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APPARATUS FOR SEALING CHAMBERS IN A PERFORATING TOOL

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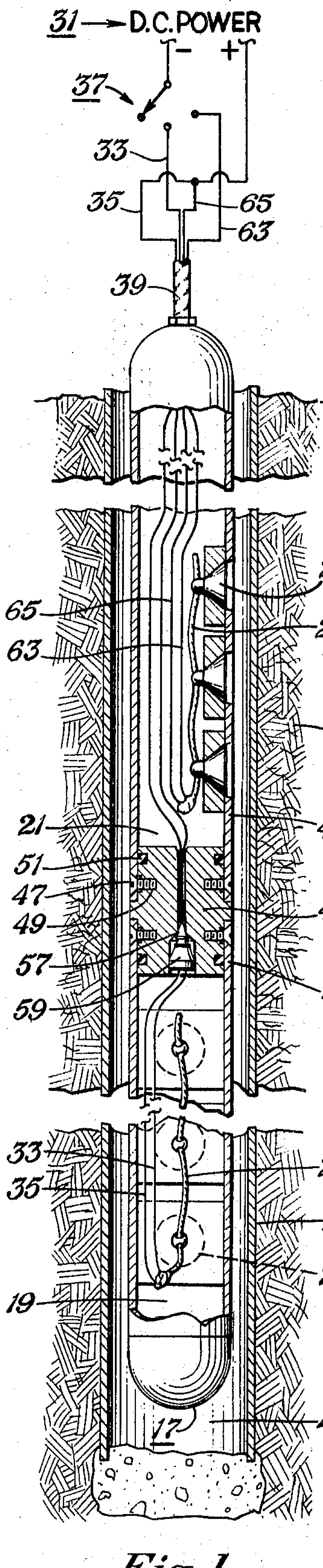

Fig. 1

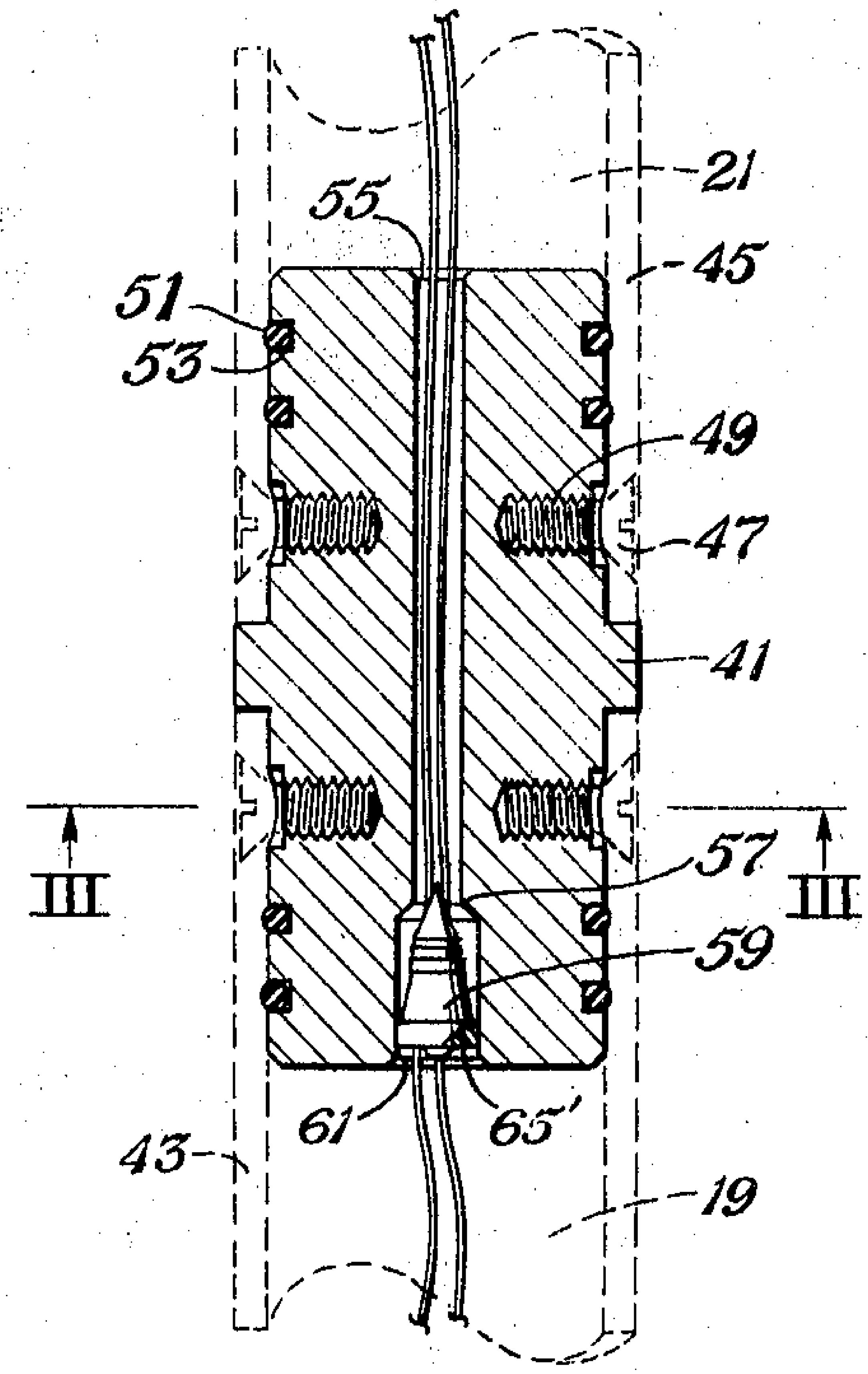

Fig. 2

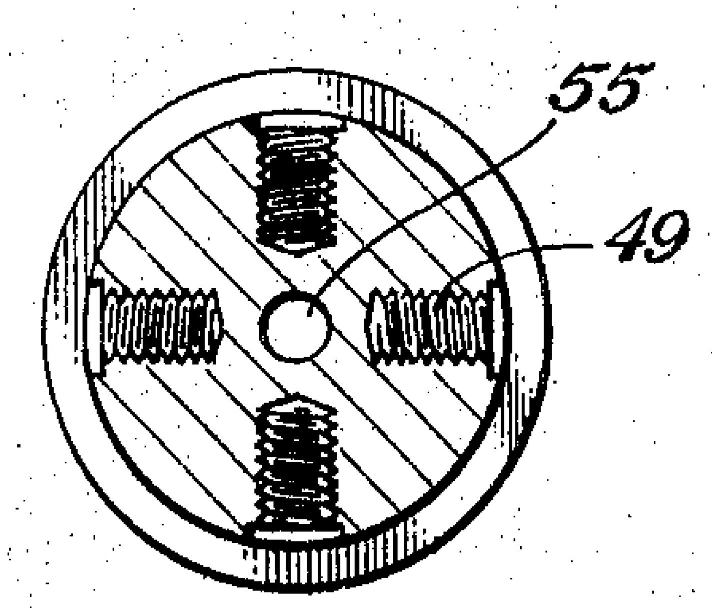

Fig. 3

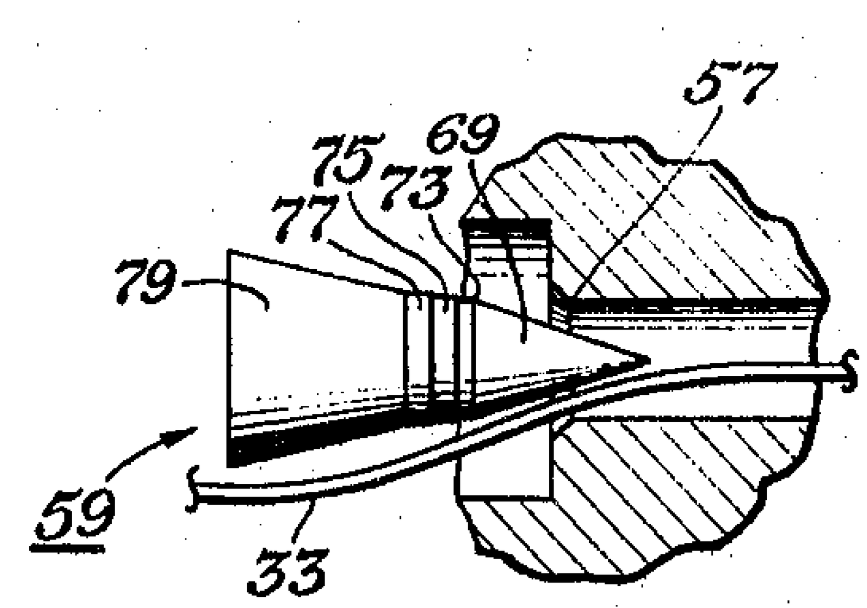

Fig. 4

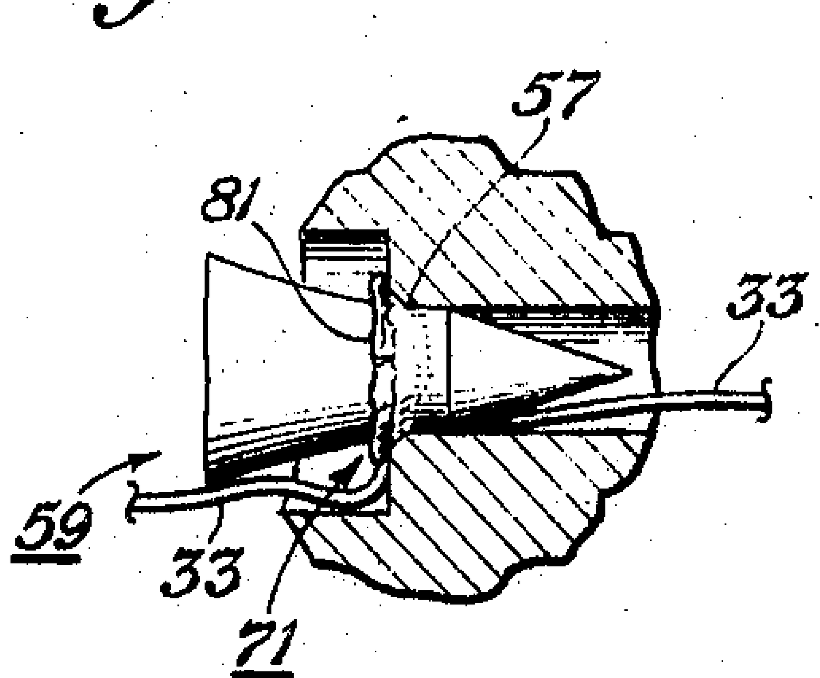

Fig. 5

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APPARATUS FOR SEALING CHAMBERS IN A PERFORATING TOOL

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ABSTRACT OF THE DISCLOSURE

This specification discloses apparatus for isolating a chamber in a perforating tool having a plurality of chambers and conductor means that connects an explosive charge in one of the chambers to a firing means, characterized by:

(a) providing a sealing partition means between the chamber with the explosive charge and an adjacent chamber and having, connecting the chambers, a passageway through which the conductor means pass;

(b) providing a seat in the passageway;

(c) inserting a sealing projectile adjacent the seat and between the seat and the explosive charge; and

(d) detonating the explosive charge to drive the sealing projectile into the seat.

This specification also discloses a specific construction of apparatus in which retaining means is provided behind the projectile and in which a preferred projectile comprises:

(a) a cone-shaped guide portion no larger in diameter than the seat in the partition means;

(b) a frustum base portion larger in diameter than the seat to prevent the projectile from passing completely through the seat; and

(c) a plurality of successively larger cylindrical portions connecting the cone-shaped guide portion with the frustum base portion.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to perforating tools. More particularly, it relates to perforating tools such as are employed in establishing communication through casing between a well bore and subterranean formations.

Description of the prior art

In producing hydrocarbon fluids from subterranean formations it is conventional practice, in completing a well in which casing has been set through the productive subterranean formation, to perforate the casing to effect communication between the well bore and the subterranean formation. Ordinarily, such communication employs the detonation of an explosive charge, either in jet perforating or in driving a bullet through the casing, cement sheath thereabout, and into the subterranean formation. The chambers housing the explosive charges for effecting perforations are conventionally relatively short; for example, on the order of a few feet or less. In many instances, therefore, it becomes necessary to employ a plurality of chambers to effect perforations over the desired interval, which may extend for a hundred feet or more. In such an arrangement, the explosive charges in the bottommost firing chamber will be detonated first, and the perforating proceed upward through successively higher firing chambers. It was early recognized that the later firing chambers must be isolated from the earlier firing chambers to prevent damage and ensure that subsequent chambers will fire in their turn. The damage oc-

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curred not only from the detonation itself, which often would prevent the firing or cause misfiring of the explosive charges in the subsequent chamber, but also from the invasion of the bore hole fluids, ordinarily at a relatively high pressure. The pressure is usually greater at greater depths.

In the prior art, the respective chambers were isolated during the assembly of the tool, including the firing chambers. To seal against the high temperatures and pressures with the conductors running through the sealing partition between the chambers created a difficult sealing problem, requiring expensive, elaborate and difficultly assemblable seals. Thus, prior art processes of sealing each chamber during assembly of the explosive charges, the explosive Primacord connecting the charges, and the conductors passing to the respective chambers, to effect an adequate seal; yet, ensure that the conductors would be operative to fire the charges in the respective chambers; was a very costly operation. Still further disadvantages attended the prior art seals since they were frequently unreliable and allowed some "blow-by" of the fluid during or after the detonation of the explosive charge in the chamber therebelow. This was particularly acute in wells deeper than about 9,000 feet, where the hydrostatic pressure on the fluids in the well bore became significant; for example, about 4,000 lbs. per sq. in. with salt water. Blow-by of hot detonation gases was disadvantageous, as would be expected, in that it could cause the explosive charges in the chamber immediately above to misfire or fire improperly.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view partly in section and partly schematic of a down hole perforating tool employing one embodiment of the invention.

FIG. 2 is a longitudinal cross-section of a sealing partition employed in one embodiment of the invention.

FIG. 3 is a lateral cross-sectional view along the lines III—III of FIG. 2.

FIGS. 4 and 5 are side views, partly in section, showing the sealing projectile in place before and after detonation of an explosive charge in accord with one embodiment of the invention.

DESCRIPTION OF PREFERRED EMBODIMENT

It is a particular feature of the invention to provide an isolation means effecting isolation of a firing chamber with a seal that resists extremely high pressures, that eliminates difficulties sealing around conducting means, and that alleviates the other problems encountered in prior art devices; yet, to reduce labor costs to about ½ of that formerly required, to reduce materials costs for the seals to about ⅐ of the fomer cost, and to reduce manufacturing costs for the partition means to about 80% of that formerly required.

In accordance with one aspect of the invention, there is provided an improvement in a method of isolating a chamber in a tool being used to perforate a steel casing thereabout, the tool having conductor means leading into a plurality of chambers, the conductor means connecting an explosive charge in one chamber to a firing means. The improvement comprises:

(a) Providing a sealing partition means in the tool between the chamber having the explosive charge and an adjacent chamber, having a pasageway connecting the chambers, and having the conductor means passing through the passageway;

(b) Providing a seat in the passageway;

(c) Inserting a sealing projectile adjacent the seat and between the seat and the explosive charge; and

(d) Detonating the explosive charge to drive the sealing projectile into the seat and effect a seal to thereby isolate the chamber in which the explosive charge has been fired from the adjacent chamber.

In accordance with another aspect of the invention there is provided an improvement in a downhole tool for establishing communication through a casing from a well bore into a subterranean formation by detonating an explosive charge within one of a plurality of chambers in the tool. The improvement comprises:

(a) A partition means intermediate the one chamber containing the explosive charge and an adjacent chamber and sealingly connected to the walls thereof;

(b) A passageway passing through the partition means and communicating with both of the chambers;

(c) Conductor means within the passageway connecting the explosive charge with a firing means;

(d) A seat provided in the pasasgeway; and

(e) A sealing projectile adjacent the seat and between the seat and the explosive charge.

The invention may be clearly understood by referring to the figures. FIG. 1 illustrates apparatus for establishing communication through a casing **11** from a well bore filled with fluid **13** into subterranean formation **15**. Therein tool **17** has a plurality of chambers **19** and **21**. In chamber **19**, perforating means, including explosive charges **23**, are set to perforate into the formation. In chamber **21** perforating means, including explosive charges **25**, are also set to perforate into the formation. Explosive charges **23** are detonated by appropriate detonating means, such as Primacord **27**. Similarly, second detonating means, such as Primacord **29**, serves to detonate explosive charges **25**.

As a firing means, a DC power source **31** may be connected by conductors **33** and **35** via a stepping switch **37** with Primacord **27** and explosive charge **23**. Conductor means, such as conductors **33** and **35**, are carried inside cable **39** which ordinarily has a tensile load bearing member in addition to the conductors. Cable **39** may have an exterior armored portion which will serve as a ground for the conductor means if desired.

Ordinarily, tool **17** is introduced into the well through a lubricator to maintain the well pressure, especially after perforating. Cable **39**, suspending tool **17**, is lowered over a sheave and is lowered into and withdrawn from the well in response to winching means. Additionally, depth measuring means may be employed in connection with cable **39** and its supporting sheave to position tool **17** in order to effect perforations at exactly the desired depth in the subterranean formation **15**. The lubricator, sheave, winching means and depth measuring means are well known, and do not form any part of this invention and, hence, need not be described herein.

Partition means **41** is interposed between chamber **19** and chamber **21**. Partition means **41** is sealingly connected with wall **43** of chamber **19** and with wall **45** of chamber **21**. The connection may be effected by any means; such as, threaded bolts **47** having countersunk, recessed heads and passing through the respective walls and into the partition means having an aperture **49** tapped with matching threads, shown in greater detail in FIG. 2. The sealing may be effected by any means, such as O-rings **51** mounted in grooves **53** and interposed between partition means **41** and the walls **43** and **45** of the respective chambers **19** and **21**.

Passageway **55** penetrates longitudinally through partition means **41**. The conductor means passing through passageway **55** connects explosive charges **23** with the firing means. Seat **57** is formed in the passageway. Ordinarily, seat **57** is formed by reaming to a particular dimension for a depth; for example, about 1 inch; into passageway **55**. If desirable, seat **57** may be coated by a hard coating, such as silicon carbide or Stellite.

Sealing projectile **59** is positioned adjacent seat **57** such that it is between seat **57** and explosive charges **23** (FIG. 1).

It has been found advantageous to employ a retaining means such as enlarged portion **61** to maintain sealing projectile **59** adjacent seat **57** and to help maintain it aligned therewith.

As can be seen in FIG. 3 threaded apertures **49** do not penetrate through the sidewall of the partition means to passageway **55**; hence, there is no problem of communication of fluids between the well bore and passageway **55** except by way of chamber **19** following detonation of explosive charges **23**.

In operation, the components are assembled in tool **17** as described hereinbefore. Thereafter, tool **17** is lowered, via cable **39** into well bore **13** to the depth interval to be perforated. Stepping switch **37** is stepped onto conductor **33**. This detonates Primacord **27**, also detonating explosive charges **23** in chamber **19**. The detonation of the explosive charges **23** and Primacord **27** simultaneously perforates through casing **11** into subterranean formation **15**, and drives sealing projectile **59** deeply into seat **57** to isolate firing chamber **19**. Thereafter, the gases liberated by detonation of explosive charges **23** are dispelled through openings in chamber **19** into well bore **13**.

Sealing projectile **59**, in being driven into seat **57**, severs conductor **33** and seals against seat **57**. In this way, misfiring of explosive charges **25** in chamber **21** is prevented, either by damage from the detonation gases or from subsequent invasion of fluids from the pressurized well bore **13** into chamber **21**.

Stepping switch **37** can be stepped onto conductor **63**, which, via its connection with DC power source through conductor **65**, detonates Primacord **29**; in turn, (1) detonating explosive charges **25**, (2) isolating chamber **21** by driving its sealing projectile into its seat, and (3) perforating into the formation.

Thus, it can be seen that any number of chambers may be fired successively to effect perforation over the desired interval by employing this embodiment of the invention.

It has been found preferable to employ a back up material **65** (FIG. 2) in retaining means **61** and interposed between sealing projectile **59** and explosive charges **23**. Back up material **65'** functions to help retain sealing projectile **59** in place adjacent seat **57** and aligned therewith before the detonation of charges **23**; helps ensure that a maximum pressure is applied to the frustum base portion of sealing projectile **59** to drive it deeply into seat **57**; and disintegrates to fill any voids that might occur, block "blow-by" of any detonation gases, and effect complete sealing. Back up material **65** is composed of short asbestos fiber formed into a disc. The asbestos fiber withstands high temperature and yet disintegrates readily because of its short fiber to fulfill the desired functions. Because it is asbestos, it may be pressed into retaining means **61** without harming conductors that pass therethrough.

Sealing projectile **59** may be of any shape that will form a seal with seat **57**. For example, sealing projectile **59** can be in the form of a sphere or a cone. A cone having three sections differing in degree of taper, or slope, from the adjacent section can be employed as the sealing projectile.

It has been found, however, that dramatically improved results are obtained when sealing projectile **59** has a shape illustrated in FIG. 4. Therein, cone-shaped nose portion **69** aids in assembly and alignment, automatically dispersing conductors such as conductor **33** around the sealing projectile. Cone-shaped nose portion **69** need not be completed to its apex but can be frusto-conical. Its maximum diameter will be no larger than the diameter of seat **57**. Preferably, cone-shaped nose portion has a slope with respect to its longitudinal axis of between 10 and 30 degrees.

Next, there is a section **71** of at least two stepped cylindrical portions. First cylindrical portion **73**, contiguous with the base of the cone-shaped nose portion **69**, has a diameter substantially equal to the seat diameter. Thus, when sealing projectile **59** is driven into seat **57**, first cylindrical portion **73** severs conductor **33**, instead of merely compressing it and allowing blow-by through openings at the edge of the compressed conductor.

Second cylindrical portion **75** contiguous with first cylindrical portion **73** has a diameter slightly larger than the seat diameter. The diameter of the second cylindrical portion is at least 0.002 inch, preferably about 0.005 inch, larger than the seat diameter. The second cylindrical portion serves to make the projectile self aligning in order to get seal material all around the seat opening and somewhat cushion the impact of the projectile. The amount of metal larger than the seat must not be so great as to diminish the wall to wall contact penetration into the seat to less than about 1/8 inch. Although the maximum diameter will vary with the material of construction; ordinarily, the diameter of the second cylindrical portion will be no more than about 0.010 inch larger than the seat diameter.

It has been found that improved results are obtained by including a third cylindrical portion **77** contiguous with the second cylindrical portion which has a diameter similarly slightly larger than the diameter of the second cylindrical portion. Specifically, similarly as described with respect to the second cylindrical portion and the seat diameter, the diameter of the third cylindrical portion is, ordinarily, 0.002–0.010 inch, preferably about 0.005 inch, larger than the second cylindrical portion. The third cylindrical portion **77** improves the self aligning characteristics of the projectile and by the additional metal around its periphery further cushions the impact of the projectile into seat **57**; yet, does not accumulate metal so rapidly as to prevent the projectile from being driven deeply into the seat for a better seal.

Ultimately, there is a frustum base portion **79**, adjacent the last cylindrical portion, that has a minimum diameter substantially the same as the last cylindrical portion and sloping to a diameter at its base large enough to ensure that the projectile does not pass completely through the seat under the force of the explosive charge. Although the maximum diameter of the base will depend somewhat upon the material from which sealing projectile **59** is made and on the degree of slope, ordinarily, a maximum diameter of at least 50% more than the diameter of the seat is adequate to ensure that the sealing projectile does not pass completely through the seat. Preferably the frustum base portion has a slope of between 10 and 30 degrees with respect to its longitudinal axis.

FIG. 5 illustrates sealing projectile **59** after it has been driven deeply into seat **57** by the detonation of explosive charges **23**. Conductor **33** is cleanly severed. Excess metal **81** is driven onto the reamed seat and into any small openings thereabout to effect a complete seal that is resistant to high temperature and high pressure.

Sealing projectile **59** may be constructed of any material that will resist the high temperature and high pressure; yet, be malleable enough to be driven deeply into the seat to effect a seal. Ideally, the material of which the sealing projectile is constructed should be lightweight such that it would have little inertia and will be moved into sealing position quickly when the explosive charge is detonated. It should have a uniform density so as to truly align itself and properly seat into seat **57**. It should withstand temperature as high as 500 degrees Fahrenheit down hole plus instantaneous temperature as high as 1000 degrees Fahrenheit. It should be capable of shear and flow; i.e., not be frangible; should have less hardness than the seat but should have high enough density and resistance to shear and flow to keep from being forced completely through the seat. Specifically, soft, malleable metals; such as, brass, copper, and mild steel may be employed. Aluminum is particularly preferred. Any other material having the desired properties can be employed.

A specific embodiment that has been found to work well in several different tools having different diameters was the following. A passageway 5/16 inch in diameter was drilled longitudinally through the partition means. A retaining means 5/8 inch in diameter was drilled 1 inch deep into the passageway before the seat was formed. A seat 21/64 inch was reamed 1 inch deeper into the passageway. A sealing projectile was fabricated of aluminum. It had a maximum diameter at the base of the frustum base portion of about 9/16 inch. The frustum base portion had a slope of about 13 degress with respect to its longitudinal axis. The cone-shaped nose portion has a slope of about 15 degress with respect to its longitudinal axis and had a maximum diameter of 0.328 inch. The first cylindrical portion had a diameter of 0.328 inch and a length of 1/32 inch. The second cylindrical portion had a diameter of 0.333 inch and a length of 1/16 inch. The third cylindrical portion had a diameter of 0.338 inch and a length of 1/16 inch. The overall length of the sealing projectile was 1 5/32 inch, affording 1/2 inch each for the cone-shaped nose portion and the frustum base portion.

Thus, it can be seen that the invention provides a method of effecting a seal in situ, using the explosive force of the detonation of an explosive charge, to effect a seal that is resistant to high temperatures and to pressures in excess of 4,500 p.s.i. The seal alleviates difficulties with blow-by of fluid, either during the detonation or from the well bore fluids following the detonation, that could cause misfiring of the explosive charges in the remaining chambers. Yet, even with the improved results, the invention effects a cost reduction by cutting the labor costs on loading and assemblying the gun in half, reducing the material cost for the seal itself to about 1/7 the former cost and reduces the manufacturing cost for the sub-assembly by about 20%.

Although the invention has been described with a high degree of particularity, it is understood that the present disclosure has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

What is claimed is:

1. Apparatus for establishing communication through a casing from a well bore filled with fluid to a subterranean formation comprising:

(a) a tool having a plurality of chambers;

(b) perforating means in at least one chamber and employing an explosive charge to effect perforation of said casing;

(c) a firing means;

(d) a cable leading into said tool carrying conductor means that is connected with said explosive charge so as to ultimately effect detonation thereof when suitable current is impressed onto said conductor means;

(e) partition means interposed between said one chamber having said explosive charge therein and an adjacent chamber and sealingly connected with the walls of said one chamber and said adjacent chamber;

(f) a passageway penetrating longitudinally through said partition means and having said conductor means passing therethrough;

(g) a seat formed in said passageway;

(h) a sealing projectile adjacent said seat interposed between said seat and said explosive charge; said sealing projectile being adapted to sever said conductor means and be driven deeply into and sealed with said seat; and

(i) retaining means for holding said projectile adjacent said seat.

2. The apparatus of claim 1 wherein said seat has a first diameter and said sealing projectile comprises a cone-shaped guide portion no larger in diameter than said seat first diameter, a first cylindrical portion contiguous with base of said cone-shaped guide portion and having a diameter substantially equal to said seat first diameter, a second cylindrical portion contiguous with said first cylindrical portion and having a diameter at least 0.002 inch larger than said seat first diameter, and a frustum base portion adjacent said last cylindrical portion and having a minimum diameter substantially the same as said last cylindrical portion and sloping to a diameter large enough to ensure that said pojectile does not pass completely through said seat.

3. The apparatus of claim 2 wherein said second cylindrical portion has a diameter 0.02–0.010 inch larger than said seat first diameter.

4. The apparatus of claim 3 wherein said second cylindrical portion has a diameter of about 0.005 inch larger than said first cylindrical portion.

5. The apparatus of claim 2 wherein a third cylindrical portion is interposed between said second cylindrical portion and said frustum base portion of said sealing projectile contiguous with said second cylindrical portion and having a diameter .002–.010 inch larger than said second cylindrical portion.

6. The apparatus of claim 5 wherein said third cylindrical portion has a diameter about 0.005 inch larger than second cylindrical portion.

7. The apparatus of claim 2 wherein said cone-shaped guide portion has a slope in the range of 10–30 degrees with respect to its longitudinal axis.

8. The apparatus of claim 2 wherein said frustum base portion has a slope in the range of 10–30 degrees with respect to its longitudinal axis.

9. The apparatus of claim 1 wherein said retaining means includes back up material interposed between said sealing projectile and said explosive charge.

10. The apparatus of claim 9 wherein said back up material consists essentially of short fiber asbestos arranged in the form of a disc which can be inserted behind said sealing projectile in said retaining means and about said conductor means.

11. The apparatus of claim 1 wherein said seat con-

sists essentially of substantially uniformly cylindrical aperture formed in metal and concentric with said passageway.

12. The apparatus of claim 1 wherein said partition means comprises a steel cylindrical block having a central cylindrical portion of larger diameter adapted to abut ends of walls of chambers, having diametrically disposed threaded apertures on each side of said cylindrical portion and matching with countersunk apertures in said walls of said chamber and adapted to conformingly receive a stud bolt inserted through the apertures in said walls, and having at least one groove at each end of said partition means containing a ring seal to sealingly engage the respective walls of said chambers, said threaded apertures penetrating only into said steel and not into said passageway penetrating longitudinally through said partition means.

13. In a down hole tool for establishing communication through a casing from a well bore into a subterranean formation by denoting an explosive charge within one of a plurality of chambers in the tool, the improvement comprising:

(a) a partition means intermediate said one chamber and an adjacent chamber and sealingly connected to the walls thereof;
(b) a passageway passing through said partition means and communicating with both of said chambers;
(c) conductor means within said passageway connecting said explosive charge with a firing means;
(d) a seat provided in said passageway; and
(e) a sealing projectile adjacent said seat and between said seat and said explosive charge.

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