Dec. 10, 1968 A. A. VENGHIATTIS 3,415,321

SHAPED CHARGE PERFORATING APPARATUS AND METHOD

Filed Sept. 9, 1966 2 Sheets-Sheet 1

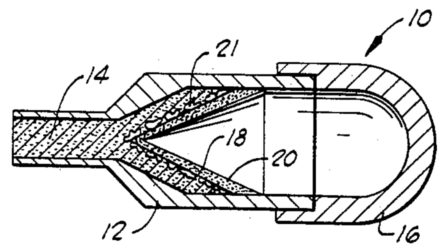

Fig-1

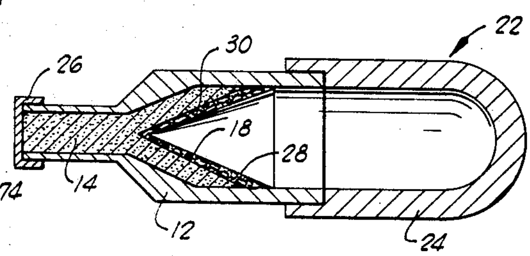

Fig-2

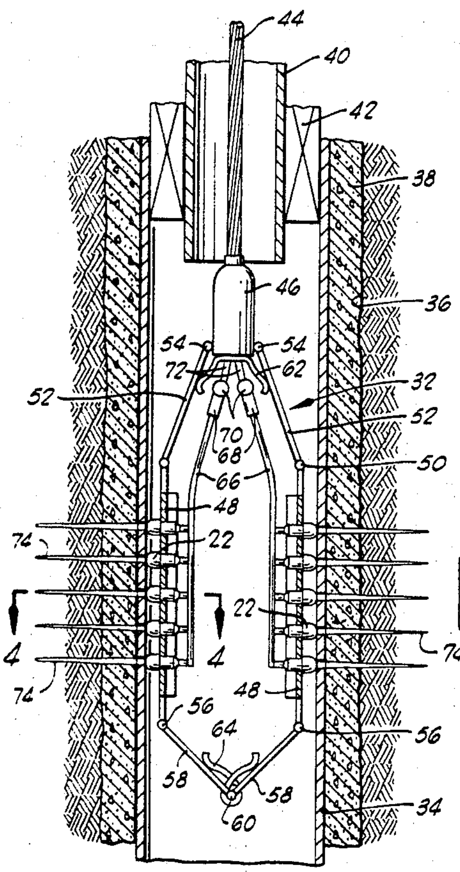

Fig-3

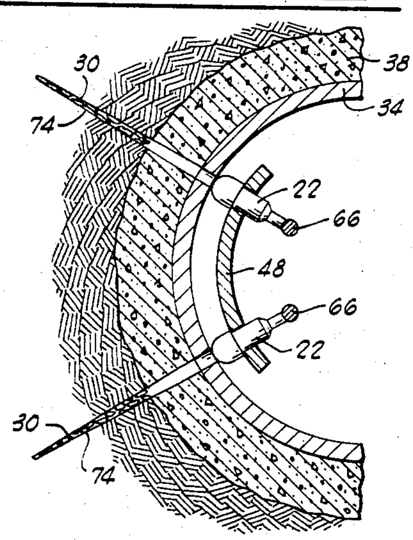

Fig-4

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SHAPED CHARGE PERFORATING APPARATUS AND METHOD

Filed Sept. 9, 1966 2 Sheets-Sheet 2

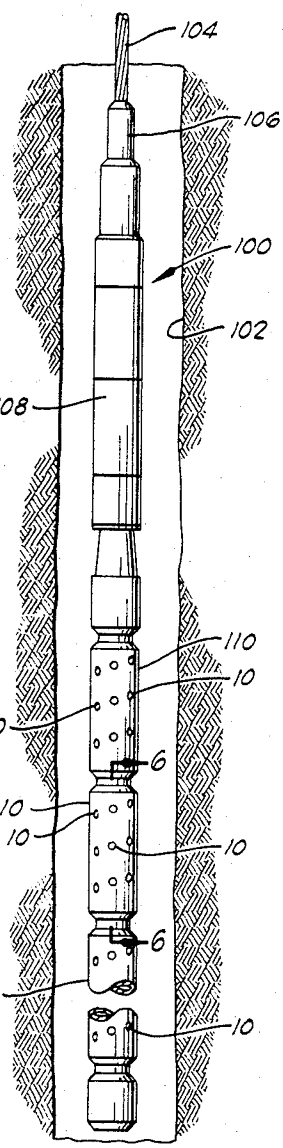

FIG-5

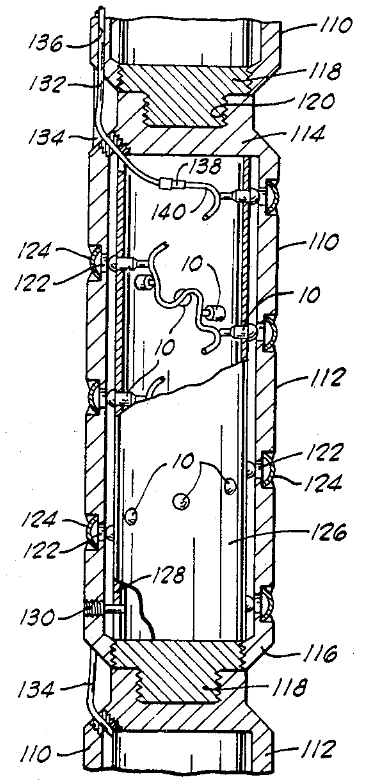

FIG-6

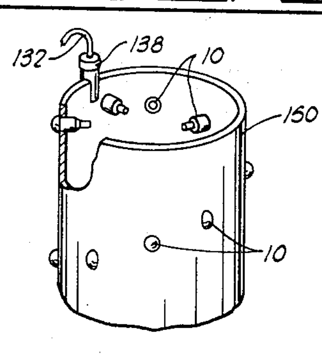

FIG-7

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United States Patent Office 3,415,321
Patented Dec. 10, 1968

3,415,321

SHAPED CHARGE PERFORATING APPARATUS AND METHOD

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Filed Sept. 9, 1966, Ser. No. 578,216
11 Claims. (Cl. 166—35)

ABSTRACT OF THE DISCLOSURE

Apparatus for perforating oil and gas wells and the like and methods for completing such wells in an unconsolidated formation. The apparatus includes one or more shaped charges having inert particles located therein arranged to be carried, upon detonation of the charge, into the perforation formed by the charge and also including a carrier for positioning the shaped charge in the well. The method includes the steps of positioning the shaped charge and carrier in the well adjacent the unconsolidated formation to be perforated and detonating the charge to simultaneously form the perforation and place the inert particles in the perforation to form a permeable bridge therein.

This invention relates generally to improved methods and apparatus useful in perforating oil and gas wells and the like. More particularly, but not by way of limitation, this invention relates to improved perforating apparatus and methods for completing a well in an unconsolidated formation.

Generally, in the completion of oil and gas wells and the like, an elongated metal casing is positioned in the well bore. Due to the irregularity of the well bore and due to the difference in diameter between the well bore and the metal casing, a cementitious material is usually pumped into the annular space. The cementitious material serves to permanently fix the metal casing in the well bore and to prevent migration of well fluids through the annular space. It is obvious that the metal casing and the cementitious material disposed adjacent a productive formation will prevent the flow of fluids from the formation into the interior of the casing. Therefore, the practice has been to perforate the casing, cementitious material, and the formation by the use of either shaped charge or bullet perforators. The perforators are lowered into the casing to a position adjacent the productive formation and then fired from the surface through an appropriate electrical circuit.

The aforesaid procedure has been very successful, but a great deal of difficulty has been encountered when the productive formation consists of an unconsolidaated sand or similar substance. The particle size of unconsolidated sands will vary between $\frac{2}{1000}$ of an inch and $\frac{20}{1000}$ of an inch while the diameter of the perforation made with the usual perforators will be somewhere between ¼ and ¾ of an inch. As is obvious from the foregoing, even the largest sand particles are very small as compared to the smallest diameter of perforation made by conventional perforating apparatus. Thus, as well fluids are produced through the perforation into the interior of the casing, sand particles will, more than likely, be produced therewith. If a sufficient quantity of sand is produced into the casing, the sand may accumulate therein and completely block the production of well fluids or if pumping or valve apparatus is disposed in the well, the sand may have a serious erosive effect thereon.

One attempt made to solve the foregoing problem utilizes an array of very small bullet perforators fired simultaneously in a prearranged pattern. Although the perforations made are too large in diameter to be useful in preventing the migration of sand into the casing, the bullets will, when fired into friable cementitious material, shatter the cementitious material forming a permeable bridge in the perforations to inhibit the migration of the unconsolidated sand.

Another attempted solution involves the use of shaped charges constructed to provide small diameter perforations. However, the diameter of the perforations are still sufficiently large so that they do not effectively inhibit the flow of sand into the casing. Unlike the bullet perforators, the shaped charges form a clean hole or perforation and do not shatter the cementitious material even when the material is friable. Therefore, small perforations formed by shaped charges have not been effective to inhibit the flow of sand into the casing.

Very often in the completion of wells, a relatively small diameter production tubing will be run within the casing. Packers, of a type well known in the well tool art, or other similar apparatus, are usually utilized to hold the tubing in the casing and to prevent the flow of fluid through the annular space between the tubing and casing. In such instances, the perforating apparatus must be run through the tubing prior to reaching the zone to be perforated. Usually, the tubing terminates above the producing formation so that the perforating apparatus is disposed within the relatively large diameter of the casing when the perforator is fired.

To make the most efficient use of perforators, it is highly desirable to be able to control the distance from the shaped charge or bullet to the casing, that is, to control the standoff. Manifestly, perforating apparatus small enough to be run through the tubing will have a considerable standoff when located in the casing and will not provide the optimum conditions for firing the bullets or shaped charges to perform the perforating operation in the most efficient manner.

Summary of the invention

Generally, this invention provides improved perforating apparatus including a carrier arranged to be moved through the well bore; a plurality of shaped charges carried by the carrier, each charge being oriented in a direction whereby the detonation thereof forms an explosive jet that perforates the formation, each charge including a plurality of inert particles arranged to be carried into the perforations forming a permeable bridge therein; and ignition means for detonating the charges.

In another aspect, this invention contemplates the construction of a shaped charge that includes a plurality of inert particles that are carried into the perforation and that are sized and shaped to form a permeable bridge therein.

Also, this invention provides a collapsible carrier whereby shaped charges may be lowered through relatively small diameter tubing and positioned in relatively larger diameter casing for efficiently performing the perforating operation. Additionally, this invention contemplates the construction of another carrier for the shaped charges that includes a member constructed from sheet explosive that holds an array of charges and provides for their simultaneous detonation.

One object of the invention is to provide an improved method of completing a well in an unconsolidated formation wherein permeable bridges are formed in the perforations to inhibit the migration of sand therethrough.

Another object of the invention is to provide an improved perforating apparatus wherein a selected array of shaped charges may be simultaneously detonated from a plurality of such arrays.

Still another object of the invention is to provide an improved perforating apparatus arranged to form relatively small diameter perforations and to form permeable bridges therein.

The foregoing and additional objects and advantages of the invention will become more apparent as the following detailed description is read in conjunction with the accompanying drawings wherein like reference characters denote like parts in all views and wherein:

FIGURE 1 is a cross sectional view of a shaped charge constructed in accordance with the invention;

FIGURE 2 is a cross sectional view similar to FIGURE 1, but illustrating another embodiment of shaped charge also constructed in accordance with the invention;

FIGURE 3 is a vertical cross sectional view illustrating perforating apparatus constructed in accordance with the invention disposed in a cased well bore;

FIGURE 4 is a cross sectional view taken substantially along the line 4—4 of FIGURE 3;

FIGURE 5 is an elevational view of another embodiment of perforating apparatus also constructed in accordance with the invention and disposed in a well bore;

FIGURE 6 is an enlarged cross sectional view of a portion of the apparatus of FIGURE 5 taken substantially along the line 6—6 of FIGURE 5; and

FIGURE 7 is a fragmentary pictorial view illustrating a modification of the member for holding the shaped charges utilized in the perforating apparatus of FIGURE 5.

Shaped charge

Referring to the drawing and to FIGURE 1 in particular, shown therein and generally designated by the reference character **10** is a shaped charge constructed in accordance with the invention. The shaped charge **10** includes a hollow body **12**, an explosive material **14** partly filling the interior of the hollow body **12**, and a cap **16** closing one end of the hollow body **12**.

The explosive material **14** has a conical cavity **18** in the end thereof adjacent the cap **16**. A liner **20**, which is also of conical configuration, is located in the hollow body **12** in juxtaposition with the surface of the explosive material **14** forming the cavity **18**. The liner **20** may be constructed from relatively thin sheet metal, but is preferably constructed from a granular metal as disclosed in U.S. Patent No. 3,255,659 issued on June 14, 1966 to Alexis A. Venghiattis.

A plurality of particles **21** are located between the surface of the explosive material **14** and the liner **20**. The particles **21** are preferably formed from an inert material and preferably have at least one dimension that is not less than one-half the diameter of the perforation that is formed upon detonation of the shaped charge **10**.

FIGURE 2 illustrates another embodiment of shaped charge generally designated by the reference character **22**. The shaped charge **22** includes the previously described hollow body **12** and explosive material **14**. One end of the hollow body **12** is closed by a cap **24**, which is constructed similarly to the cap **16** but, as is apparent from a comparison of FIGURES 1 and 2, is more elongated to provide additional standoff for the shaped charge **22** for reasons that will be explained more fully hereinafter.

The opposite end of the hollow body **12** is closed by a sealing cover **26**. The sealing cover **26** is optional, but its use is preferred when the shaped charge **22** is used in open or capsule type carriers wherein the explosive material **14** would otherwise be exposed to well fluids.

As illustrated in FIGURE 2, the shaped charge **22** also includes the conically shaped cavity **18** that is formed in the explosive material **14** and a conical liner **28** disposed in juxtaposition therewith. A plurality of particles **30** are disposed in the liner **28**. As previously mentioned with respect to the liner **20**, the liner **28** is preferably formed as taught in U.S. Patent No. 3,255,659.

As will be understood by those skilled in the art of shaped charges, the conical cavity **18** in the charges **10** and **22** produces the so-called Munroe effect upon detonation that results in a high energy jet of sufficient energy magnitude to form perforations. Preferably, the shaped charges **10** and **22** are of a size that will result in the formation of a perforation having an average diameter of .050 inch. The particles **21** and **30** in the shaped charges **10** and **22**, respectively, are arranged to be carried into the perforation formed by the charges and are of such size and shape that they will form a permeable bridge therein for reasons that will be discussed.

Perforating apparatus of FIGURE 3

FIGURE 3 illustrates perforating apparatus generally designated by the reference character **32** and disposed in a casing **34**. As shown therein, the casing **34** is located in a well bore **36** and is retained therein by cementitious material **38** disposed in the annular space between the wall of the well bore **36** and the exterior of the casing **34**.

The lower end of a relatively small diameter tubing **40** is illustrated as being disposed within the casing **34**. The tubing **40** is retained in a central position in the casing **34** by a packer **42** that also serves to prevent the flow of fluid through the annular space between the tubing **40** and the casing **34**.

The perforating apparatus **32** is suspended in the casing **34** on a wire line or cable **44** that extends upwardly through the tubing **40** to the surface (not shown) of the well bore **36**. The cable **44** has sufficient mechanical strength to support the perforating apparatus **32** and also contains the necessary electrical conductors (not shown). The lower end of the cable **44** is connected to an adapter **46** that forms the upper end of the perforating apparatus **32**.

The perforating apparatus **32** also includes a pair of shaped charge holding members **48** that are disposed in generally parallel spaced relationship and extend substantially parallel to the longitudinal axis of the casing **34**. The upper end of each of the shaped charge holding members **48** is connected by a hinge **50** with a linkage member **52**. The opposite end of each of the linkage members **52** is connected by a hinge **54** with the adapter **46**.

The lower end of each of the shaped charge holding members **48** is connected by a hinge **56** with a linkage member **58**. The lower ends of the linkage members **58** are pivotally joined by a hinge **60**. The hinged connecting structure joining the shaped charge holding members **48** provides an articulated linkage wherein the shaped charge holding members **48** can move relatively together and relatively apart in substantially parallel relationship.

A spring **62** is illustrated as being connected with the adapter **46** and having its free end portions in engagement with the linkage members **52**. The spring **62** constantly biases the linkage members **52** and the holding members **48** relatively apart.

Similarly, a spring **64** encircles the hinge **60** and has its free end portions in engagement with the linkages **58**. The spring **64** serves to bias the linkages **58** and the holding members **48** relatively apart thus maintaining the shaped charge holding members **48** in substantially spaced, parallel relationship.

As illustrated in FIGURE 3 and also in FIGURE 4, the shaped charge holding members **48** each includes a plurality of the shaped charges **22**. Manifestly, the shaped charge **10** could be utilized in lieu of shaped charge **22** as could any of the well-known constructions of shaped charge. Preferably, the shaped charges used include a sealing cover, such as the cover **26** shown in FIGURE 2, so that the explosive material **14** will not come into contact with fluids in the well bore **36**.

The shaped charges **22** are each connected with some means for detonating the shaped charges. For example, FIGURES 3 and 4 illustrate a Primacord **66** connecting each of the charges **22** with a respective one of a pair of boosters **68** and detonators **70**. The detonators **70** are connected with wires **72** that extend upwardly through the adapter **46** and the cable **44** to a source of electrical energy (not shown) located on the surface (not shown) adjacent the upper end of the well bore **36**. As is well known, electric current passing through the conductors **72** ignites the detonators **70**, boosters **68** and the interconnected Primacord **66**. Manifestly, the ignition of the Primacord **66** detonates the shaped charges **22** essentially simultaneously due to the high explosive nature of the Primacord **66**.

Operation of the embodiment of FIGURE 3

To utilize the perforating apparatus **32**, the shaped charges **22** are disposed in the shaped charge holding members **48** in accordance with the desired perforation pattern and number of perforations to be formed. The adapter **46** is connected with the cable **44** and the perforating apparatus **32** is then extended into the tubing **40**. As will be apparent from viewing FIGURE 3, the holding members **48** are moved relatively together, compressing the springs **62** and **64** to permit the insertion of the apparatus **32** into the relatively small diameter tubing **40**.

The apparatus **32** is then lowered through the tubing **40**, passing through the open end thereof into the relatively larger diameter casing **34**. When the apparatus **32** is disposed adjacent the formation to be perforated, its downward movement is arrested and the apparatus **32** is suspended on the cable **44** in the well bore **36**. The conductors **72** are then energized igniting the detonators **70**, boosters **68** and the Primacord **66**. When the Primacord **66** detonates, the shaped charges **22** are simultaneously detonated to form a plurality of perforations **74** as illustrated in FIGURES 3 and 4.

As the shaped charges **22** detonate, the perforations **74** are formed through the casing **34**, the cementitious material **38**, and extend into the formation surrounding the well bore **36**. Simultaneously, the inert particles **30** are carried into the perforations **74** as illustrated in FIGURE 4, forming permeable bridges therein to prevent or at least inhibit the migration of unconsolidated materials from the formation through the perforations **74** into the interior of the casing **34**.

Generally, detonation of the shaped charges **22** disintegrates a large portion of the shaped charge holding members **48** dropping the linkages **58** into the lower portion of the well bore **36**. For this reason, the linkage members **52** and **58** and the shaped charge holding members **48** are preferably constructed from a material that is easily drillable, such as aluminum, or one of the plastics. After the detonation of the shaped charges **22**, the portion of the apparatus **32** remaining intact can be retrieved from the well bore **36** by withdrawing the cable **44** therefrom as is well known in the art.

It should be evident from the foregoing that utilizing the relatively small shaped charges **22** permits their close spacing in the holding members **48** whereby the formation is perforated by a large number of relatively small perforations **74**, that is, the formation is saturated with small diameter perforations **74** whereby a flow area of relatively large size is obtained. It will also be noted, that the shaped charges **22** are properly positioned relative to the casing **34**, that is, they will have the desired standoff to perform the perforating operation in the most efficient manner due to the preselected length of the cap **24** (see FIGURE 2). Thus, while the shaped charges **22** form relatively clean perforations **74**, the perforating apparatus **32** is effective in unconsolidated formations to form the desired perforations while inhibiting the flow of sand from such formations due to the permeable bridge formed by the inert particles **30**.

Perforating apparatus of FIGURE 5

FIGURE 5 illustrates another embodiment of perforating apparatus generally designated by the reference character **100**. As shown therein, the perforating apparatus **100** is suspended in a well bore **102** on a cable **104**. The cable **104** includes members of sufficient structural strength to support the perforating apparatus **100** as well

as including the necessary electrical conductors for detonating the perforating apparatus **100** as will be described.

The perforating apparatus **100** also includes an adapter **106** that is connected with the cable **104** and a selective ignition control device **108** that is constructed as described in U.S. Patent No. 3,221,655, issued Dec. 7, 1965 to Alexis A. Venghiattis. Connected with the lower end of the selective ignition control means **108** is a plurality of identically constructed shaped charge carriers **110**.

As is evident from viewing FIGURE 5, the shaped charge carriers **110** are arranged in end-to-end relationship. The number of shaped charge carriers **110** utilized depends upon the number and concentration of perforations desired. Manifestly, and although not illustrated, spacers can be utilized between the shaped charge carriers **110** to provide any desired spacing.

FIGURE 6 illustrates in more detail the construction of the shaped charge carriers **110**. As shown therein, each of the shaped charge carriers **110** includes a tubular housing **112** having a closed upper end **114** and a threaded lower end **116**. A plug **118** is threaded into the lower end **116** of the housing **112** thereby closing the lower end **116** thereof. The upper end **114** of the tubular housing **112** is partially threaded as shown at **120** to receive the plug **118** forming a portion of the adjacent shaped charge carrier **110**.

The tubular housing **112** is provided with a plurality of apertures **122** that extend through the wall thereof. Closure members **124** are pressed into the apertures **122** to close the apertures **122** against the entrance of well fluids. The tubular housing **112** is constructed to withstand the pressures encountered within the well bore **102**.

A cylindrical shaped charge holding member **126** is disposed substantially coaxially within the tubular housing **112** with its upper end abutting the end **114** of the housing **112** and its lower end abutting the plug **118**. The cylindrical holding member **126** is provided with a slot **128** for receiving one end of a partially threaded pin **130** to align the charge holding member **126** in the housing **112** for reasons that will be described. The partially threaded pin **130** extends through the wall of the tubular housing **112** and into the slot **128** as shown.

A plurality of shaped charges **10** are located in the holding member **126** and each is aligned with a respective one of the apertures **122**. The alignment of the shaped charges **10** with the apertures **122** is assured by the relationship of the slot **128** and the partially threaded pin **130**.

As illustrated in the upper portion of FIGURE 6, electrical conductors **132** and **134** extend through an opening **136** formed in the side wall of the tubular housing **112**. The opening **136** is provided to protect the electrical conductors from damage as the perforating tool **100** passes through the well bore **102**.

The conductor **132** extends through the wall of the tubular housing **112** and is connected with a detonator and booster **138** which is in turn connected with a Primacord **140**. The Primacord **140** is connected with each of the shaped charges **10** within a single carrier **110** whereby all the shaped charges **10** contained therein will be simultaneously detonated.

As shown in the lower portion of FIGURE 6, the conductor **134** extends through the tubular housing **112** of the subjacent carrier **110** and, although not shown, will be connected to the shaped charges therein as previously described. It will of course be understood that the electrical conductors **132** and **134** are electrically interconnected with the electrical conductors (not shown) contained in the cable **104** and extend to the surface (not shown) adjacent the well bore **102** wherein they will be connected to a source of electrical potential (not shown).

Operation of the perforating apparatus of FIGURE 5

The perforating apparatus **100** is lowered into the well bore **102** on the cable **104** until it is adjacent the formation or zone to be perforated. When the zone to be perforated is reached, the perforating apparatus **100** is suspended by the cable **104** and the downward movement thereof terminated.

One of the conductors, conductor **132** for example, is energized through the selective ignition control **108** as described in the previously mentioned Venghiattis Patent No. 3,221,655 to detonate the shaped charges **10** contained in the interconnected shaped charge carrier **110**. It should be emphasized that only the shaped charges **10** in the selected carrier **110** will be detonated.

When the shaped charges **10** detonate, the explosive jet formed thereby perforates the cover **124** and extends into the formation forming the number and arrangement of perforations therein as predetermined by the number and distribution of charges in the carrier **110**. Manifestly, the perforating apparatus **100** may also be used in cased and cemented wells as previously described in connection with the perforating apparatus **32**.

After the shaped charges **10** have been detonated in a selected one of the carriers **110**, the remaining carriers **110** may be actuated to detonate the shaped charges **10** contained therein or the perforating apparatus **100** may be raised or lowered to a different formation prior to the detonation of the shaped charges in each of the carriers **110**.

As will be understood from the foregoing detailed description of the shaped charges **10**, they are very small and are capable of forming relatively small performations whereby a large number of the shaped charges **10** may be contained within a single carrier **110**. Thus, the formation adjacent the shaped charge carrier **110** will be saturated with relatively small performations formed by the shaped charges **10**.

FIGURE 7 illustrates a modification of the shaped charge apparatus **100**. More specifically, FIGURE 7 illustrates a shaped charge holding member, designated by the reference character **150**, that can be utilized in lieu of the shaped charge holding member **126**.

Although only a portion of the cylindrical charge holding member **150** is illustrated it will be understood that it will extend the full length of the tubular housing **112** as did the holding member **120**. The shaped charge holding member **150** is constructed from a sheet explosive and thereby eliminates the necessity for the Primacord **140** illustrated in FIGURE 6.

It will be noted in FIGURE 7 that the conductor **132** and the detonator and booster **138** are connected directly to the holding member **150**. The shaped charges **10** are planted directly in the holding member **150** and are arranged to be simultaneously detonated thereby upon detonation of the detonator and booster **138**.

Manifestly, the operation of the perforating apparatus with the shaped charge holding member **150** therein will be substantially the same as with the shaped charge holding member **126** therein. The charge holding member **150** has the advantage of eliminating the necessity for interconnecting the shaped charges **10** with the Primacord **140**. Thus, there is less chance of detonation failure when using the holding member **150**.

It will also be understood that the performing apparatus **100** utilizing either the shaped charge holding member **126** or the shaped charge holding member **150** can be effectively utilized to perforate unconsolidated sands as previously described in connection with the perforating apparatus **32**. The shaped charges **10** also include the inert particles **21** (see FIGURE 1) so that the perforations formed thereby will also include a permeable bridge to inhibit the flow of sand through the perforations.

It will be understood that the embodiments described in detail hereinbefore are presented by way of example only and many changes and modifications can be made thereto without departing from the spirit of the invention or from the scope of the annexed claims.

What I claim is:

1. A shaped charge for perforating an unconsolidated formation surrounding a well bore, said charge comprising:
   - a tubular body member;
   - an explosive material located in said tubular body member, said explosive material having a concave, generally conical end surface;
   - a generally conical liner disposed in said body member in juxtaposition with the conical end surface on said explosive material; and
   - a plurality of inert particles located in said body member and arranged to be entrained in the jet formed by the detonation of said charge and carried into the perforation forming a permeable bridge therein.

2. The shaped charge of claim **1** wherein said inert particles have at least one dimension at least one-half the average diameter of the perforation formed by said charge, whereby said particles form a permeable bridge therein to inhibit the flow of sand into the well bore.

3. The shaped charge of claim **2** wherein said particles are disposed between said liner and explosive material.

4. The shaped charge of claim **2** wherein said particles are embedded in said liner.

5. Perforating apparatus for use in completing a well in an unconsolidated formation comprising:
   - carrier means arranged to be moved through the well bore;
   - a plurality of shaped charges carried by said carrier means and oriented in a direction whereby the explosive jet from each said charge perforates the formation surrounding the well bore, each said charge including a plurality of inert particles arranged to be carried into the perforations forming a permeable bridge therein; and
   - ignition means for detonating said shaped charges.

6. The perforation apparatus of claim **5** wherein said carrier means includes:
   - a pair of shaped charge holding members disposed in generally parallel relationship;
   - first linkage means pivotally connected with one end of each shaped charge holding member and including resilient means biasing said charge holding members relatively apart; and
   - second linkage means, pivotally connected with the other end of each shaped charge holding member and including resilient means biasing said charge holding members relatively apart, whereby said charge holding members move relatively together to pass through a relatively small diameter portion of the well bore and are moved apart when in relatively larger diameter portions of the well bore.

7. The perforating apparatus of claim **5** wherein said carrier means includes:
   - a tubular housing having upper and lower closed ends and having a plurality of apertures extending traversely through the wall of said housing;
   - closure means closing each of said apertures; and
   - generally cylindrical shaped charge holding means located substantially coaxially in said housing and holding each said shaped charge in alignment with a respective one of said apertures.

8. The perforating apparatus of claim **7** wherein:
   - said holding means is constructed from a sheet explosive; and
   - said ignition means extends into said housing and is connected with said sheet explosive.

9. The perforating apparatus of claim **5** wherein said carrier means includes:
   - a plurality of tubular housings, each said housing

having upper and lower closed ends and a plurality of apertures extending through the wall thereof, said housings being connected in end-to-end relationship,
closure means closing each of said apertures, and
a generally cylindrical shaped charge holding member substantially coaxially located in each said housing; and,
said ignition means includes:
selective ignition control means attached to said carrier means, and
detonation means located in each said housing operably connected with said shaped charges and with said control means, whereby the shaped charges in a selected housing are simultaneously detonated.

10. A method of completing a well that extends through an unconsolidated formation that includes the steps of:
positioning a shaped charge having inert particles therein adjacent the formation;
perforating the unconsolidated formation by detonating said charge; and
simultaneously forming a permeable bridge in said perforation by depositing a plurality of said inert particles in said perforation to inhibit migration of portions of the unconsolidated formation into the well.

11. A method of completing a well extending through an unconsolidated formation comprising the steps of:

positioning a casing in the well adjacent said formation;
depositing a cementitious material in the annular space between said formation and said casing;
positioning an array of shaped charges having inert particles therein in the casing adjacent said unconsolidated formation;
perforating said casing, cementitious material, and formation by detonating said shaped charges; and,
simultaneously forming a permeable bridge in said perforations by depositing a plurality of said inert particles in said perforations to inhibit the migration of portions of the unconsolidated formation into the well.

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DAVID H. BROWN, *Primary Examiner.*

U.S. Cl. X.R.

175—4.6; 102—24