

Oct. 27, 1953

L. W. TOELKE

2,656,891

APPARATUS FOR PLUGGING WELLS

Filed March 2, 1948

2 Sheets-Sheet 1

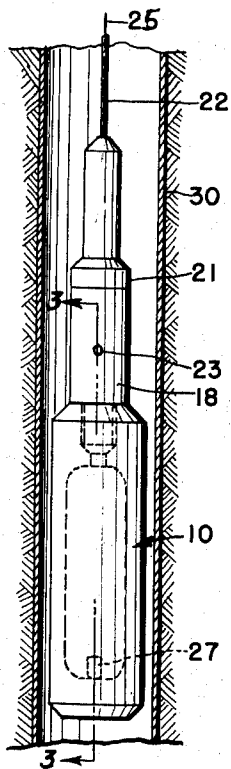


FIG. 1

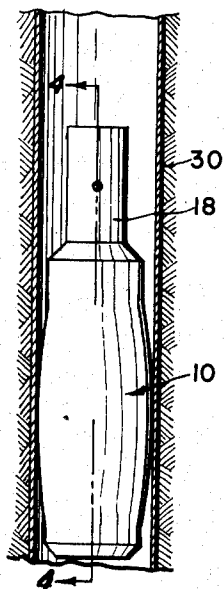


FIG. 2

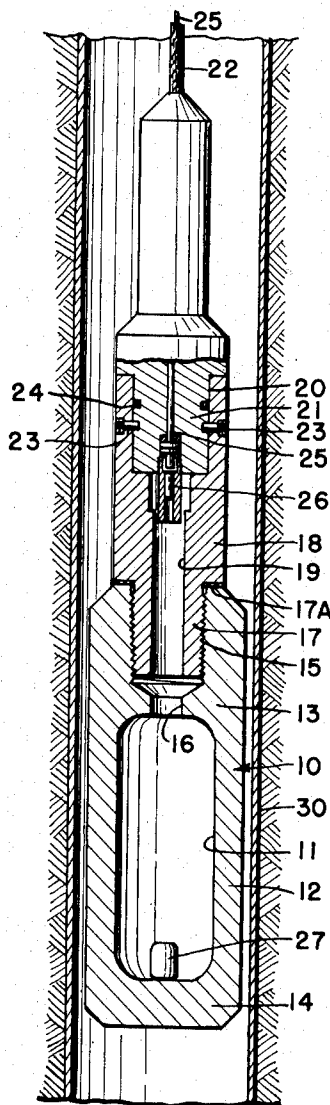


FIG. 3

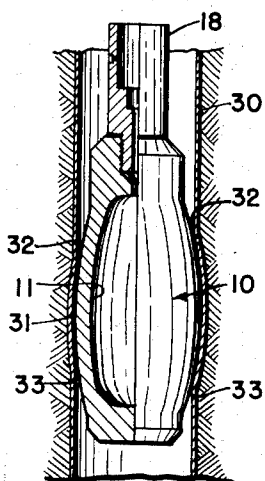


FIG. 5

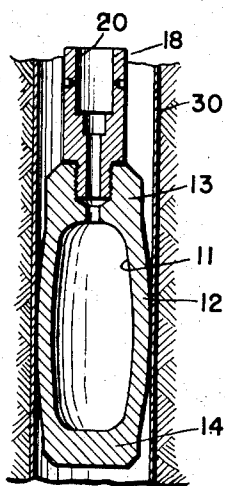


FIG. 4

L. W. TOELKE  
INVENTOR.

BY

*L. W. Toelke*  
ATTORNEY

Oct. 27, 1953

L. W. TOELKE  
APPARATUS FOR PLUGGING WELLS

2,656,891

Filed March 2, 1948

2 Sheets-Sheet 2

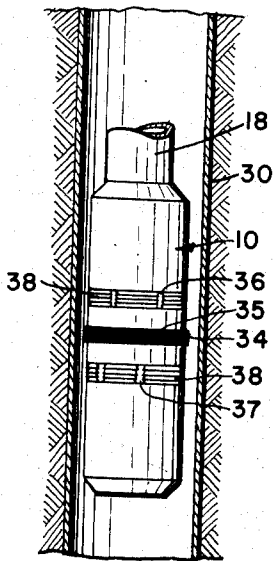


FIG. 7

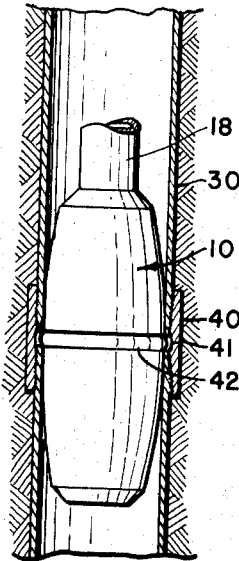


FIG. 6

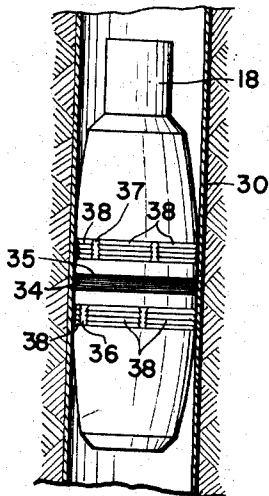


FIG. 8

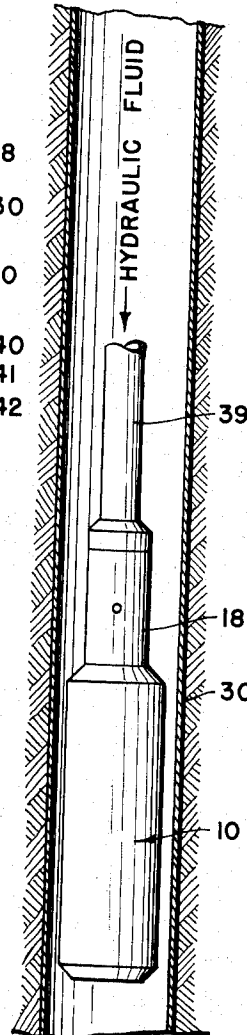


FIG. 9

L. W. TOELKE  
INVENTOR.

BY

*R. W. Toelke*  
ATTORNEY

## UNITED STATES PATENT OFFICE

2,656,891

## APPARATUS FOR PLUGGING WELLS

Lester W. Toelke, Houston, Tex.

Application March 2, 1948, Serial No. 12,523

3 Claims. (Cl. 166-13)

1

The present invention relates to improvements in apparatus for plugging wells and particularly to improved forms of plugging devices and bridging plugs useful for such purposes.

Bridging plugs are conventionally employed in wells, such as oil or gas wells, for plugging off one section of a well from another for various operational purposes, as, for example, in connection with the testing of strata at several elevations to determine their respective oil or gas producing characteristics. Most plugs heretofore employed for this purpose use a sealing body composed of rubber or similar resilient material which is compressed or otherwise distended to expand it into sealing engagement with the well casing and require some form of toothed slips or other gripping means to support the sealing body in its expanded position in order to maintain the required seal. These conventional forms of plugs are commonly of rather complicated mechanical construction; require elaborate setting tools; frequently fail to establish or maintain a fluid-tight seal; are difficult to remove when it is desired to clear the well or to return to the portion of the well below the plug; are relatively expensive to construct; and require considerable time and effort to set them properly.

The practice of this invention, briefly stated, comprises inserting into a well bore, casing or other pipe in a well to the desired setting depth a hollow metallic plug designed and constructed in accordance with this invention, and expanding the walls of the plug through the application internally thereof of fluid pressure of sufficient force to expand the plug into tight plugging engagement with the surrounding casing, the expansive force applied being generally in excess of the elastic limit of the material of which the plug is constructed, whereby the plug becomes permanently deformed and set in its expanded condition.

The fluid pressures employed for setting the plugs may be either pneumatic or hydraulic and may be developed in various ways. One method for developing and applying the requisite force is by setting off inside the plugging device a suitable explosive material which is adapted to rapidly generate gases of sufficient volume and pressure for the purpose. Devices in accordance with this invention possess the important advantages of relative simplicity in operation and high speed in effecting the plugging operation, the ability to attain any desired pressures, and to form seals capable of withstanding high external pressures without leakage. Also, since

2

the pressure-generating characteristics of various types of explosive materials are well known, the quantity of explosive material required to develop the desired pressure in each case may be readily pre-determined, thereby providing effective control of the plug expanding operation.

The requisite pressures may also be developed hydraulically by the use of generally conventional means for pumping a suitable hydraulic fluid, such as water or oil, into the interior of the plug until the desired expansive pressure is attained. This embodiment will normally require more time and equipment than the explosive embodiment but may be successfully employed, if desired.

The plugging devices which may be employed in the practice of this invention are of extremely simple design and relatively cheap construction and, in general, comprise a hollow generally cylindrical metallic body, having a normal outside diameter somewhat less than the internal diameter of the well casing in which it is to be inserted. The metallic materials employed for construction of the plugging device may be any metallic material possessing a sufficient degree of ductility or plasticity such that when subjected to the requisite pressure, the walls thereof will expand to the desired extent without rupture or cracking and will become permanently set in their expanded condition. Many metals and their alloys possess these characteristics, some of the more useful examples of which are aluminum and magnesium and their various alloys, copper and its alloys including various brasses and bronzes, mild steels, etc. Generally speaking the metallic materials will be employed in their non-heat treated forms which are generally softer and have greater ductility and plasticity than their heat-treated forms. It will also be found more generally desirable to employ metals having a relatively wide spread between their elastic limits and their ultimate strengths, this spread, of course, being to some extent a measure of the ductility or elongation characteristics of the particular metal. Ordinarily, metallic materials capable of elongation of 15% or more in two inches, as determined by standard test methods, will be found to be preferable, although materials of lesser elongation characteristics may be used in particular cases. Generally speaking, the type and character of metal selected in any instance will normally depend upon the particular conditions to be met, such as the degree of expansion required, the pressures to be withstood by the seal, etc.

Accordingly, among the principal objects of

this invention are the provision of a plugging device for plugging wells which is adapted for simple and quick operation; which effects permanent seals capable of withstanding without leakage any external pressures which may be encountered in oil or gas wells; which does not require elaborate or expensive setting tools; and which is of relatively simple and cheap constructions.

A further object is the provision of a device for plugging a well pipe by the expansion therein of a hollow metallic plug through the application of a fluid pressure sufficient to expand the plug into permanently set plugging engagement with the well pipe.

An additional object is the provision of a hollow metallic plug which is expandible into plugging engagement with a well bore through the application to the interior of the plug of pressure generated therein by the use of explosive material.

Other and more specific objects and advantages of this invention will become apparent from the following detailed description when read in conjunction with the accompanying drawings which illustrate several useful embodiments in accordance with this invention.

In the drawings:

Fig. 1 is an elevational view of a bridging plug in accordance with one embodiment of this invention as it appears when suspended in a well casing from a conductor cable preparatory to setting the plug;

Fig. 2 is a corresponding elevational view showing the plug set in the casing and the conductor cable removed;

Fig. 3 is an enlarged sectional view through line 3—3 of Fig. 1, showing the parts of the bridging plug in the positions assumed when running into the well casing and before being set;

Fig. 4 is an enlarged sectional view through line 4—4 of Fig. 2 showing the form and position of the parts of the plug after it has been set;

Fig. 5 is a quarter-sectional view of a plug similar to that shown in Figs. 1 to 4 inclusive which has been set under pressure sufficient to expand the portion of the casing which is in contact with the plug;

Fig. 6 is an elevational view of a plug which has been set opposite a casing coupling;

Figs. 7 and 8 are elevational views, before and after setting, of a somewhat modified form of plug; and

Fig. 9 is a view similar to Fig. 3 of a plugging structure employing hydraulic means for generating the necessary internal pressure.

In accordance with one embodiment of this invention (Figs. 1, 2, 3 and 4), the plugging device comprises a generally cylindrical body, designated generally by the numeral 10, having a bore or cavity 11 internally thereof enclosed by a circumferential wall 12, and upper and lower end closures 13 and 14, respectively. Body 10 may be constructed of a metallic material of the character mentioned above and may be fabricated in any conventional manner, as by forging, casting, machining, etc. While body 10 will normally, and generally preferably, be constructed from a single piece of metal, it will be understood that wall 12 and end closures 13 and 14 may be fabricated of separate pieces of metal and assembled in any conventional and well-known manner. End closures 13 and 14 will normally be made of greater thickness and mass than wall 12 in order that the fluid pressure to be applied, as hereinafter described, in cavity 11

will generally preferentially expand wall 12. Upper end closure 13 is provided with an internally threaded box 15, the lower end of which communicates with the interior of cavity 11 through an axial passageway 16. Box 15 is adapted for threaded connection to the threaded pin 17 of a connector sub 18, which is provided with an axial passageway 19 registering with passageway 16. A sealing gasket 17a, of conventional form is interposed between contiguous faces of sub 18 and box 15 to form a tight seal therebetween. The upper end of passageway 19 is enlarged to form a smooth-walled socket 20 which is adapted to slidably receive therein the connection head 21 carried by the lower end of an electrical conductor cable 22 which serves also as a means for suspending and lowering the plugging device in a well to be plugged. A plurality of shear pins 23 extend radially through the wall of socket 20 into suitable recesses provided in head 21 and serve to attach the plugging device to the cable. A seal ring 24, of any suitable and conventional form is suitably mounted between socket 20 and head 21 to prevent entrance of any extraneous fluids into the interior of the plugging device through this connection. Cable 22 contains an electrical lead 25 which is threaded through head 21 and is adapted to make contact with a cooperating contact carried by the end of a conventional electrically ignitable fuse cartridge or initiator 26 which is suitably mounted in the lower end of head 21 and extends into passageway 19. Cartridge 26 is of a well known form which is adapted, when set off, to discharge into cavity 11 a jet of gases at sufficient pressure to ignite or detonate the main charge of explosive material, indicated generally by the numeral 27, disposed in cavity 11. Other more or less conventional initiator arrangements, well known in the explosive art, may be employed for setting off main charge 27. It will also be understood that lead 25 of cable 22 will be connected at its upper end to any suitable source of electric current with conventional switching mechanism (not shown) for setting off cartridge 26. Such mechanisms and their operation are well known and of themselves form no part of this invention.

The main explosive charge 27 may consist of any of the well known chemical explosive substances including the various detonating and deflagrating types. The detonating type explosives may be exemplified by trinitrotoluene, penta-erythritol tetranitrate, "Pentolite," "Amytol," "Cyclonite," "Tetryl," "Tetrytol," and the like. The deflagrating types include the various smokeless nitrocellulose base explosives and the various black powders. These explosive materials may be employed in granular, plastic or molded highly compressed pelletized form, the pressure generating characteristics of all such explosive being well understood and readily determinable for each particular case. It will be understood that the quantity of explosive used will depend in general upon the character of the particular explosive material and the pressures to be developed in each particular case.

The method of plugging a well, using the above-described apparatus, may be as follows: A main charge 27 of the selected explosive material in the predetermined quantity to generate the desired pressure, will be introduced through passageway 16 into cavity 11 of the plug. Sub 18 will be screwed tightly into the plug body, and head 21 carrying cartridge 26 will be inserted

into socket 20 of the sub and locked thereto by means of shear pins 23. The plugging device, thus attached to cable 22, will be lowered into the well casing 30 to the desired point in the well at which it is to be set. When the setting point is attained, cartridge 26 will be fired by suitable manipulation of the firing mechanism at the top of the well, and the resulting blast will travel through passageways 19 and 16 into cavity 11 where it will set off main charge 27. The gases generated by the explosion of the main charge, being closely confined within cavity 11, will almost instantaneously develop very high pressure inside cavity 11. The resulting force will cause wall 12, being the relatively weaker portion of the plugging body, to expand radially outwardly into tight engagement with the wall of casing 30. The pressure developed in cavity 11 will be substantially uniformly distributed about the interior of the cavity, and the resulting expansion of wall 12 will be generally uniform radially in all directions, so that a tight circumferential seal will be effected between body 10 and casing 30. Figs. 2 and 4 illustrate the general shape assumed by body 10 following expansion. As noted previously, the quantity and density of the particular explosive material selected, will be predetermined to develop the pressure necessary to produce the desired expansion of the plug body. This pressure will exert an expansive force on wall 12 such as to exceed the elastic limit of the material of which the wall is constructed but which will not attain the rupture strength of the wall. Under such a force, wall 12 will become permanently deformed and will be permanently set in its expanded position so that a tight seal with casing 30 will be maintained even after the internal pressures are relieved through normal cooling or escape of the explosive gases.

When the plug has thus been set in the casing, an upward pull or jerk will be applied to cable 22 of sufficient force to break shear pins 23. Thereupon cable 22 may be withdrawn from the well bringing with it head 21 which can then be re-prepared for use in conducting another plugging operation. Body 10 and connector sub 18 will remain in the well and, due to their relatively simple structural form and the relative softness of the metal of which they are normally constructed, may be easily cut or drilled-out by conventional methods whenever it may become necessary or desirable to clear the well for any purpose.

As noted previously, the known pressure-generating characteristics of the various explosive materials permits pre-determination of the pressure to be developed in each particular case in relation to the physical characteristics of the material of which the plugging device is constructed, so that the degree of expansion of the plug walls may be regulated and controlled within relatively narrow limits. In determining the pressure to be developed, any pre-existing pressures in the pipe in which the plug is run will be taken into account in arriving at the total pressure load to be applied in the plug. Under the force of the explosion, it is found that the metal of which the plug is constructed will be extruded into any cracks, pits or crevices which may be present in the inner surface of the casing, thereby forming a plurality of inter-engaging abutments for mechanically locking the plug to the casing which, together with the compressive and frictional forces developed, will provide a seal which is sufficiently tight to withstand

any fluid pressures which may be encountered in the well. It may be assumed that the high temperature, which is the normal concomitant of the disintegration of the explosive material, will be a factor in the expansion of the plug and in causing the described flow of plug metal, whereby the outer surface of the plug will accommodate itself more or less perfectly to the exact form and condition of the casing surface against which it is forced. This is suggested merely by way of theoretical explanation of the plugging action and is not intended to be construed as a limitation upon the described method.

A similar result may be obtained in a more positive manner in cases where exceptionally high pressures are anticipated in the well, by employing a quantity of explosive material such as to expand the plug sufficiently to produce some degree of bulging of the surrounding well casing. This modification, illustrated in somewhat exaggerated form in Fig. 5, has the additional advantage that an annular recess 31 will be formed in the casing which is of slightly greater diameter than the normal diameter of the casing. The distended walls of the plug having, of course, a complementary shape, will extend into the recess and will be lodged therein between shoulders, indicated at 32 and 33, formed by the upper and lower edges, respectively, of recess 31. Thus, in addition to the compressional and frictional forces tending to hold the expanded plug in place, a positive locking means will be provided to prevent dislodgment of the plug along the casing by forces which may be exerted from above or below the plug. In connection with this modification it will be understood that the ultimate strength of the casing will be considered in computing the quantity of explosive to be used so that the total force applied by the expansion of the plug will not attain or exceed the bursting strength of the casing.

Alternative to the modification illustrated in Fig. 5 the plug may purposely be set opposite a joint in the casing and expanded to accomplish a similar result by causing the plug metal to be extruded into the annular crevice normally present between the abutting ends of adjacent casing sections screwed into the usual coupling collar. Fig. 6 serves to illustrate this modification.

Two sections of casing 30 are shown screwed into a conventional collar 40. Normally, a narrow annular crevice 41 will be provided between the abutting ends of the casing sections when they are made up to a normal degree of tightness in the collar. The plug will be run into the casing to a point opposite a coupling 40 nearest the desired setting point and will be expanded by the application of fluid pressure in the manner previously described. It will be found that the plug metal will be extruded into crevice 41 forming an annular abutment 42 on the outer surface of the plug body which is generally complementary in shape to the seat formed by crevice 41 and is firmly locked therein. The portions of the plug surface immediately above and below abutment 42 will be tightly compressed against the adjacent portions of the casing section and the whole forms a tight immovable plug in the casing.

Figs. 7 and 8 illustrate another embodiment of a plugging device in accordance with this invention, which is adapted to be set in the same manner as the previously described form of plug and which includes supplemental means for addition-

ally assuring tight engagement between the plug and the casing. These means include a circular band 34, which may be constructed of rubber or other resilient material, and which is seated in a suitable groove 35 cut in the outer surface of body 10 at a point about mid-way along wall 12. Band 34 will generally be of a thickness such that, prior to expansion of the plug, it will extend somewhat beyond the surface of the plug. A pair of grooves 36 and 37 are cut in the exterior of body 10, respectively above and below groove 35 and generally parallel thereto. A number of toothed or wickered segmental slip members 38—38 are mounted in each of these grooves, those in upper groove 36 having their teeth pointing generally upwardly and those in lower groove 37 having their teeth pointing generally downwardly. Slip members 38 are so-disposed in the respective grooves that the teeth will ordinarily protrude slightly from the grooves. When this type of plug has been set in the same manner as previously described, band 34 will be compressed very tightly between the exterior of the plug and the casing (see Fig. 8), thereby forming a supplemental seal which will further assure a very tight seal between the plug and the casing, and the teeth of slip members 38 will be driven forcibly into the wall of the casing and maintained therein by the compressive force of the expanded plug. This engagement will further assure against slipping of the plug under any external forces which may be applied in the casing against the opposite ends of the plug.

Fig. 9 illustrates another embodiment in accordance with this invention by which expansion of the plug may be accomplished by means of hydraulic pressure instead of the pneumatic pressure employed in the previously described embodiments. In this embodiment body 10 will be of the same character and construction as those previously described but connector sub 18 will be attached to a pipe 39 through which any suitable hydraulic fluid, such as water or oil may be pumped from the surface by any well known means (not shown) into the interior of body 10 at sufficient pressure to effect the desired degree of expansion. Or sub 18 may contain any suitable and generally conventional form of compounding mechanism to build up the pressure of the hydraulic fluid supplied from the surface to the desired expansion pressure.

As one specific example of the apparatus employed in accordance with this invention, a plugging device of the form illustrated in Fig. 3 was constructed of an aluminum alloy, having a yield strength of about 6000 pounds per square inch, a tensile strength of about 16000 pounds per square inch and an elongation factor of 40% in 2 inches. This plug was made  $4\frac{1}{2}$  inches in outside diameter and  $1\frac{1}{4}$  inches inside diameter, thus providing a wall thickness of approximately  $1\frac{3}{8}$  inches. The overall length of the plug body was about 12 inches and the internal cavity was about  $5\frac{3}{8}$  inches long. 800 grains of a commercial smokeless type explosive, known as "Hercules Bull's Eye No. 2," compressed into a single pellet, was introduced into the interior

of the plug. The plug was then connected to the sub and to the head of an electric cable provided with an ignition cartridge, and inserted inside a piece of  $5\frac{1}{2}$  inch, 24 lb. standard casing and the charge set off. The plug wall was expanded so tightly in the casing that no leakage occurred when the seal was tested with water at a pressure of 6000-7000 pounds per square inch.

It will be understood that the plugging devices of the character herein described may be used alone as bridging plugs. They may also serve as a base or retainer for cement when desired, and may be used in any other connection in which it may be desirable to plug a well for various purposes.

It will be further understood that various changes and alterations may be made in the details of this invention and in the various embodiments thereof herein described without departing from the scope of the appended claims but within the spirit of this invention.

What I claim and desire to secure by Letters Patent is:

1. A well plugging device, comprising, a generally cylindrical hollow closed body insertible in a well bore, said body having a tubular side wall and end closures of greater thickness than said side wall, said side wall being constructed of metallic material which is expandible under internally applied fluid pressure into permanently set plugging engagement with said well bore without rupture of said side wall, an explosive material confined within said body adapted upon being set off to generate said fluid pressure within said body, an internally threaded box in the upper one of said end closures, a passageway providing communication between said box and the interior of said body, a tubular sub having its lower end screwed into said box and having an axial bore communicating with said passageway, an electrically fired initiator element extending into said bore adjacent its upper end, and connector means for releasably connecting said sub to a lowering cable adapted to carry electric current to said initiator element, said initiator being mounted in said connector means.

2. A well plugging device according to claim 1 wherein said metallic material is of the class consisting of aluminum, magnesium, copper, the alloys thereof, and mild steels characterized by an elongation factor of from 15% to 40% in two inches.

3. A well plugging device according to claim 1, wherein said connector means comprises a plug member carried by the end of said cable slidably insertible in the bore of said sub and shear pins connecting said plug to the wall of said bore.

LESTER W. TOELKE.

#### References Cited in the file of this patent

##### UNITED STATES PATENTS

| Number    | Name    | Date           |
|-----------|---------|----------------|
| 1,400,401 | Allan   | Dec. 13, 1921  |
| 2,212,619 | Roe     | Aug. 27, 1940  |
| 2,214,226 | English | Sept. 10, 1940 |