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EXPLOSIVE CHARGE COUPLER

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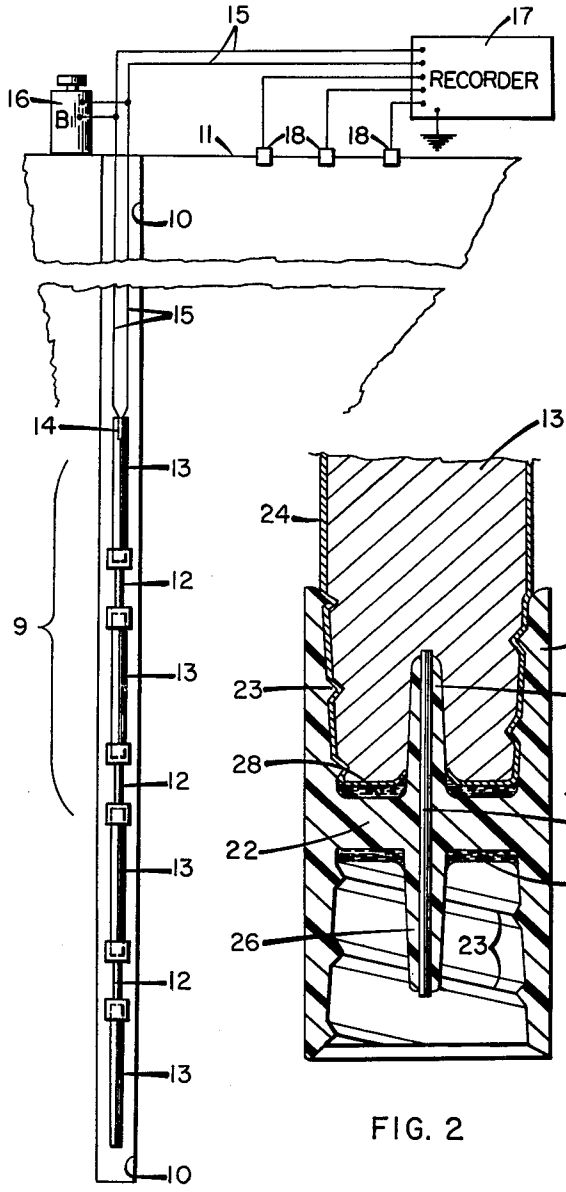

FIG. 1

FIG. 2

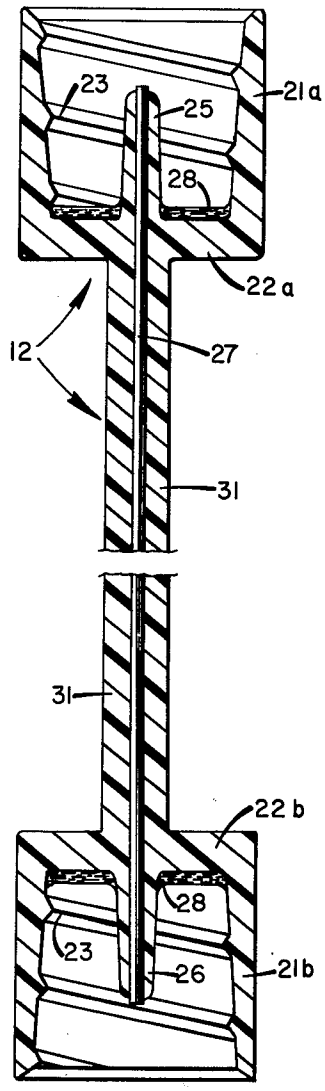

FIG. 3

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EXPLOSIVE CHARGE COUPLER

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This invention relates to seismic geophysical surveying and is directed to improvements in the explosives used for generating seismic waves. More specifically, the invention is directed to an elongated charge array which may have an end-to-end detonation velocity matching the seismic-wave transmission velocity of the medium in which the charge is to be detonated. The term "matching," as used herein, is to be understood as including both the usual sense of "equal" and also intentional deviations from equality, as when the detonation velocity of a charge is purposely made somewhat greater or less than the formation seismic-wave transmission velocity to vary the energy-directive properties of the charge.

For generating seismic waves in geophysical surveying, elongated seismic wave velocity-matching charges are finding increasing use due to their ability to reduce secondary or "ghost" reflections, ground roll, and other shot-generated noises in relation to the reflection energy. The two types of elongated charge construction in most general use are (1) a continuous length of low-velocity explosive, and (2) an array of spaced high-detonation-velocity cartridges connected by delay connectors. Both types of charge construction have certain advantages and disadvantages. While the continuous type is theoretically most free of undesirable noise generation, it is ordinarily commercially supplied only in certain discrete values of length and detonation velocity and in rather large total weights of explosive. The spaced-cartridge type is more easily adjustable as to charge size, total weight, effective velocity along the array, and the like, but the delay connectors generally commercially available have only certain discrete values of length and delay and are sometimes inaccurate in providing their nominal delay.

An additional way of constructing velocity-matching distributed or elongated charges is that described in my Patent No. 2,770,312, issued November 13, 1956. Alternate lengths of high- and low-detonation-velocity explosives are assembled into a continuous column having an over-all or average velocity of detonation propagation, for velocity-matching purposes, which lies somewhere between the high and low detonation velocities. The ratio of lengths of the two materials determines the exact average detonation velocity. In certain of its aspects, the present invention is an improvement on that of my prior patent.

It is a primary object of my invention to provide a novel and improved coupling mechanism to facilitate the assembly of individual explosive sticks into elongated charges in a safe manner. A further object of the invention is to insure the propagation of detonation of such an elongated charge across the gaps between individual cartridges. A still further object is to provide a device which functions not only as a cartridge-coupling member but also to adjust the effective detonation velocity of the resulting charge for matching purposes. A still further object is to provide a coupling unit which effectively seals the ends of the coupled explosive cartridges against the entrance of moisture. Still another object is to provide a coupling member made of such materials that it will leave no debris in a shot hole which may cause blocking and prevent subsequent entry of a second explosive charge. Other and further objects, uses, and advantages of the

present invention will become apparent as the description proceeds.

Briefly stated, the foregoing and other objects are accomplished by a coupling member particularly adapted for coupling a plurality of individual explosive cartridges together into an elongated charge for generating seismic waves in seismic exploration. The coupling member preferably comprises a pair of cup-shaped members facing away from each other and internally threaded so as to provide for firm connection to the end of an explosive stick by impressing threads in the paper jacket of the stick. As the end of the stick is forced into the threaded cup with a twisting motion, a projection extending axially along the cup from the center of its base, is driven into the end of the explosive stick directly into the explosive medium. Two such cup-shaped members coupled together form a unit to be inserted between the adjacent explosive sticks of an elongated charge array, thus make a firm joint between adjacent charges.

To insure the propagation of detonation from one charge to the other, a length of high-detonation-velocity detonating cord, such as the cord known commercially as Primacord, extends along the axis of the coupling unit from the tip of one projection in one stick to the tip of the other projection in the adjacent explosive stick. As still further insurance of the proper progation of detonation, the bottom of each cup-shaped member is preferably covered with a layer of viscous water-excluding material which is capable of forming a water-tight seal against the end of the explosive cartridge.

For velocity-matching purposes, it is preferred that the coupling of the present invention be manufactured in a variety of axial lengths of Primacord. These couplers may then be used in accordance with the teachings of my prior Patent No. 2,770,312 as the high-detonation-velocity explosive units. In the present invention, however, it will be apparent that the main explosive power of the elongated charge array is provided by the explosive cartridges, which are ordinarily composed of low-velocity explosive material, while the coupling elements serve as the velocity-adjusting elements.

This will be better understood by reference to the accompanying drawing showing, for illustrative purposes, typical embodiments of the invention and its use in seismic geophysical surveying. In the drawing,

FIGURE 1 is an earth cross-sectional view showing a shot hole and the manner of use of the present invention in seismic geophysical surveying; and

FIGURES 2 and 3 are detailed cross-sectional views of an embodiment of the invention and one modification thereof.

Referring now to these drawings in detail and particularly to FIGURE 1 thereof, a typical embodiment of the invention is shown in use in a shot hole for the generation of seismic waves in seismic geophysical surveying. Thus, an elongated explosive charge array **9** is lowered into a shot hole **10** extending from the earth's surface **11** to a substantial depth therebelow, at a location where it is desired to generate seismic waves. Charge **9** is made up of one or more coupling units **12** embodying the invention connecting together a plurality of explosive-charge stocks **13** into an elongated array. For the purpose of detonating the array **9**, an electric blasting cap **14** in the uppermost charge **13** is connected by insulated electrical leads **15** to a blaster **16** at the ground surface **11** and to a recorder **17** also at the ground surface, for recording the instant of initiation of the detonation. Also connected to the recorder **17** at the ground surface are a plurality of seismic-wave receivers **18** spaced at any desired distance from each other and from the upper end of

the shot hole **10** in a manner well known in the seismic surveying art.

Further, as is well known in this art, the charges **13** and coupling units **12** are so chosen and arranged with respect to lengths and explosive detonation velocities that the over-all or average rate of travel of the detonation wave from the cap **14** downwardly along the length of the charge array **9** is matched to the seismic-wave propagation velocity of the earth medium surrounding the shot hole **10**. In operation, therefore, seismic waves created in the surrounding earth medium by the detonation in sequence of the various charges **13**, after transmission, reflection, and refraction in the earth's subsurface are subsequently received by the detector units **18** and recorded by the recorder **17**.

As it is to the particular manner of construction of the coupling units **12** that the present invention is addressed, two different ways of constructing such units are shown in FIGURES 2 and 3 of the drawing. Thus, as appears in FIGURE 2, the coupling **12** comprises a generally cylindrical hollow shell **21** open at the ends and having a partition **22** extending across it at its center. The shell and partition thus form a pair of cups with their openings directed away from each other and their bases together. On the interior wall of the cylindrical shell **21** are inwardly projecting threads **23** preferably of slightly smaller diameter than a cartridge **13** to be coupled thereto, so that when the end of the cartridge is inserted into the shell **21** and twisted, the threads **23** deform the jacket **24** of paper or the like of the charge **13** and thereby grasp it firmly. Preferably, but not necessarily, the inner wall of shell **21** and the threads **23** taper slightly inwardly near the partition **22** as shown on the drawing, so that an increasingly tighter fit is made against the paper jacket **24** as the stick **13** is thrust toward the bottom of the cup-shaped member.

Extending along the axis of the shell **21**, in opposite directions from the center of the partition **22**, is each of a pair of rod-shaped projections **25** and **26**, preferably slightly tapered from the partition toward the tips, which may be somewhat pointed. Also extending along the axis of the shell **21** longitudinally through the projections **25** and **26** and through the center of partition **22**, is a length of high-detonation-velocity detonating cord **27**, such as the cord known commercially as Primacord. The ends of the cord **27** are exposed at the tips of the projections **25** and **26**, so that when a cartridge **13** is forced into the shell **21** and downwardly toward the partition **22**, the projection **25** penetrates the center of the cartridge **13** and places the tip of the cord **27** in intimate contact with the explosive material inside the cartridge.

In order more positively to insure the exclusion of water from the joint thus made between the Primacord **27** and the explosive medium in cartridge **13**, the bottom of the cup, i.e., the face of the partition **22**, is preferably covered with a viscous sealing medium **28** against which the base of the cartridge can be pressed to cause the medium **28** to flow and fill any void spaces through which water might enter and permeate the explosive material of the cartridge **13**. Any of a great number of substances may be used as the sealing medium **28**, one such being the viscous petroleum jelly product known commercially as Vaseline.

Besides thus forming a water-repellent, detonation-transmitting joint and a firm mechanical connection between adjacent sticks **13** of an elongated charge, it is within the scope of the present invention to utilize the principle of adjusting of the charge detonation velocity in accordance with my prior Patent No. 2,770,312 mentioned above. This may be done by providing the couplings **12** with different lengths of the Primacord segment **27**. Thus, as will be apparent from the following table wherein the stated velocities are in feet per second, a small number of different low-velocity dynamites and a small number of effective lengths of Primacord **27** in the coupler **12** can be combined to provide a large range of adjustment of

the velocity of detonation of the assembled charge in accordance with my prior patent. For the sake of this example, it is assumed that the velocity of detonation of the Primacord is 20,000 feet per second, that the minimum length of Primacord is one inch, and that the length of the cartridge **13** is one foot.

Table I

Velocity of Detonation of Dynamite	Effective Length of Coupler, Inches	Velocity of Detonation of Assembly
6,500	1	6,900
6,500	2	7,350
6,500	3	7,750
6,500	4	8,100
6,500	5	8,450
8,200	1	8,600
8,200	2	9,100
8,200	3	9,500
8,200	4	9,850
8,200	5	10,200
10,000	1	10,400
10,000	2	11,000
10,000	3	11,400
10,000	4	11,800
10,000	5	12,100

While this table shows that a wide variety of detonation velocities of the resultant elongated charge are possible in accordance with the principles of my present and prior inventions, in assembling such elongated charges it will normally be convenient to use charges of the low-velocity dynamite **13** substantially longer than the one-foot length assumed for the example. Similarly, it will sometimes be desirable that the maximum length of the Primacord be substantially greater than the five inches assumed for the example. When such greater lengths of Primacord **27** are desired, the coupler **12** may be formed as shown in FIGURE 3 wherein the individual cup-shaped members **21***a* and **21***b* have their respective bases **22***a* and **22***b* spaced apart but structurally connected by a stem or rod-like member **31**.

Preferably the entire coupler assembly of both FIGURES 2 and 3 is molded or cast of an inexpensive thermo-plastic or thermo-setting synthetic resin, with the Primacord **27** being either present during the molding process or subsequently inserted into an opening left for the purpose and cemented therein, as may be appropriate in the manufacturing process chosen. Such additional mechanical strength as is required by the plastic material forming the assembly can be imparted by the use of reinforcing glass fibers in a manner well known in the plastic-molding art. When the coupler **12** is thus formed of a sufficiently strong but relatively brittle material, the detonation of an elongated charge employing the couplers in a shot hole causes such shattering of the individual couplers that no large pieces are left in the hole **10** to cause blocking of the hole and prevent subsequent entry of another explosive charge.

An additional feature of the present invention is the safety it possesses for transportation and field handling. As the cord **27**, in spite of its reliable propagation of a detonation wave at high speed, has a relatively small explosive power, it can be and is routinely shipped and handled in commerce without the extra precautions necessary and legally required for explosives. In field use, a charge array **9** is normally assembled at the mouth of a shot hole, the assembled portion of the array being lowered into the hole each time a new stick **13** and coupler **12** is added, until the array is complete. The final act of course is to insert the cap **14**, whereupon the charge is immediately lowered to shooting depth. This procedure safeguards the personnel in two ways: a minimum amount of explosive is exposed during assembly of the charge; and in the event of a premature detonation, damage and injury would be minimized by having as much as possible of the charge below the ground surface.

While my invention has thus been described with reference to the foregoing specific details and embodiments, it is to be understood that the scope of the invention should not be considered as limited to the particular details set forth. The scope of the invention is properly to be ascertained by reference to the accompanying claims.

I claim:

1. An elongated explosive charge array for use with means for receiving and recording, after travel through the earth's subsurface, seismic waves created by detonating said array from one end thereof, said array comprising a plurality of cylindrical low-detonation-velocity explosive charges connected together by detonation-transmitting coupling means, each of said coupling means comprising a pair of co-axial cup-shaped members with their bases toward and their openings facing away from each other, each of said members surrounding the end of one of said cylindrical charges coupled thereby, threads on the inner cylindrical wall of each of said members of a diameter slightly less than the diameter of said charges and projecting inwardly so as to frictionally engage the outer cylindrical surface of the charge coupled thereto, a pair of projections each extending along the cup cylindrical axis into one of said members from the center of the base thereof, and a high-detonation-velocity detonating cord extending along said axis of said members from the end of one of said projections to the end of the other of said projections, the length of said cord being less than the length of said charge so as to provide an effective detonation velocity between the ends of said array substantially matching the seismic-wave velocity of the earth medium wherein said array is to be detonated.

2. An explosive charge array for use with means for receiving and recording, after travel through the earth's subsurface, seismic waves created by detonating said array from one end thereof, said array comprising a plurality of cylindrical low-detonation-velocity charges connected together by detonation-transmitting coupling means, each of said coupling means comprising a hollow cylindrical member, a transverse partition extending across said member at its center, whereby said member and partition form a pair of oppositely facing cups having a common base, threads on the inner cylindrical wall of said member of a diameter slightly less than the diameter of said charges and projecting inwardly to frictionally engage the outer cylindrical surface of the charge coupled thereto, a pair of pointed, rod-shaped projections each extending perpendicularly from the center of said partition into one of said cups, and a high-detonation-velocity detonating cord extending along the axis of said member with its ends exposed at the tips of said projections, the length of said cord being less than the length of said charge so as to provide an effective detonation velocity between the ends of said array substantially matching the seismic-wave velocity of the earth medium wherein said array is to be detonated.

3. An explosive charge array for use with means for receiving and recording, after travel through the earth's subsurface, seismic waves created by detonating said array from one end thereof, said array comprising a plurality of cylindrical low-detonation-velocity explosive charges connected together by detonation-transmitting coupling means, each of said coupling means comprising a pair of cup-shaped members with their openings facing away from and their bases facing toward each other, a spacing member connected between the centers of said bases, threads on the inner wall of each of said members

of a diameter slightly less than the diameter of said charges and projecting inwardly so as to frictionally engage the outer cylindrical surface of the charge coupled thereto, a pair of pointed, rod-shaped projections each extending into one of said cup-shaped members perpendicularly from the center of the base thereof, and a high-detonation-velocity detonating cord extending through the centers of said spacing member and of said projections with its ends exposed at the tips of said projections, the length of said cord being less than the length of said charge so as to provide an effective detonation velocity between the ends of said array substantially matching the seismic-wave velocity of the earth medium wherein said array is to be detonated.

4. A detonation-transmitting coupler for coupling low-detonation-velocity cylindrical charges, said coupler comprising a pair of co-axial cup-shaped members facing away from each other, inwardly projecting threads on the inner wall of each of said members adapted to frictionally engage the outer cylindrical surface of one of said charges, a projection extending from the base of each of said members into said each member along its axis so as to project into the interior of a charge engaged by said threads, and a high-detonation-velocity detonating cord extending along said axis of said members with an end exposed at the tip of each said projection, the length of said cord being related to the lengths of said charges to be coupled and to said high and low detonation velocities so that the resultant detonation velocity of an array of said charges connected by said couplers substantially matches the seismic-wave propagation velocity of a medium in which said array is to be detonated.

5. A detonation-transmitting coupler for coupling cylindrical sticks of low-detonation-velocity explosive material, said coupler comprising a hollow cylindrical member, a transverse partition extending across said member whereby said member and partition form a pair of oppositely facing cups having a common base, internally projecting threads on the inner cylindrical wall of said member of a diameter slightly less than the diameter of said sticks and adapted to frictionally engage an outer cylindrical surface of said sticks, a pair of pointed, rod-shaped projections each extending perpendicularly from the center of said partition into one of said cups so as to project into the interior of a stick engaged by said threads, and a high-detonation-velocity detonating cord extending along the axis of said coupler through said projections and said partition between the tips of said projections, the length of said cord being related to the lengths of said sticks to be coupled and to said high and low detonation velocities so that the resultant detonation velocity of an array of said sticks connected by said couplers substantially matches the seismic-wave propagation velocity of a medium in which said sticks are to be detonated.

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