width of cut necessary for the trench. The configuration of the spacing of the charges is determined the structure for supporting the charges. The length of the structure is determined in part by the profile of the target and equipment for handling the charge supporting structure.

The rock breaking for underwater targets is preferably performed by a multiplicity of shaped charges prepositioned in a sinkable structure, which can be lowered intact onto the target area. As shown in FIG. 4, a sinkable raft having a series of 5 spaced shaped charges in 7 rows is formed of outer frame members 20, 21, 22 and 23 forming a box shaped raft. The raft is formed of wooden members which break into small fragments and float out of the target area, helping to maintain a cleared trench. The boxes are reinforced by heavy composite timbers 24 and 25 which extend through the raft, and which provide means for securing lifting eyes 28 and 29 on one side and lifting eyes 30 and 31 on the opposite side. Leg sleeves 100 are, also, secured to these members. Containers for the shaped charges are then secured in the frame work by means of beams. For example, at the left end of the sinkable raft, a beam 33, extended between the sides 21 and 23, secure the shape charges 35 in position. In like manner, each row of shaped charges are secured between a pair of beams. For example, beams 33*a* and 33*b* secure a row of explosives 35*a* therebetween in a spaced relation to the explosive charges 35, generally one behind another. Diagonal support beams 37 provide additional rigidity to the raft.

One form of positioning and securing an explosive charge in the raft is illustrated in FIG. 6, wherein a shaped charge canister 35*a* is positioned between two timbers 33*a* and 33*b*. The container 35*a*, which may be a commercially available device, includes a internal cone positioned to face downwardly so that a jet from the detonation of contained explosive material is directed downwardly. In some instances, it may be desirable to provide a concrete base around the canister 35*a* for weighting and as shown, a concrete base 38 is formed around the bottom of the canister. By providing wires, bolts, or the like in the concrete base, the canister is easily attached to the raft. Other conventional attachment means may be used. The canisters are essentially well known devices usually formed of two compartments; the upper compartment being the compartment for containing the explosive material and having as its base a conically shaped partition, the lower container is normally maintained at or below atmospheric pressure. Primer cord or detonating cord 39 is extended from a primer in the canister, as will be explained below.

The rafts may be made in modules of rows of explosives, and the module shown is a series 5 explosive charges in 7 rows, or 7 charges in 5 rows. Other modular rafts may be made, for example, a 3 charge row with 5 rows on the raft, or a 3 by 4 arrangement or any other desired number. The rafts may, also, be joined together along either a short side or a long side. For example, the raft of FIG. 4 may be joined with a similar raft along the 5 charge side or along the 7 charge side depending upon the width of trench desired in a location. As illustrated in FIG. 7, 3 rafts are joined together, each raft includes 3 rows of a series of charges, for example, 5 charges in a row. Raft module 40 having rows 41, 42 and 43 is articulately connected to raft module 45, which contains rows of explosives 46, 47 and 48, which in turn is connected to a raft module 50 having rows of explosives 51, 52 and 53. This arrangement is provided with an articulated connection between each of the raft modules since the profile of the ocean bottom at that location is curved and recurved forming mounds and gullies. It is desireable to provide as level a trench as possible, and the charge arrangement helps this feature. The rows of explosives 42 and 43 are in contact with the top of mound 55, and at the contact positions, jet penetration, shown by 42*a* and 43*a* respectively, will provide the deepest penetration of the explosive charges on the raft module 40, approximately to the indicated trench bottom line 57. The explosive charges 41, however, are not in contact with the cap rock and, therefore, the standoff will reduce the penetration of the jet 41*a* to somewhat less than the penetration of jets 42*a* and 43*a*. In like manner, the explosives of raft module 45 are in contact with the ocean bottom, and their respective jets produce a equivalent penetration to the jets of the explosive charges 42 and 43. The module 50, however, has its rows of explosives 51 and 52 in an standoff position while the row of explosives 53 are generally in contact with the bottom. Therefore, the jets from the rows 52 and 51 penetrate less than the jets from the row of explosives 53. The total effect of stand-

off or contact is to produce a leveling effect of the bottom 57 of the broken rock. Further, in some instances it may be desirable to provide non-articulated composite sections, where two or more modules are formed into a rigid structure, as may be determined by the profile of the ocean bottom.

To provide optimum denotation of the rows of explosive charges, thereby producing optimum breaking, each row of explosives should be essentially simultaneously denotated. For this purpose a bridle arrangement of primer cord, or denotating cord, as shown in FIG. 8, attached to the explosive charges provides essentially simultaneously explosion of each row of charges. The assembly includes a length of primer cord 60 which extends from the barge vehicle to a juncture 61 of primer cord sections 62 and 63. The junction 61 is made so that the detonating train travelling along the primer cord is split and initiates the detonating train in the primer cords 62 and 63. The length of the cord 62 and 63 are the same, and the juncture 61 should preferably be at an angle of less than about 60 degrees between the two lines. Alternate or changes of directiof detonating cord should be maintained at less than 30 degrees change. The cord 62 terminates in a juncture 65 from which 4 equal length of cords 66, 67, 68 and 69 extend to charges 35d, 35e, 35f and 35g. By having the same length of cord, as the detonating train travels along the cords at the same velocity it provides denotation of the four charges at the same instant. Since the middle charges are closer to the juncture 65 than the two outer charges the lines 67 and 68 are slack, while the lines 66 and 69 are taut. To prevent fouling of the lines, floats 70*a*, 70*b*, 70*c* and 70*d* are placed on all lines 69 through 66 respectively which keeps the lines taut by floating and keeps them from fouling. A equivalent set up extends from the cords 63 at a junction 75 to the charges 35*g*, 35*h*, 35*i* and 35*j*. The lines 76, 77, 78 and 79 are equivalent to the lines 66 through 69 and the floats 70*e* through 70*h* are equivalent to the floats 70*a* through 70*d*. This produces a redundant system for the center explosive charge 35*g*, which may then be extended rearwardly to the next row of explosives either as a two cord system or as a single cord system as may be desired. A tension wire 80 secured to the raft extends from the forward outer timber 20 to a connector 82 on the primer cord 60 which relieves tension on the bridle portions extending to the charges from the junction 61 and helps maintain the bridle of the denotating cord from fouling on one another. The same length of primer cord extends between each row of charges to provide sequential detonation of row after row.

A redundant system is shown in FIG. 9, that is, two detonating cords are attached to primers for each explosive charge, providing backup systems to insure the denotation of each charge. In this case, a single or double cord 84 is attached to two pairs of cords 85 and 86 connected at a joint 87. This splits the detonating train travelling along the cord 84 into the cords 85 and 86. One cord lead 88 is attached to one of the cords of the pair 85 and this is split into cords 89 and 90 with the lead 90 attached to explosive 35*n*, and the lead 89 attached to explosive 35*m*. Further down the pair 85, a second lead 91 branches off and it in turn is branched into leads 92 and 93, with the cord 93 attached to the explosive 35*m* to provide two cords for that explosive, while the cord 92 is attached to the explosive 351. A still further distance down the cords 85, another lead 94 takes off and is connected with the explosive charge 351 to provide a pair of cords attached to that explosive system. The cord pair 85 then proceeds on and is attached to the explosive charge 35k. The cords extend in pairs from each explosive charge row to the next explosive charge row following the first one. This provides a redundant system for each set of charges. The length of the denotating cord from the junction 87 to each charge is the same length so that the detonating train proceeds uniformly to the individual charges in each row to provide an essentially simultaneously explosion of the first row of charges, and then sequentially to each row of charges. The pair of denotating cords 86, in like manner is branched to the charges on the other half of the raft, and since the system is the same as the othe side, detailed discussion is merey repetitious. A tension wire 97 attached to the raft and to the denotating cord 84 provides means for maintaining the cords essentially taut to prevent fouling and breaking the junctions. Floats may, also, be added to keep lines taut where some rotation of the charge assembly is expected.

In many instances, the rafts are to be positioned on a laterally sloping sea mound in which one side of the raft wil be in contact with the sea mound and the opposite side, if th raft is to remain level, will be extended above the slope of sea mound. For optimum results, the sinkable raft should be maintained essentially horizontal for the denotation of the charges. In effect, the jets will break rock deeper where the charges are in contact with the sea mound and to lesser extents as the standoff increases. To provide a leveling leg, as shown in FIG. 10, a sleeve 100 is mounted on a raft 101 near the side which requires supporting above the ocean bottom, e.g., the sleeves shown in FIG. 4. A leg 103 of sufficient length is telescoped in the sleeve 100 and pins 104*a* and 104*b* passed through a leg 103 secures the leg in position for providing a brace for the raised edge of the raft. A series of such legs may be required along the side of the raft which is to be placed above the ground. By using sonar profiles, the exact length of the legs to provide for a level raft may be readily determined. The legs may be arranged with a catch so that they may be lower after the raft is raised from the barge deck.

In some instances, a pivoted leg arrangement provides leveling means. FIGS. 11 and 12 show an arrangement of two legs 105 and 106 pivoted about pivot pin 102*a* mounted in a leg support 102*b*. A pin 107 holds the legs outwardly during transport of the raft and pin 108 holds the legs vertically. The pin 107 may be pulled manually or automatically. The length of legs is determined by the bottom profile. The longer of the two legs provides stability for the raft in lateral movement. In some instances, a single pivoted leg is all that is necessary.

The placement of the multiple charges is critical to economically produce the desired trench. The charges must be accurately placed, as shown in FIGS. 1–3, to achieve the maximum effect, particularly in overlay or superimposed position of shots. The sinkable rafts are conveyed to the point of use by a floating vessel. A crane is used to pick up the raft and swing it over the barge into the water.

A barge 110 having a crane 111 and haul rope 112 provides a bridle 113 for attachment to a sinkable raft 114 having the shaped charges mounted thereon, as explained above. A guide line 115 from the barge 110 to

the raft provides means for controlling the raft. A primer cord line from the barge to the raft provides means for detonating the charges. The charges on the raft are lowered, when in position, onto the bottom **117** on line **118** of the proposed trench center line.

The barge is anchored into position and is preferably held by four anchors or more depending on the currents, tides, wind etc. The barge may be accurately anchored by survey methods, including such means as a laser beam - target assembly, survey instruments from shore, sonar triangulation from fixed sonar generators, etc. The means of positioning is determined by the particular situation. Where line of sight is possible, survey instruments, laser beams, etc., may be used. Where line of sight is not possible, for example, the barge is too far from shore, the fixed sonar stations, celestial navigation systems, etc. may be used.

Once in position, the barge is used as a base for placing the raft. The raft is swung pendulum-like from the crane and lowered toward the ocean bottom. Currents, tides, etc., affect the raft once it is in the water, and it moves in the direction of the force. However, as the raft approaches closely to the bottom, the currents, tides, etc. reduce substantially to zero and the raft swings pendulum-like into a vertical position. The rope (or ropes) holding the raft is too thin to be affected and the line is essentially vertical. The line **112** is easily aligned where desired by using a laser generator **120** on shore **121** positioned along the center line of the trench. A receiver or reflector **123** on the barge may be used for positioning the barge or the rope. A laser beam is easily seen on the barge, and it is discernable as the rope cuts the beam. This provides very accurate placement of the raft. Also, the reflected laser beam may be used to position and measure the distance of the barge along the trench line. When accurately positioned, the raft is lowered to the bottom, the lines released, and the barge backed off for the explosion. The detonating cord may be extended from the backed off barge or a float with radio frequency detonation, etc.

The location of the barge and the lift line for rafts may be accurately determined by triangulation. Transets **130** and **131** on the shore **121**, sight on target **132** on the barge **110** for obtaining readings for the triangulation. Radio messages back and forth permit fast information for the positioning. The barge is easily positioned within a few inches by the use of power winches on the anchor cables, eg taking up one side and letting out the other side. In some cases surveying crews as well as radar may be necessary for proper positioning.

In one test of the system in a bay in which the tides averaged 30 feet, rafts of the 5 × 7 and 3 × 7 modular charge configurations were used to form a trench somewhat less than a quarter of a mile. The rafts weighed over 20,000 pounds. The rafts oscillated strongly in the high current (6–8 knots), but on nearing the bottom the rafts swung into near vertical positioning. In swells of 5–15 feet the rafts were positioned within a few inches of the target.

I claim:

1. A method of remotely breaking target material comprising forming an explosive charge array of a framework of a predetermined size; suspending said array in a generally horizontal position by at least one haul rope in a pendulum-type suspension; lowering said array to approximately the location of desired break of target material, and supporting said array in close proximity to and spaced from the surface of said target material; suspending said array in horizontal position with said haul rope in vertical position; aligning said vertical haul rope from remote points above the desired target material; placing said array on the surface of said target material by lowering said array to said target material; releasing said haul rope; and then detonating said explosive charge array.

2. A method according to claim **1** wherein a laser beam is extended from a remote point along a proposed ditch line, and said haul rope is aligned in said laser beam.

3. A method according to claim **1** wherein said target material is under water and said remote points are on shore.

4. A method according to claim **1** wherein said target material is under water and said remote points are fixed sonar generators in predetermined positions.

5. A method according to claim **1** wherein said array is a plurality of shaped charges mounted in a structure in a predetermined pattern.

6. A method of explosively forming in sloping mounds a ditch which is generally levelled in relation to the surface of such target material through which the ditch is cut, comprising forming an array of shaped explosive charges in a predetermined pattern and in a predetermined spaced arrangement; suspending said array in a generally horizontal position by at least one essentially vertical haul rope adjacent to and above the surface of the target material; placing said array of charges substantially level on said target material whereby charges in contact with the surface or said target material break said material deeper than charges spaced above said surface thereby forming a levelled ditch; and detonating said charges.

7. A method according to claim **6** wherein said array is formed in a modular structure which is essentially rigid, and leveling legs on said structure positions said structure on the target material with said structure substantially level.

8. A method according to claim **6** wherein said target material includes sloping mounds and gullies and said array is formed of articulate modules, and said articulated modules rest on the surface of said such mounds of target material so that such mounds are cut deeper than the gullies on said surface, forming a generally levelled ditch.

9. A method of determining optimum breakage of target material with shaped charges of predetermined characteristics, comprising arranging a series of at least about four similar shaped charges along a line in material of a character similar to said target material; each said charge in said series being spaced a different distance from its neighboring charges, with the second charge spaced from the first charge and subsequent charges being spaced from its immediate front neighbor a progressively greater distance; simultaneously detonating said charges, and then visually inspecting the resultant breakage of target material to determine optimum breakage.

10. A method according to claim **9** wherein said charges are spaced progressively at two, three and four charge diameters apart.

11. A method according to claim **9** wherein at least five charges are placed in a line and each being progressively further from its immediate front neighbor.

12. A method according to claim **9** wherein the distance apart of said charges ranges from 1.4 to twelve charge diameters apart.

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