

[72] Inventor **Charles Robert Garner**
Tulsa, Okla.
 [21] Appl. No. **42,785**
 [22] Filed **June 2, 1970**
 [45] Patented **July 27, 1971**
 [73] Assignee **Cities Service Oil Company**

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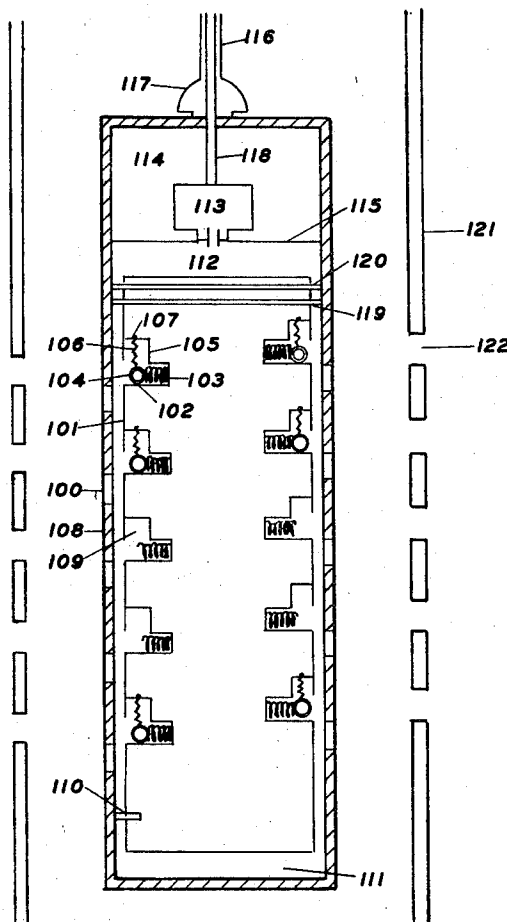
Primary Examiner—James A. Leppink
 Attorney—J. Richard Geaman

[54] **APPARATUS FOR SELECTIVELY PLUGGING PORTIONS OF A PERFORATED ZONE**
10 Claims, 4 Drawing Figs.

[52] U.S. Cl. 166/192,
 166/243
 [51] Int. Cl. E21b 33/13
 [50] Field of Search 166/100,
 169, 192, 193, 243

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ABSTRACT: Wellbore apparatus having perforation ball sealers attached thereto and properly spaced along the length of the tool is positioned in a perforated wellbore liner. The wellbore apparatus is positioned so that ball sealers are adjacent to the perforations through which fluid is not desired. When fluid is pumped down the wellbore, the ball sealers are forced to enter the desired portion of the perforated wellbore liner. The apparatus provides a means for selectively plugging an interval of a perforated wellbore liner while allowing fluid to flow in other zones of the wellbore.



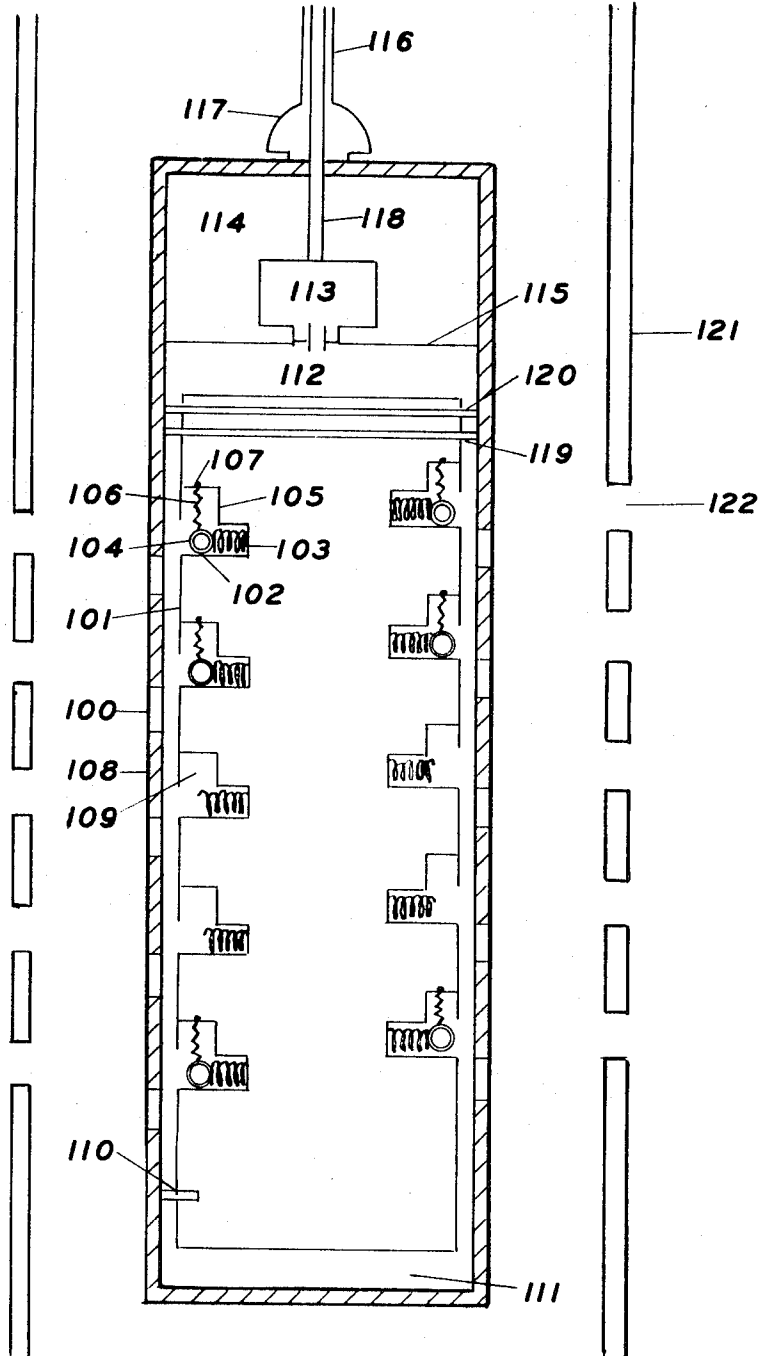


Fig. 1

INVENTOR
CHARLES R. GARNER
 BY *Robert J. Garner*
 ATTORNEY

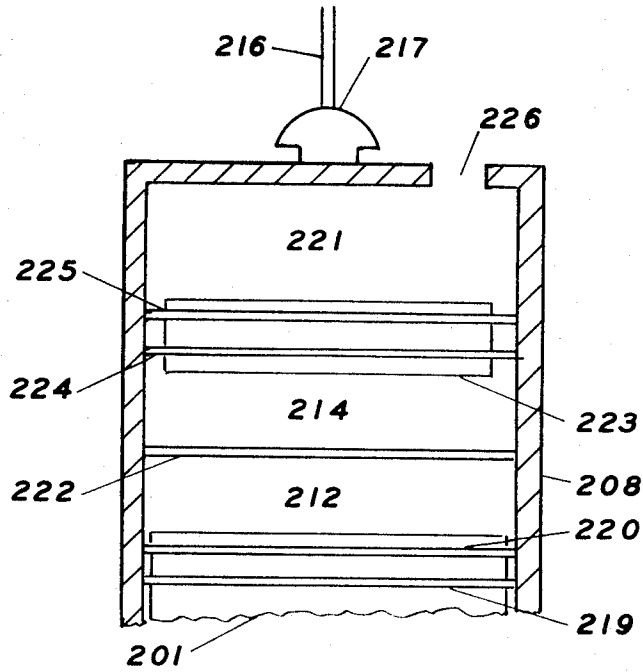


Fig. 2

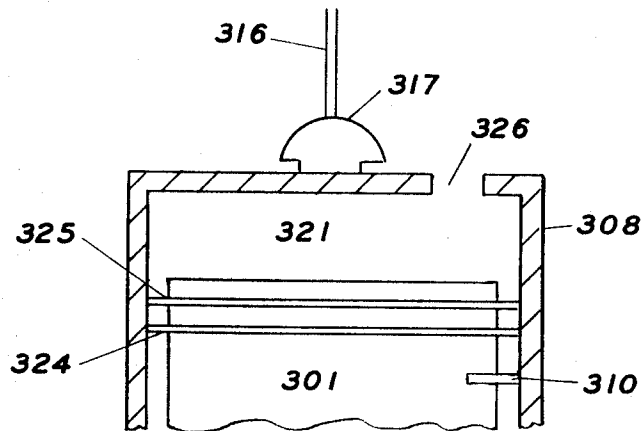


Fig. 3

INVENTOR
CHARLES R. GARNER
 BY *Michael J. ...*
ATTORNEY

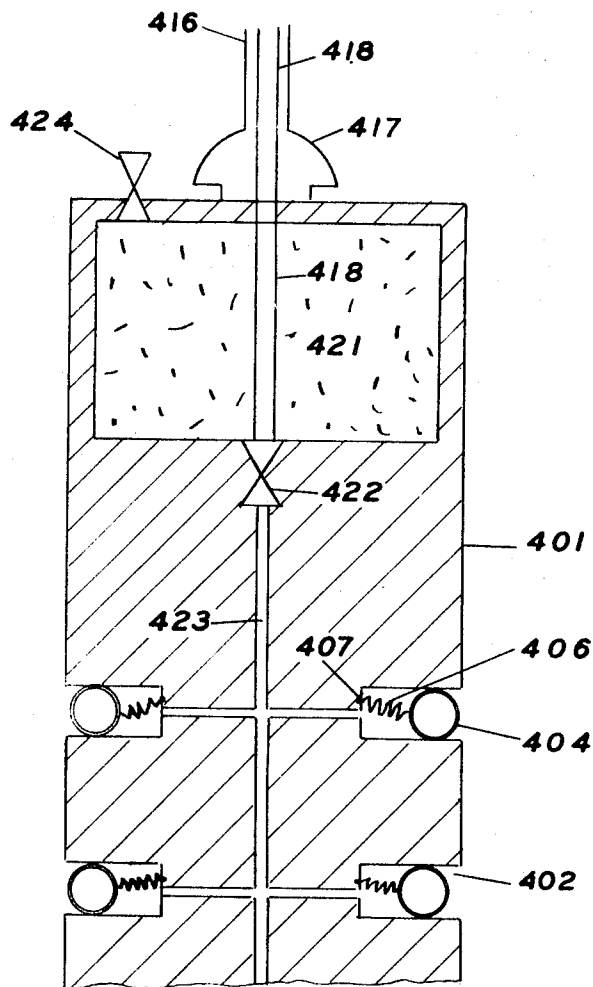


Fig. 4

INVENTOR
CHARLES R. GARNER
 BY *[Signature]*
ATTORNEY

APPARATUS FOR SELECTIVELY PLUGGING PORTIONS OF A PERFORATED ZONE

BACKGROUND OF THE INVENTION

The present invention encompasses an apparatus for selectively plugging portions of a perforated zone. More particularly the apparatus of the present invention utilizes apparatus by which certain portions of a perforated interval in a wellbore may be selectively plugged while treatment of other unplugged perforated intervals is enhanced.

In the treatment of production and injection wellbores such as a stimulation treatment by acidizing or hydraulic fracturing, the method generally used is that of forcing the liquid into the producing formation through the wall of the well. A particular problem is encountered when a perforated wellbore liner is attached to the wellbore wall in that acidizing or stimulating technique will be applied over the entire perforation interval unless perforations in undesired zones such as a watered out zone or a gas cap may be selectively plugged. The stimulation treatment may be confined to the less permeable strata by use of chemical sealing agents which temporarily seal the more permeable strata before the acid is applied. By this technique a thin solution of a jelly or gelatinous-type material may be forced under pump pressure into the more permeable strata. After a given interval of time, the solution gels into a semisolid state which seals the strata against invasion by the stimulation fluid. Many methods have been developed for displacing the gelatinous material from the wellbore when the given production or injection interval is commenced. One of the methods for removing the gelatinous material from the wellbore is to inoculate the material before introduction with bacteria, which after a given interval of time consumes the solid parts of the gel so that it will then assume a liquid state and flow further into the formation or be produced in the wellbore, whichever the case may be. Other methods for removing the material after stimulation involve penetration of the material with a reagent which upon contacting the gelatinous material precipitates it so that it may be removed from the wellbore or pushed from the wellbore into the formation.

Other techniques previously utilized to selectively plug a perforated wellbore liner involve the use of a plugging agent such as a rubber covered or solid rubber ball which is pumped down the well hole during the stimulation treatment to plug off casing perforations which are receiving undesired amounts of fluid. By this procedure, the fluid is then diverted to those portions or zones of the reservoir which are least receptive to the fluid. An inherent problem in this procedure is that no control is maintained over which perforated interval of the wellbore liner will receive the balls and in many instances results in undesired stimulation in some portions of the reservoir. The balls are released from the perforations by decreasing the differential pressure in the wellbore and recovered from the wellbore with the produced fluid or allowed to fall to the bottom of the well. Methods have been proposed for recovering the balls from the perforations by attaching wires thereto so that after the desired stimulation technique is accomplished, the wires may be removed from the wellbore thereby removing the attached balls with them.

Another method utilized to selectively plug perforated zones in a perforated wellbore liner involves the use of several packing glands which are introduced below and above the perforated zones to be treated. By this procedure no stimulation fluid is allowed to enter those perforations below the lowermost packer, whereas the top packer has a tubing string attached thereto through which treatment solution is introduced only into that portion of the perforated zone to be stimulated. Subsequent to the stimulation technique, the packers may be shifted to another zone in which stimulation is desired or removed from the well for continuity of production from or injection into the wellbore.

The problems associated with selectively plugging perforated zones in a wellbore liner suggest that one must use

considerable equipment in order to selectively plug zones of a wellbore liner. Generally, the methods involve more than a one-step process for the treatment of these intervals. What is required is apparatus by which intervals of a production or injection wellbore liner may be selectively treated by a single step process and subsequent to the treatment the perforated wellbore liner may again be opened for fluid flow therethrough.

It is an object of the present invention to provide apparatus by which certain zones of a perforated wellbore liner may be selectively plugged.

It is another object of the present invention to provide apparatus by which a perforated liner may be selectively plugged and the unplugged zones of the wellbore liner treated simultaneously.

It is still a further object of the present invention to provide apparatus by which perforated zones of a perforated wellbore liner may be selectively treated and subsequently returned to an unplugged state after treatment.

With these and other objects in mind, the present invention is hereinafter set forth with reference to the following description and drawings.

SUMMARY OF THE INVENTION

The objects of the present invention are accomplished by apparatus comprising a housing having one or more recesses along its length. Some of the recesses contain ball sealers which are attached to the housing by a flexible member. The apparatus also contains means for compressing the ball sealer in said recess. In addition, the apparatus comprises means for expelling the ball sealers from the housing and means for positioning said apparatus in said wellbore. The means for retaining the ball sealers may comprise a sleeve surrounding the housing having one or more holes larger than the ball sealers at the same intervals as the recesses in the housing and springs positioned in the recesses between the housing and the ball sealers. In most instances the housing and sleeve of the apparatus will be circular so as to conform with the wellbore into which it is introduced. The flexible member used to connect the ball sealer to the housing is generally a length of wire. Suitable means for positioning the apparatus in the wellbore may comprise a cable securely attached to the upper portion of the sleeve so that standard logging techniques may be used to raise or lower the housing and sleeve in the wellbore.

Appropriate means for expelling the ball sealers from the housing may also comprise a fluid storage chamber contained in the upper portion of the sleeve accompanied by a release chamber within the sleeve below and adjacent to the fluid chamber and above the upper portion of the housing, and a reversible hydraulic pump situated between the fluid chamber and the release chamber. Also included are means for actuating the hydraulic pump, means for sealing the sleeve from the upper portion of the housing at a position above the uppermost recess in the housing and flexible means for positioning the sleeve such that the holes therein are not aligned with the recessing in the housing.

Another embodiment of the apparatus consists of the means for expelling the ball sealer from the housing comprising a gas storage chamber positioned in the upper portion of the sleeve. The release chamber within said sleeve will be positioned below and adjacent to the gas chamber and above the upper portion of the housing. An electronically activated pressure release valve is situated between the fluid chamber and the release valve. The release valve is situated between the fluid chamber and the release valve. The release valve is attached to the cable extending from the surface which is used to activate the valve. Also provided is a means for sealing the sleeve from the upper portion of the housing at a position above the uppermost recess in the housing and releasable means for positioning the sleeve such that the holes therein are not aligned with the recesses in the housing. The sleeve may be eliminated by providing a channel through which fluid may

pass within the housing connected to each recess. The ball sealers are loaded in the recesses and the means for expelling the ball sealers provided by a fluid rapidly passed through the channel and out the recesses.

Still Another apparatus may be used for the means for expelling the ball sealer from the housing which comprises one or more shear pins positioned at the upper portion of the housing in a position above the uppermost recess in the housing. The uppermost portion of the sleeve has an opening therein whereby the fluid surrounding the sleeve is in direct contact with the upper portion of the housing. There are also provided means for sealing the sleeve from the upper portion of the housing at a position above the uppermost recess in the housing but below the shear pins applied to the sleeve and housing and releasable means for positioning the sleeve such that the holes therein are not aligned with the recesses in the housing.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is hereinafter described in further detail with particular reference to the accompanying drawings in which:

FIG. 1 depicts a wellbore perforation plugging apparatus activated by a hydraulic pump;

FIG. 2 represents a piston and rupture disc activated wellbore perforation plugging apparatus;

FIG. 3 illustrates a wellbore perforation plugging apparatus using shear pins for means for expelling the ball sealers; and

FIG. 4 shows a wellbore perforation plugging apparatus which utilizes a pressurized fluid to expell the ball sealers towards the perforated liner.

DETAILED DESCRIPTION OF THE INVENTION

Many methods and apparatus have been proposed for the selective plugging of perforations in wellbore liners. All of the methods, however, suffer from the fact that exact perforation plugging of different perforated intervals is difficult. Many methods merely teach the introduction of perforation balls into the well followed by treatment fluid. By this random introduction method the balls seek the path of least resistance and proceed to those perforations through which the greatest quantity of fluid is flowing. Therefore, the ball sealers do not always selectively plug the area of the wellbore which is desired. The present invention, however, provides an apparatus for selectively plugging distinct perforated zones of a wellbore and also leaves the zones for which treatment is desired unplugged.

The perforation plugging apparatus consists of a housing having selective recesses at intervals along its length. The housing is circular and made somewhat smaller in diameter than the diameter of the wellbore to be treated. Ball sealers are set in selected recesses and loaded so that they may be released from the apparatus when desired. The ball sealers are further attached to the apparatus by a length of wire so that when the apparatus is removed from the perforated zone the ball sealers are retrieved from the perforated liner. Means are provided for expelling the ball sealers so that the ball sealers are shot towards the wellbore liner and seek the perforations therein.

Referring to FIG. 1, a wellbore perforation plugging apparatus is depicted consisting of a housing 101, which is circular and of a diameter slightly smaller than that of the wellbore. Generally, the diameter of the housing will be 2 to 3 inches smaller than that of the wellbore casing. The housing is of sufficient length to allow treatment of the total perforated zone which is to be treated. The housing 101 has recesses 102 located at intervals along its length commonly used for perforating wellbore liners. Each of the recesses 102 may contain a ball sealer 104 which is spring loaded by a spring 103 if plugging at that interval is desired. The recesses have an upward indentation 105 in which a wire 106 is contained which is attached to the ball sealer 104 and welded to the circular housing 101 by weld 107. Therefore, when the ball sealer 104

is released by the spring 103, it is forced out of recess 102 towards the perforation in the wellbore but is restricted from falling to the bottom of the well by wire 106 and also retrieved by the wire 106 when the apparatus is removed from the wellbore. The ball sealers 104 are positioned and compressed by sleeve 108. The sleeve 108 contains holes 100 within its body slightly larger than the recesses 102 so that as the holes 100 are positioned over the recesses 102 the ball sealers 104 are ejected. The sleeve is secured by shear pin 110 in a position such that the holes 100 are slightly below each of the recesses 102 in the housing 101. The shear pin 110 is securely attached to the inside of the sleeve 108 and penetrates into the housing 101 and is of such shear strength that a nominal amount of pressure on the housing 101 will break the shear pin 110 and allow the chamber 101 to move downwardly within sleeve 108.

The means for engaging the sleeve 108 consists of a two chamber compartment located in the sleeve 108 at the top of the housing 101. A first fluid chamber 114 is located in the uppermost part of the sleeve 108 into which hydraulic fluid is introduced. The fluid chamber 114 is separated from the top of the housing 101 by structural member 115 which is a circular plate welded to the walls of the sleeve 108 so as to form a release chamber 112 above the housing 101. Secured to the structural member 115 is a hydraulic pump 113 which has a reversible mechanism so that fluid may be transferred from fluid chamber 114 to the release chamber 112 and vice versa. The hydraulic pump 113 has an electrical drive which receives its current from two-wire electrical line 118 which is secured to cable 116 which extends to the surface with the opposite end attached to the hydraulic pump 112. Cable 116 is a typical logging cable which is secured to wellbore connector 117. The connection to wellbore connector 117 is a fluid tight connection so that no wellbore fluid may enter the wellbore perforation plugging apparatus. Release chamber 112 is protected from invasion of wellbore fluids by sealing with O-ring seals 119 and 120 in their respective races positioned in the upper portion of housing 101. O-rings 119 and 120 are of sufficient size so as to be mounted flush with the inside portion of the sleeve 108. Therefore, the entire housing 101 acts as a piston within the sleeve 108.

In the operation of the wellbore perforation plugging tool the hydraulic pump 113 is activated by introduction of electric current through the two-wire line 118 secured to cable 116. This activation transports hydraulic fluid from fluid chamber 114 through structural member 115 into release chamber 112. The introduction of fluid into release chamber 112 drives the entire housing downward with slippage of O-rings 119 and 120 along the inside of the sleeve 108. This downward movement breaks the shear pin 110 and allows the housing 101 to touch the bottom of the sleeve 111. In this downward position the holes in sleeve 108 align themselves with the recesses 102 in the housing 101 to touch that the ball sealers 104 are expelled by the compression release of spring 103 and are projected towards the perforations 122 in the wellbore casing 121. Subsequent to plugging of the desired perforations 122, wellbore treatment is begun. After the formation has been treated the apparatus 110 is removed from the wellbore and the ball sealers 104 are retrieved from the perforations 122 as they are connected by wire 106 to the housing 101. The apparatus 110 is brought to the surface and reloaded by replacing ball sealers 104 in the respective recesses 102 in the housing 101 by compressing spring 103 and replacing the sleeve 108 into its original position with the recesses closed to the outside environment. The shear pin 110 is placed in the housing 101 and the hydraulic fluid evacuated by reversal of the hydraulic pump 113 and retransporting of the hydraulic fluid from release chamber 112 to fluid chamber 114. The apparatus 110 is then readied for another introduction into the wellbore. When loading the apparatus 110 some intervals of the wellbore casing may not be desired to be plugged. These intervals may be left unplugged by not loading the ball sealer 104 in the respective recesses 102 such as depicted by recess 109 which

does not contain a ball sealer. Therefore, as the ball sealers are released the respective intervals along the tool will not be selectively plugged and left open for treatment.

FIG. 2 depicts wellbore perforation apparatus which utilizes the hydrostatic pressure of a fluid introduced in the well to manipulate the sleeve into the position such that the ball sealers are released. The sleeve 208 is positioned in the same manner about the housing 201 as previously discussed above. The upper portion of the wellbore tool is sealed by O-rings 219 and 220 as in the previous invention embodiment. No external mechanism is required to actuate the sleeve 208 when the apparatus reaches the perforated zone at which plugging is desired. The sleeve 208 is actuated by movement of the piston 223 which is sealed against the inside wall of the sleeve 208 by O-rings 224 and 225. In normal loading, the piston 223 is positioned in the upper portion of the sleeve 208 to form a fluid cavity 214 containing a hydraulic fluid resting upon a rupture disc 222. This rupture disc 222 is manufactured such that at a specified pressure it will break and allow hydraulic fluid from fluid chamber 214 to enter release chamber 212 which is formed by the space between the rupture disc 222 and the top of the housing 201. There is a cavity above the piston 221 which is in direct contact with the wellbore fluid through opening 226 in sleeve 208.

The tool is lowered by cable 216 attached to wellbore connector 217. When the tool is positioned in the appropriate portion of the wellbore so that the ball sealers are directly opposite those perforations to be plugged, fluid is pumped into the wellbore at sufficient pressure so that the fluid enters the sleeve 208 through opening 206, fills chamber 221 and drives piston 223 downward against hydraulic fluid 214. As the piston moves in the downward position the hydraulic fluid 214 develops sufficient pressure so that rupture disc 222 breaks and allows fluid to enter release chamber 212 and thereby drives the housing 201 into the position at which the openings in the sleeve are adjacent to the ball sealers. The ball sealers are released so as to selectively plug the perforations in the wellbore casing. In the use of this invention embodiment no external apparatus is required with the wellbore liner perfora-

FIG. 3 depicts another embodiment of the present invention in which the housing 301 is secured and sealed from the chamber 321 and direct contact with wellbore fluid by means of O-rings 324 and 325. The entire housing 301 then acts as a piston slideably mounted within sleeve 308. There is also an opening 326 in the top of sleeve 308 through which wellbore fluid may contact chamber 321 and the top of housing 301. The tool is similarly fastened to cable 316 at tool connector 317 and lowered into the well. As fluid is injected into the well the O-rings 324 and 325 hold the housing 301 stationary until sufficient pressure is built up and the shear pin 310 breaks and allows housing 301 to slide downwardly. Therefore, with a surge of wellbore fluid injection the housing 301 is driven downward and the holes in the sleeve 308 are aligned with the ball sealers so as to release the ball sealers and allow perforation plugging of the wellbore liner as desired.

The sleeve may be entirely removed by use of an apparatus of the type shown in FIG. 4. Housing 401 contains recesses 402 as previously described and containing ball sealers 404 slightly larger than said recesses 402 so as to be held tightly within the recesses, connected by wire 406, welded to housing 401 by spot weld 407. The housing 401 also contains a pressurized fluid chamber 421 which contains a pressurized fluid. Channel 423 connects pressurized fluid chamber 421 with recesses 402. An electrically activated pressure release valve 422 is axially positioned between pressurized fluid chamber 421 and pressurized fluid channel 423 and activated from the surface by two-wire line 418 secured to cable 416, passing through connector 417 and connected to pressure release valve 422. When plugging is desired and the apparatus is properly positioned, the pressure release valve is opened by an electric impulse through two-wire line 418. The pressurized fluid contained within pressurized fluid chamber 421 is

released through channel 423 so as to expell ball sealers 404 from the apparatus. The apparatus and ball sealers are retrieved as described previously. The pressurized fluid chamber 423 is refilled through fluid fill valve 424.

The wellbore perforation plugging apparatus may be comprised of standard wellbore tool materials. Generally, high grade stainless steel or other noncorrosive metals are used for the construction of the sleeve and housing mechanisms. Standard O-rings may be used as sealing means and generally those of the neoprene or Teflon variety are applicable. The ball sealers most often will consist of a rubberlike or resilient material normally consisting of butadiene or neoprene rubber which is noncorrosive in the wellbore elements and through which a wire generally made of stainless steel or another noncorrosive high strength material may be attached. Normal springs for the spring loaders may be used but should be of sufficient material to give lasting life, resiliency and noncorrosiveness. In the embodiment of the invention utilizing a hydraulic pump any standard oil or hydraulic fluid may be used for pressuring the housing and allowing the piston type motion. Standard wellbore cables and connectors are also used for the tool.

The present invention provides an apparatus with which perforations in a wellbore liner may be selectively plugged so that the wellbore may be hydraulically fractured in preferential zones, stimulated through preferential zones, or treated in other manners such as selective plugging, etc. and thereby allow the wellbore after treatment to be returned to its original perforated sequence.

While the invention has been described herein with respect to particular embodiments and thereof, it will be appreciated by those skilled in the art that various changes and modifications may be made, however, without departing from the scope of the invention.

Therefore, I Claim:

1. Apparatus for selectively plugging perforated wellbore casing comprising:

- a. a housing having one or more recesses therein;
- b. ball sealers contained in one or more of said recesses;
- c. flexible members, one end of which is attached to said housing and the other to said ball sealers;
- d. means for containing said ball sealers within and expelling said ball sealers from said housing; and
- e. means for positioning said apparatus in said wellbore.

2. The apparatus of claim 1 in which the means for containing said ball sealers within and expelling said ball sealers from said housing comprises:

- a. a sleeve surrounding said housing having one or more holes larger than said ball sealers at the same intervals as the recesses in said housing;
- b. means for compressing said ball sealer in said recess; and
- c. means for expelling said ball sealer from said housing.

3. The apparatus of claim 2 in which said means for compressing said ball sealers in said recesses is a spring, positioned in each of said recesses between said housing and said ball sealers so as to compress the ball sealers against said sleeve.

4. The apparatus of claim 3 in which said means for positioning said apparatus in said wellbore is a cable securely attached to the upper portion of said sleeve.

5. The apparatus of claim 4 in which the means for expelling said ball sealer from said housing comprises:

- a. a fluid storage chamber in the upper portion of said sleeve;
- b. a release chamber within said sleeve below and adjacent to said storage chamber and above the upper portion of said housing;
- c. a reversible hydraulic pump situated between said storage chamber and said release chamber;
- d. means for actuating said hydraulic pump;
- e. means for sealing the sleeve from the upper portion of said housing at a position above the uppermost recess in said housing; and

- f. releasable means for positioning said sleeve such that the holes therein are normally not aligned with the recesses in said housing and when said sleeve is released are aligned with the recesses in said housing.
6. The apparatus of claim 5 in which:
- a. said means for sealing the sleeve from the upper portion of said housing is one or more pressure rings set in races in the housing and in sealing contact with the inside of said sleeve;
 - b. said releasable means for positioning said sleeve is a shear pin having one end thereof attached to the inside of said sleeve and the opposite end introduced into said housing; and
 - c. said means for actuating said hydraulic pump is a two-wire line secured to said hydraulic pump and attached to the cable from the surface.
7. The apparatus of claim 4 in which the means for expelling said ball sealer from said housing comprises:
- a. a pressurized fluid chamber in the upper portion of said sleeve;
 - b. a release chamber within said sleeve below and adjacent to said pressurized fluid chamber and above the upper portion of said housing;
 - c. an electronically activated pressure release valve situated between said pressurized fluid chamber and said release chamber;
 - d. a two-wire line secured to said electronically activated pressure release valve and attached to the cable from the surface;
 - e. means for sealing the sleeve from the upper portion of said housing at a position above the uppermost recess in said housing; and
 - f. releasable means for positioning said sleeve such that the holes therein are normally not aligned with the recesses in said housing and when said sleeve is released, are aligned with the recesses in said housing.
8. The apparatus of claim 4 in which the means for expelling said ball sealer from said housing comprises:
- a. a piston, slideably mounted within the upper portion of said sleeve;
 - b. a circular pressure rupture disc the same cross section as the inner area of the sleeve securely attached to the inner surfaces of the sleeve below the piston and above the housing so as to form a piston chamber between the

- piston and the pressure rupture disc and a release chamber between the pressure rupture disc and the housing;
- c. the uppermost portion of the sleeve housing having an opening therein whereby the fluid surrounding the sleeve is in direct contact with the upper portion of the piston;
 - d. means for sealing the sleeve from the upper portion of said housing at a position above the uppermost recess in said housing; and
 - e. releasable means for positioning said sleeve such that the holes therein are normally not aligned with the recesses in said housing and when said sleeve is released are aligned with the recesses in said housing.
9. The apparatus of claim 4 in which the means for expelling said ball sealer from said housing comprises:
- a. one or more shear pins positioned at the upper portion of said housing in a position above the uppermost recess in said housing;
 - b. the uppermost portion of the sleeve housing having an opening therein whereby the fluid surrounding the sleeve is in direct contact with the upper portion of the housing;
 - c. means for sealing the sleeve from the upper portion of said housing at a position above the uppermost recess in said housing but below the one or more shear pins; and
 - d. releasable means for positioning said sleeve such that the holes therein are normally not aligned with the recesses in said housing and when said sleeve is released are aligned with the recesses in said housing.
10. The apparatus of claim 1 in which means for containing said ball sealers within and expelling said ball sealers from said housing comprises:
- a. a pressurized fluid chamber in the upper portion of said housing;
 - b. a channel connecting said pressurized fluid chamber and recesses;
 - c. a pressure release valve positioned so as to restrict flow of the pressurized fluid contained within said pressurized fluid chamber and said channel;
 - d. means for activating said pressure release valve so is to allow fluid to flow from said pressurized fluid chamber through said channel; and
 - e. the ball sealers are slightly larger than the recesses so as to be held firmly therein.

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