July 4, 1967 P. A. PAUSKY 3,329,219

SELECTIVELY FIRED CAPSULE TYPE SHAPED CHARGE PERFORATION

Filed June 25, 1965 2 Sheets-Sheet 1

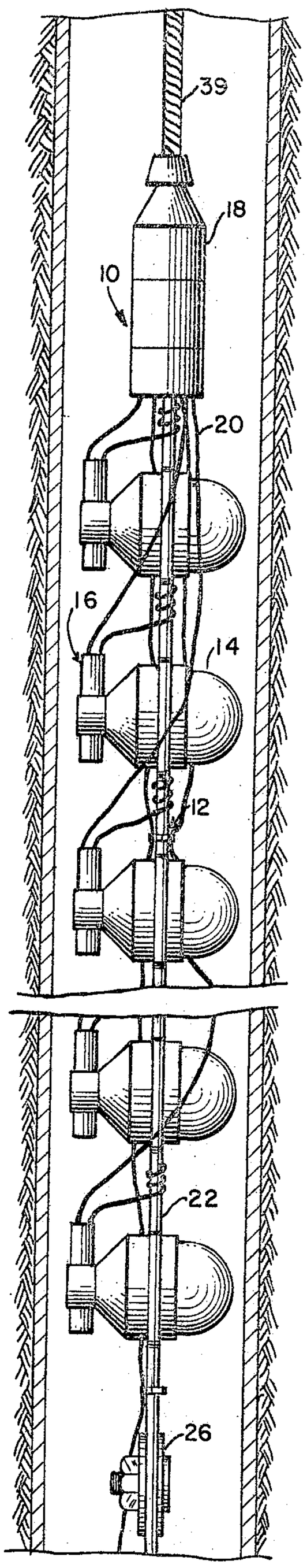

FIG. 1

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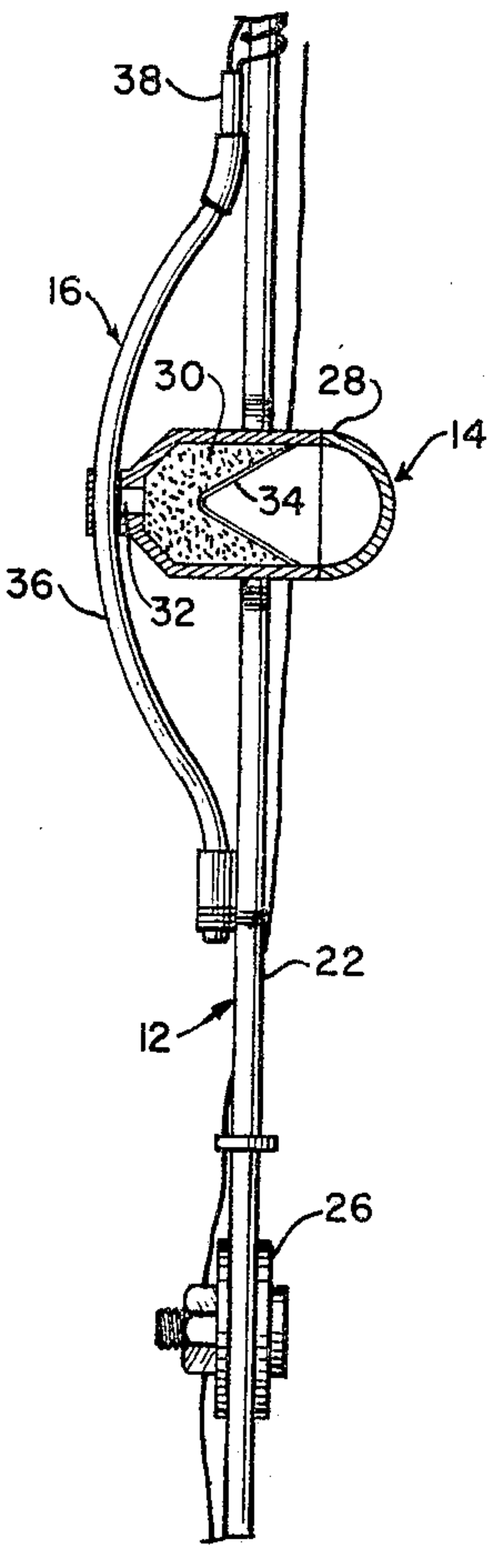

FIG. 2

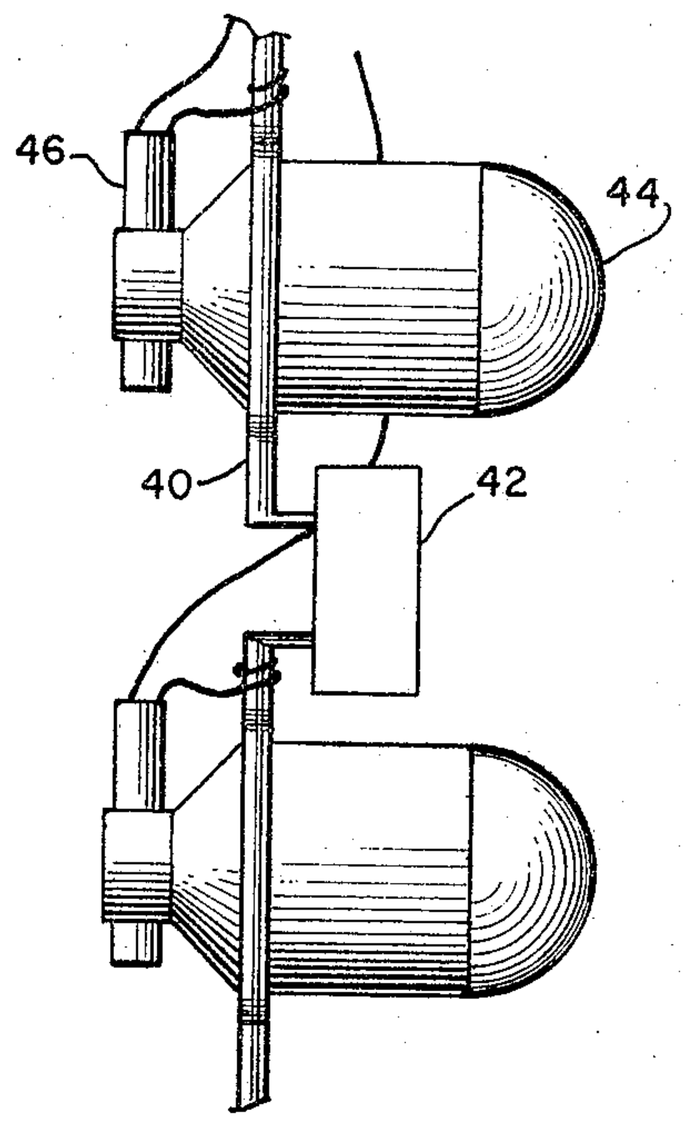

FIG. 3

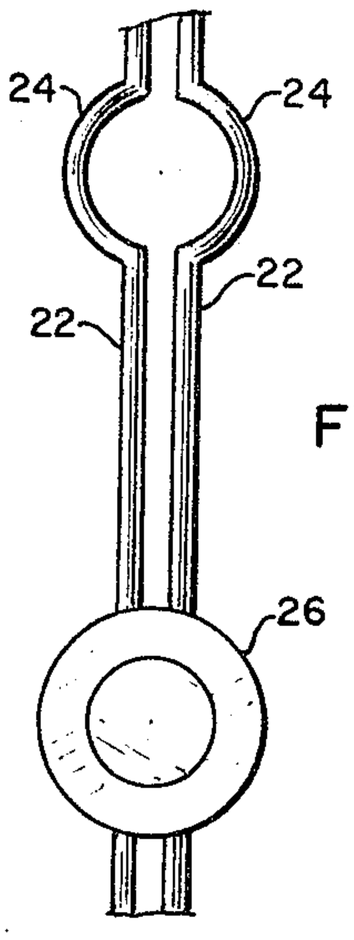

FIG. 4

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1

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SELECTIVELY FIRED CAPSULE TYPE SHAPED CHARGE PERFORATION

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3 Claims. (Cl. 175—4.55)

This application is a continuation in part of my copending application S.N. 291,413, filed June 28, 1963, subsequently abandoned.

This invention relates to well perforating apparatus and more particularly to a new and improved method and apparatus for selectively firing individual capsule type shaped charges.

It has become common practice in the completion of oil and gas wells to perforate the well casing to bring the well into production by the utilization of detonating explosives of high velocity and of the general character and form known as "shaped charges" as, for example, the type disclosed by U.S. Patent No. 2,399,211 to C. O. Davis et al., issued April 30, 1946.

In order to locate the shaped charges opposite the proper strata, the shaped charges are assembled into a gun which is lowered into the well. The guns used for shaped charge perforating are basically of two types. One, known as the hollow carrier gun, is comprised of a hollow tube containing a plurality of shaped charges, such gun is retrievable after the shaped charges have been fired and reuseable for a number of times. A common form of such gun is disclosed in U.S. Patent No. 2,494,-256. The other type of gun, which has been used particularly in smaller tubing, is the capsule type in which each individual shaped charge is encased in its own pressure container and mounted in a carrier. While some types of capsule carriers are retrievable, they are, however, as a rule, expendable. Customarily, detonation of the shaped charges has been initiated by a common detonator extending from the uppermost to the lowermost or visa versa. It has been the practice in the industry customarily to have four shaped charges per foot.

Although in the past it was the practice of the petroleum industry to complete an oil bearing strata by firing a saturation of charges into the selected strata, there has been a change in completion techniques and it is now the practice to fire only a selective number of charges into an oil bearing strata. In some instances, the charges are fired at widely spaced depth intervals as required by the industry's "Limited Entry" technique. In other instances, a number of charges are fired at one predetermined plane to form a notch as required by the industry's "Single Point Entry" technique used in high capacity hydraulic well fracturing. In order to meet the requirements of limited entry techniques with present equipment, the gun is loaded with the required number of charges at the proper spacing. The gun is then lowered into the well opposite the proper strata and then discharged. However, in many cases the selected points of perforation may stretch over a length greater than the length of the gun. In such case, it is necessary to make a number of runs into the well in order to fire the desired number of charges with the gun being loaded with a very few charges for each run. The numerous runs into the well result in considerable loss in rig time, which is a loss to the well operator. Accordingly, it would be desirable to be able to fire the required number of charges during one run into the well. Also, for single point entry technique it would be desirable to selectively fire each individual shaped charge as it is positioned opposite the predetermined plane.

While controllers for selectively firing bullet guns have been known in the art, the detonation of individual capsule type charges results, in addition to the longitudinal

2

perforating jet, in a radial force which causes a propogation wave in the well fluid and it was recognized that the firing of one shaped charge, in a capsule type gun, would be detrimental to the other shaped charges closely spaced along the longitudinal axis of the gun. It was felt that the individual charges would have to be placed so far apart as to result in a gun having an impractical length. Moreover, inasmuch as blasting caps are customarily used as detonators, the considered opinion of the industry was that there would be sympathetic detonations of any adjacent blasting caps within three feet of detonated charge. It was felt that the sympathetic detonation would result from the radial wave. However, it was discovered that, contrary to the recognized opinions, by proper positioning the individual capsule type shaped charges, each individual shaped charge could be detonated without simultaneously detonating or damaging the other shaped charges or their detonators.

Accordingly, it is the object of the present invention to overcome the disadvantages of the prior art, which requires the simultaneous firing of all shaped charges in a capsule type gun, to provide a capsule type gun for shaped charges which will permit the selective firing of individual charges whereby the required number of charges may be fired in one trip into the well.

It is another object to provide an improved, capsule type gun for shaped charges which permits the selective firing of the individual charges.

It is another object to provide a novel method for selectively firing a multiplicity of capsule type shaped charges in a well bore.

It is a further object to provide a capsule type shaped charge gun which has an individual detonator for each of the shaped charges permitting selective detonation of individual charges.

These, and other objects and advantages of the invention, which will more clearly appear from the detailed description which is about to follow, are achieved in a capsule type perforating gun which is adapted to be passed through a small diameter tubing. The capsule type gun includes a carrier element adapted to be longitudinally inserted into a well bore. A plurality of longitudinally spaced shaped charges are mounted in the carrier, spaced approximately eighteen inches apart. An individual detonator is attached to each shaped charge. A controller device is attached to one end of the carrier. Cable means is attached to the controller device with the cable extending to the surface. Leads from the controller device extend to each individual detonator and there is means at the surface to energize the controller to selectively, sequentially fire the individual shaped charges. Each shaped charge and its detonator is self-sufficient and is capable of withstanding the environmental earth well conditions and the added shock and pressure build-up encountered during and immediately after the detonation of an adjacent shaped charge. After a charge is fired, the gun is moved to its next position and then the adjacent charge is initiated. The selective feature allows the individual shaped charges to be detonated independently of adjacent charges allowing the selective location of perforation along the extent of the well bore. By using the present, it has been possible to selectivly fire ten charges in ten individual locations which formerly would have required the running in of the gun ten individual times.

The invention will be described with greater particularity with reference to the drawings in which:

FIG. 1 is a vertical sectional view of a portion of an oil well showing an exemplary embodiment of the oil perforating apparatus of the invention suspended in the well;

FIG. 2 is an enlarged elevational view partially in section of a section of the capsule gun shown in FIG. 1;

FIG. 3 is a fragmentary, elevational view of an alternative form of gun;

FIG. 4 is a fragmentary plan view of an unloaded gun of the type shown in FIG. 2.

Referring now to the drawings, the capsule type gun **10** of the present invention is formed with a carrier element **12**, a plurality of individual encapsulated shaped charges **14**, an individual detonator **16** for each shaped charge **14** and a controller device **18** for sequentially, selectively firing the capsule type shaped charge **14** and leads **20** from the controller device **18** to each detonator **16**.

The carrier element **12** may be formed of two preformed wires **22—22** having at spaced intervals mating concave contours **24** forming capsule positioners for the mounting of the individual capsule charges **14**, as shown. In order to retain the two lengths of wire in proper relation, there is provided spaced carrier retainers **26** which are formed of two washers between which the lengths of two wires **22—22** are clamped. Means are provided to tighten the two washers together so that the two wires are securely retained in position. The carrier retainer **26** keeps the carrier intact while the adjacent charge is being fired. It keeps the adjacent charge in its capsule positioner and also prevents the carrier from buckling. If desired, the carrier **12** may take any of the various forms known in the art for use in capsule guns such as strips, links, tubing, etc.

The capsule type charge **14** is formed of a pressure resistant housing **28**, within which is contained an explosive portion **30** having a booster **32** at the rear end. A liner **34** covers the concave front face of the explosive portion **30**.

The detonator **16**, shown, is comprised of a length of Primacord **36**, which is attached to the rear of the explosive porion **30**, and a commercially electrically fired pressure rate blasting cap **38** (such DuPont's E–87 or E–96), which is attached to the Primacord **36**. Since the Primacord **36** will be exposed to the well fluid, it is necessary for it to be covered. Also the connection between the Primacord and blasting cap must be made fluid tight. If desired, the Primacord may be eliminated and the blasting cap **38** directly attached to the shaped charge.

The controller **18** is a device which is provided with a number of firing positions and is provided with means which will sequentially energize the individual firing positions on a signal from the surface. An individual lead **20** extends from each firing position of the controller **18** to the charge it is to serve where it is connected to the blasting cap **38** for that particular charge. Accordingly, energization of the controller **18** will sequentially energize one firing position at a time and consequentially selectively fire the individual charges. In order to run the gun into a well bore, a cable **39** is attached to the top of the gun **10**. The cable **39** has at least one conductor to energize the controller **18** upon a signal from the surface.

As previously mentioned, individual capsule type shaped charges **14** have been used for a number of years in the perforation of well casing. While the individual capsule type charge, per se, is not part of this invention and the literature is complete as to the characteristics of the shaped charge, it is considered desirable to provide a short summary of the characteristics of the detonation of the shaped charge.

It is customary practice to detonate or "initiate" a plurality of shaped charges in rapid succession by detonating a length of Primacord or similar detonable fuse which extends through, or adjacent to, the rear of each of the shaped charges. The Primacord is structurally similar to an an elongated cord and for reasons of safety and convenience, among other things, is formed of an explosive which is not detonable by ordinary heat or mechanically or other handling shock. Accordingly, a special means, such as an electrically fired blasting cap, has

customarily been employed to initiate detonation of the Primacord. Detonation of the Primacord ignites the booster **24** which, in turn, initiates the detonation of the explosive charge **22**.

As the wave of detonation progresses from the point of initiation, it progressively encounters the cavity in the liner. A collapsing and progressive disintegration of the liner occurs with the wave front. The very fine products of the disintegration are carried into the condensing wave to form a particle laden stream commonly called the jet. A portion of most common liners is not disintegrated and falls behind the faster jet stream as a relatively slow moving slug or carrot. The perforation of the well casing is made by the particle laden jet stream much in the same way that a particle laden stream of high pressure fluid will jet a hole in some materials. In addition to the force of the explosion which discharges from the hollow end of the shaped charge in the form of the jet along the longitudinal axis of the charge, there are substantial radial forces developed which form, in the fluids surrounding the charge, a wave which usually is of sufficient magnitude to deflect the slug and therefore prevent the entry of a carrot in the penetration. Although capsule type charges are individually encapsulated in a pressure resistant housing, which is sufficiently strong to withstand the pressures developed in a well, it was felt in the industry that the radial propagation wave would cause damage to adjacent charges if closely spaced charges were selectively, individually fired. Moreover, it was the considered opinion that the radial detonation wave would most certainly cause the detonation of the blasting cap which is commonly used as a detonator for the shaped charges should an individual blasting cap be used for each individual charge. This is especially true since blasting caps are more sensitive to shock than the capsule charge. Therefore, it was a common practice in the industry to have a length of Primacord, running from one end of the gun to the other, and one blasting cap, which would ignite the Primacord. The Primacord then would detonate each individual shaped charge as the train of ignition traveling along the length of the Primacord reached each charge. Consequently, the detonation of the charges was practically a simultaneous chain reaction depending upon, of course, the speed of travel along the Primacord and the spacing of the charges.

To meet the requirements of the industry for single point entry and limited entry completion techniques developed by the industry, it was desirable that a shaped charge gun be developed which would individually, selectively fire the contained charges. However, because of the radial propagation wave, previously described, no such gun was developed for capsule type charges until the present invention. Disregarding the recognized opinion of the industry that the radial propagation wave would have deleterious effects on individual charges and blasting caps within three feet of each other in a well bore, it was found that the charges could be selectively detonated without damage to adjacent charges or blasting caps located on adjacent charges. In experiments it was found that the charges spaced 6" apart could be individually detonated without sympathetic detonation or deleterious damage of adjacent blasting caps or charges.

In view of the fact that in field application, capsule type guns are run in tubing which has an inside diameter of approximately 2½ as well as in casing which has a larger diameter, it was decided to position the charges 18" apart to provide an adequate safety factor. Such distance still provides a gun having a practical length capable of selectively firing ten to twelve charges during one run in a well bore.

An alternative method of providing an additional safety factor is shown in FIG. 3, where a carrier **40** is provided with a buffering or shock absorbing device **42** placed between individual charges **44**. The buffering device will absorb the radial forces resulting from the detonation

of a preceding charge, and will provide further protection for the shock sensitive blasting cap **46.**

In summary, the present invention provides a gun for capsule type shaped charges in which each shaped charge is provided with its individual detonator system and a controller is provided which will selectively fire the charges. The charges are so spaced along the length of the gun that radial forces generated by the detonation of a preceding charge will not damage the detonator system of adjacent charges.

What is claimed is:

1. A capsule type perforating device for a well casing comprising:

a carrier element having at spaced intervals capsule positioners adapted to receive an encapsulated shaped charge;

a plurality of encapsulated shaped charges mounted in the capsule positioners of said carrier element and extending transversely through the carrier element, said charges being spaced between six and eighteen inches apart;

an individual detonator for each shaped charge;

a controller device attached to one end of the carrier element, said controller having a plurality of firing positions, and means to sequentially energize said positions;

leads from the controller device to each of the detonators of the shaped charges, whereby each shaped charge may be individually detonated.

2. A capsule type perforating device for a well casing comprising:

a carrier element having at spaced intervals capsule positioners adapted to receive an encapsulated shaped charge;

a plurality of encapsulated shaped charges mounted in the capsule positioners of said carrier element, said charges being spaced between six and eighteen inches apart;

an individual blasting cap for each shaped charge;

a controller device attached to one end of the carrier element, said controller having a plurality of firing positions, and means to sequentially energize said positions;

leads from the controller device to each of the blasting caps of the shaped charges, whereby each shaped charge may be individually detonated;

a shock absorbing device between said charges absorbing the radial forces generated by the detonation of a charge thereby minimizing the radial shock waves received by the detonator.

3. A capsule type perforating device for well casing comprising:

a carrier element adapted to be longitudinally inserted in a well bore;

a plurality of longitudinally spaced shaped charges fixedly mounted in the carrier, each shaped charge spaced between six inches and eighteen inches from an adjacent charge;

an individual detonator attached to each shaped charge;

a controller device attached to one end of the carrier having means to sequentially energize a plurality of firing positions;

cable means attached to the controller device, said cable extending to the surface;

leads from the firing positions of the controller device to each individual detonator;

means at the surface to energize the controller to selectively fire individual shaped charges.

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