Jan. 18, 1955 R. L. KLOTZ. JR 2,699,721

EXPLOSIVE CUTTING DEVICE

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Fig. 1.

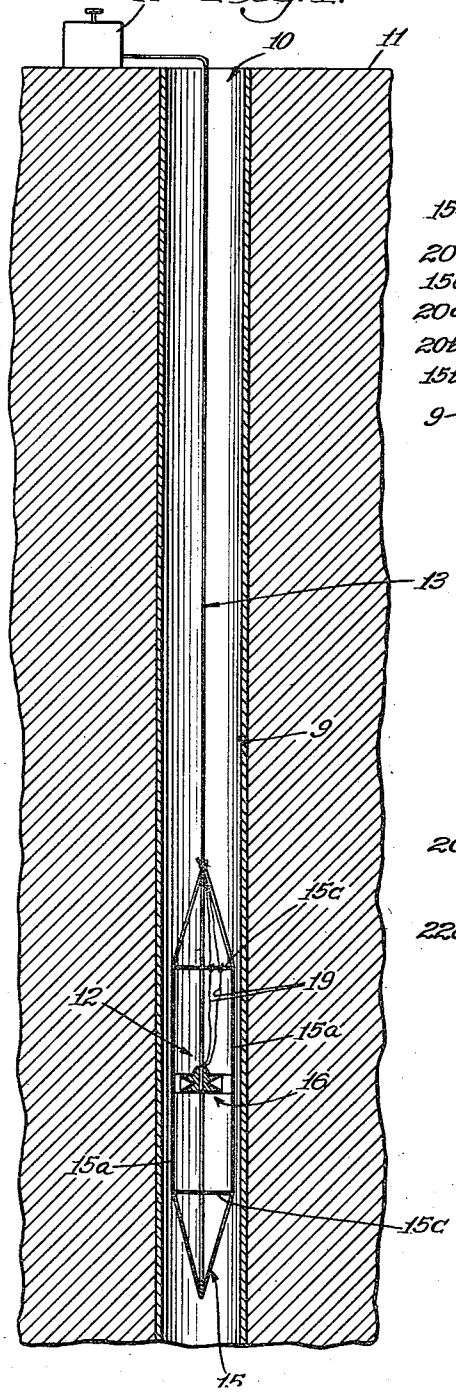


Fig. 2.

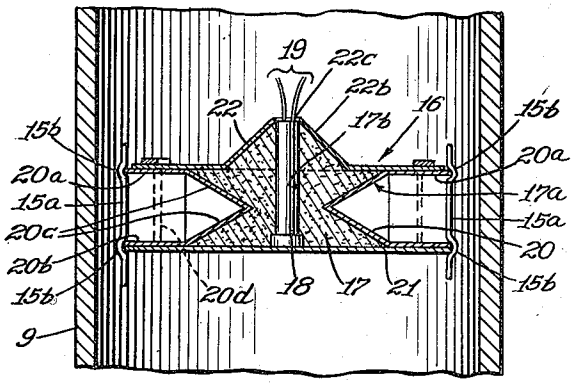
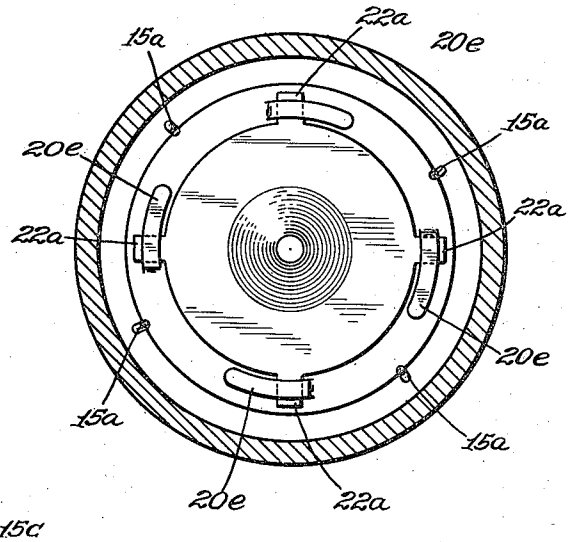


Fig. 3.



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EXPLOSIVE CUTTING DEVICE

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Fig. 4.

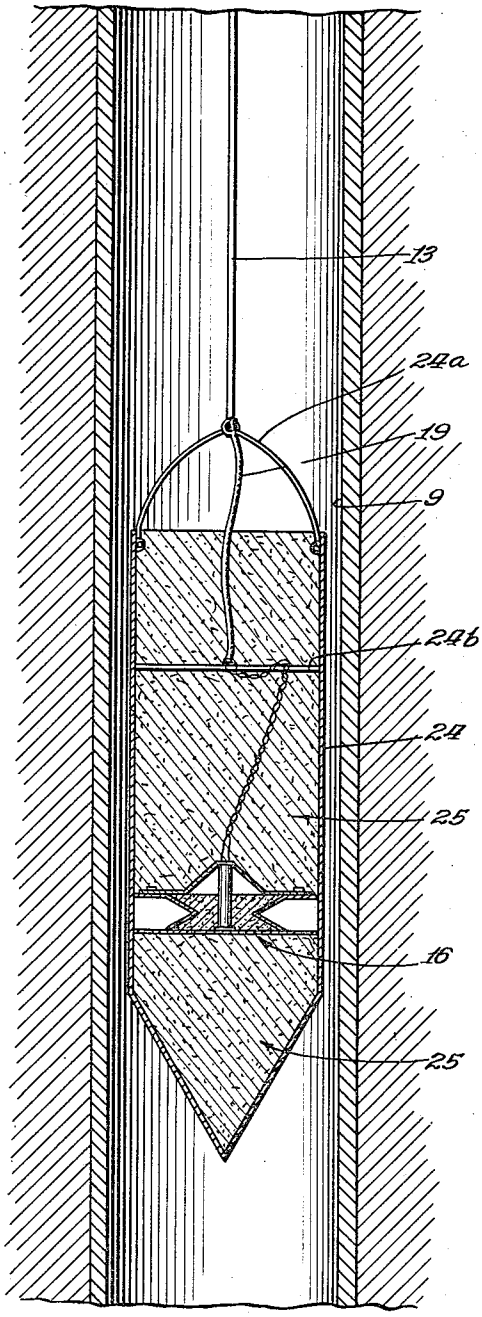
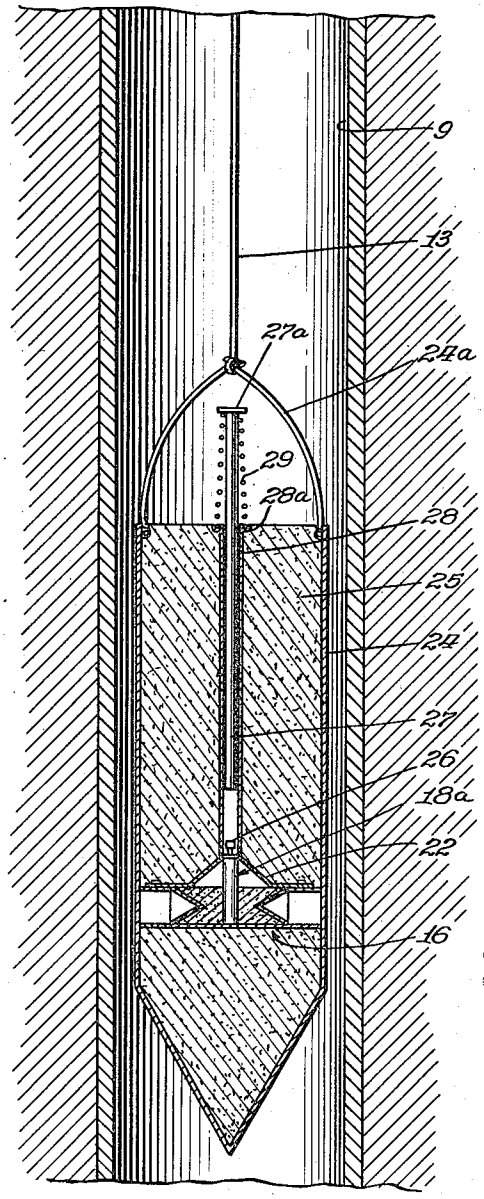


Fig. 5.



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EXPLOSIVE CUTTING DEVICE

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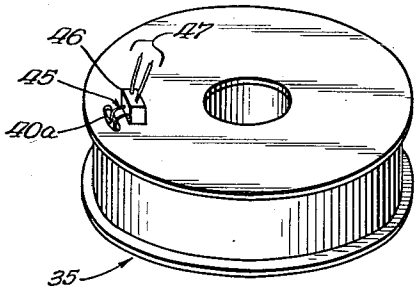
Fig. 7.



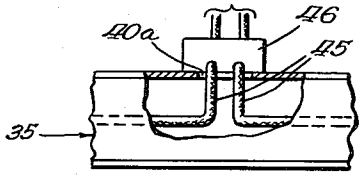


Fig. 9.

Fig. 6.

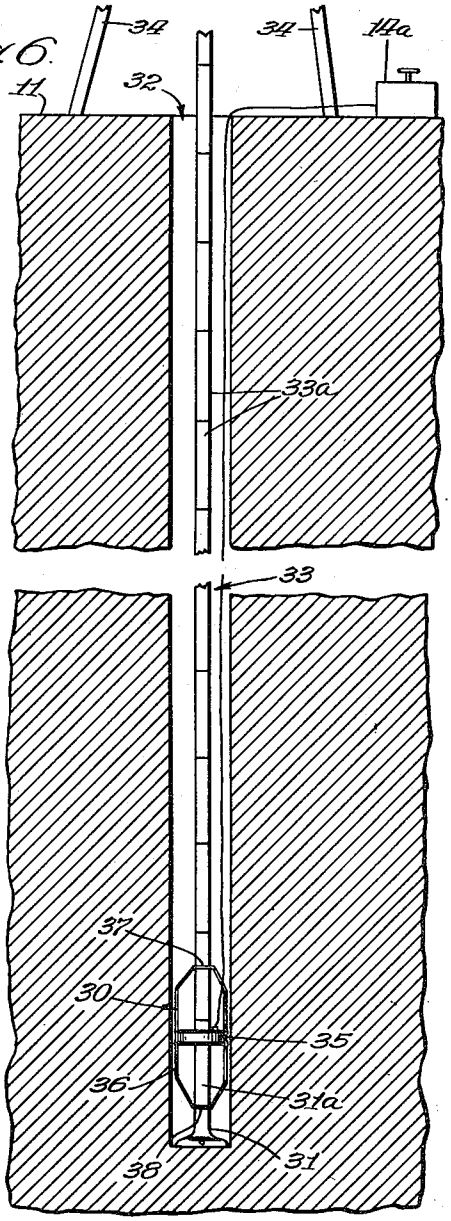
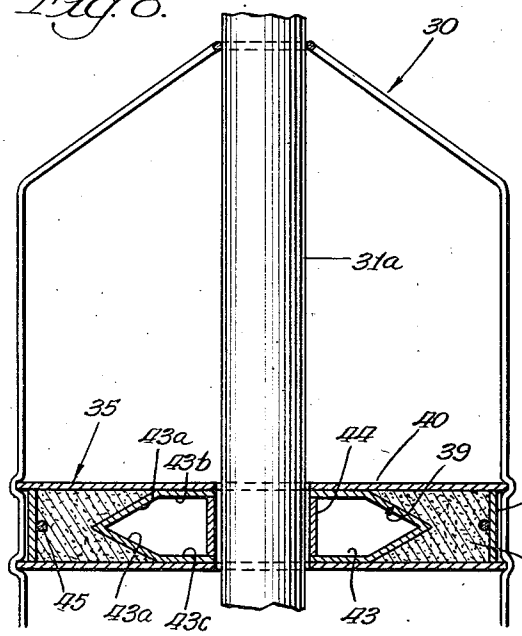


Fig. 8.



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EXPLOSIVE CUTTING DEVICE

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Application February 19, 1947, Serial No. 729,656

7 Claims. (Cl. 102—20)

The present invention relates to improvements in devices adapted to be lowered into a borehole in the earth, such for example, as an oil well, to cut an elongated metallic element, such as well casing or a drill stem of a stuck drill, tubing, etc., which extends longitudinally of the borehole.

In oil field salvage work, tools are commonly used for cutting casing set in depleted wells to permit salvaging of the casing by removal thereof in sections. Again, in the drilling of oil wells and also shot holes of the character used in seismic exploration work, tools are not infrequently used to cut the drill string or the stems of drill bits which become stuck at the bottoms of partially drilled holes, in order to permit salvaging of the drill strings or parts thereof. Generally speaking, cutting tools of the explosive type have not been satisfactory for work of this type for the reasons that clean cutting without distortion of the uncut sections of the element which it is desired to cut cannot be obtained, as belling of the casing or folding of the drill string occurs and furthermore excessive quantities of explosive material, sometimes exceeding the sectional capacity of the borehole, would have to be used to effect severance of the element.

It is an object of the present invention, therefore, to provide an improved explosive device which is adapted to be lowered into a borehole to cut an elongated element extending longitudinally of the borehole and completely obviates the above-mentioned disadvantages.

It is another object of the invention to provide an improved device of the character described which is of simple, low cost construction, is light in weight, requires a minimum of explosive material to perform a given cutting operation and is easy to handle in the field.

The invention both as to its organization and method of operation together with further objects and advantages thereof will best be understood by reference to the following specification taken in connection with the accompanying drawings in which:

Figure 1 is a fragmentary sectional view taken along a vertical section bisecting a borehole in the earth's crust, illustrating the manner in which one embodiment of the present invention may be used to cut casing which lines the borehole.

Figure 2 is an enlarged fragmentary sectional view illustrating the details of the cutting device shown in Figure 1;

Figure 3 is a top plan view of the device shown in Figure 1 also showing a section through the well casing;

Figure 4 is a view in full section illustrating a modified housing structure for the cutting device shown in Figure 1;

Figure 5 is a sectional view similar to Figure 4, but illustrating a modified form of detonating mechanism;

Figure 6 is a fragmentary sectional view taken along a vertical plane bisecting a borehole being drilled in the earth's crust, illustrating the manner in which a different embodiment of the invention may be employed to cut the stem of a drill bit stuck in the borehole;

Figure 7 is an enlarged perspective view of the cutting device shown in Figure 6;

Figure 8 is a view in full section illustrating the constructional details of the cutting device shown in Figure 6; and

Figure 9 is a fragmentary detail view partially in section illustrating the arrangement of the means for detonating the explosive charge embodied in the cutting device shown in Figure 6.

Referring now to the drawings and more particularly

to Figures 1, 2, and 3 thereof, the present invention is there illustrated in its embodiment in a cutting device generally indicated at **12** which is adapted to be lowered by means of a cable **13** into a borehole **10** extending downward from the surface **11** of the earth for the purpose of cutting the casing **9** with which the borehole **10** is lined. As will be evident from the foregoing explanation, casing cutting is commonly required in the salvaging of casing from old non-producing wells of depleted oil fields, as well as other non-producing wells. The usual practice is that of removing the casing by sections and various types of cutting tools have in the past been employed to perform the casing sectionalizing operation.

In accordance with the present invention and as best illustrated in Figures 2 and 3 of the drawings, a cutting device is provided, which comprises a disc-like body **17** of explosive material having a V-shaped cavity **17***a* extending continuously around the outer peripheral edge thereof for directionalizing toward the casing walls the explosive forces developed upon detonation of the explosive material. This body of explosive material, which may be 60 to 100 per cent blasting gelatin, such, for example, as Seismogel A, manufactured by E. I. du Pont de Nemours Company, Inc., is contained within a sheet metal structure comprising a lower bottom plate **21** of disc-like form upon which is mounted a hollow doughnut-shaped element **20** having V-related walls **20***c* which line the cavity **17***a* in the body of explosive material. The outer edges of these V-related walls terminate in upper and lower annular parts **20***a* and **20***b* which function as stand-off means to maintain the outer cavitated edge of the explosive body spaced at least a predetermined distance from the inner wall of the casing **9**. The annular part **20***a* also serves to support a cover **22** which, as best shown in Figure 3 of the drawings, is provided with radially extending locking lugs **22***a* adapted to be rotated beneath fingers **20***e* struck upwardly from the part **20***a* to lock the two elements **20** and **22** in assembled relationship. This cover is provided with a conical dome **22***b* extending upward from the annular part **20***a* and having a sealed opening **22***c* at the top thereof through which the circuit conductors **19** leading to the igniter of a detonating cap **18** may extend. This detonating cap is of cartridge form and extends transversely through the explosive body **17**, preferably at the exact central axis. It is equipped with the usual igniter or ignition wire which upon energization of a circuit including the conductors **19** is adapted to detonate the explosive body **17**. These wires which may form a part of the lowering cable **13**, or alternatively may themselves be used as the means for lowering the cutting device into the borehole **10** to the desired depth, extend to a detonator **14** located at the surface of the earth which may be of the conventional electric impulse type. Preferably all of the parts **20**, **21** and **22** are made of non-sparking metal, such as brass or copper, and have a wall thickness of the order of .075 inch.

For the purpose of protecting the assemblage of elements thus far described as making up the explosive unit **16**, while it is being lowered into the borehole **10** and the more important purpose of maintaining the disc-like body **17** of explosive material in a position extending transversely of the borehole, the unit **16** is mounted within an elongated open wire cage **15** which may be of conventional spot welded construction. The side elements **15***a* of the cage are preferably provided with formed recesses **15***b* midway between the ends thereof for receiving the spaced edges of the metal parts **20** and **21** to hold the unit **16** in a fixed position within the cage **15**. These cage side members extend around and are spot welded to spacing rings **15***c* adjacent the upper and lower ends thereof, and the ends are then brought together and welded to complete the cage structure. The upper pointed end of the cage is employed as an anchor point for the lowering cable **13** and the circuit conductors **19** extend loosely from this point to the ignition element of the detonating cap **18** to prevent their being pulled out of the detonating cap. If desired, the conductors may be wrapped around the upper spacing rings **15***c* to prevent their becoming entangled and possibly broken as the device **12** is lowered into the borehole **10**.

In using the described cutting device **12** to cut the

casing **9** with which the borehole **10** is lined, the device is first lowered by means of the cable **13** to the desired position longitudinally of the borehole, which position is obviously determined by the length of casing to be extracted, following which the detonator **14** is actuated to energize the igniter of the ignition element **18** and thus detonate the explosive material **17**. When the charge is fired, the element **20** is formed into an annular projectile and propelled by explosive forces through the adjacent segment of the casing **9**. Further, the explosive energy is concentrated into a thin expanding annulus and directed laterally outward from the longitudinal axis of the borehole due to the effect of the V-shaped cavity provided entirely around the outer edge of this body. Specifically, cavity **17***a* causes the well known Munroe effect to occur in that the explosive forces first travel perpendicularly away from the wall surfaces of the cavity **17***a*, meet and then travel in highly concentrated form radially outward from the center of the explosive body. Due to the sharpness of the explosive impulse and the high degree of concentration of the explosive energy, the casing **9** is cut cleanly around the line of impact of these forces. Thus, belling or bulging of the casing at the point of explosion is prevented. Such belling renders extraction of the casing section from the borehole very difficult. Further, due to the fact that most of the explosive energy is used in the cutting operation, and little energy is expended longitudinally of the hole, a relatively small amount of explosive material, well within the limits imposed by cross sectional area of the casing, is required. The degree of directionalization of the explosive energy is materially enhanced by the described means for maintaining at least a predetermined stand-off distance between the mouth of the cavity **17***a* and the adjacent inner wall of the casing **9**. In general, the stand-off distance as determined by the width of the annular parts **20***a* and **20***b* will depend upon the angle of the concavity of the V-shaped cavity **17**. For a sixty degree angle between the walls of the cavity **17***a* (this angle preferably ranges between 45 and 60 degrees depending upon the permissible diameter of the cutting device), the stand-off distance between the mouth of this cavity and the adjacent inner wall of the casing **9** should be at least equal to the thickness of the disk of explosive material.

In order further to enhance the directionalization of the explosive effect produced upon detonation of the body **17**, the annular chamber between the liner walls **20***c* and the outer edges of the parts **20***a* and **20***b* may be evacuated to a low subatmospheric pressure. This may be accomplished by using a ring **20***d* to seal off the space immediately in front of the cavity **17***a* and evacuating this space to a low subatmospheric pressure. It has been found that such evacuation effectively lowers the impedance to wave front propagation during the initial or starting intervals of the wave fronts emanating from the surfaces of the cavity **17** and hence enhances the extent of concentration and the degree of directionalization of the explosive forces developed upon detonation of the explosive body **17**.

Referring now more particularly to Figure 4 of the drawings, the embodiment of the invention there illustrated differs only from that described above in the type of support employed for the unit **16**. While the open wire cage construction illustrated in Figures 2 and 3 of the drawings is entirely satisfactory for shallow work, for deeper work, i. e., casing cutting in deep wells, it is preferable to use a closed or semiclosed container. Thus a conventional torpedo can **24** having a length about twice the diameter of the hole may conveniently be employed to support the explosive unit **16**. This can is equipped with a bail **24***a* for anchoring the lowering cable **13** and is provided adjacent the top thereof with a transverse bar **24***b* to which the ignition conductors **19** are anchored. The unit **16** is supported intermediate the ends of the can **24** upon a bed of packing material in the form of clay, sand, gravel, or the like, which fills approximately the lower one-third of the can. The remaining unoccupied space within the can **24** is also preferably filled with packing material in order to increase the over-all weight of the complete assembly. If the device is to be used in liquid filled wells, the top of the can is preferably covered and sealed to prevent fluid entry into the can. Sealing may, if desired, be accomplished by filling the upper third of the can with warm melted tar or an equivalent sealing compound having a low melting point. The purpose of closing and sealing the can **24** is to prevent liquid from flowing into the stand-off zone and forcing its way into the chamber in which the explosive material **17** is disposed. Aside from the differences just pointed out, the device illustrated in Figure 4 of the drawings is identical in construction and mode of operation with that shown in Figures 1, 2 and 3 of the drawings and described above.

The embodiment of the invention illustrated in Figure 5 of the drawings differs from that shown in Figure 4 only in the use of a different type of detonating mechanism. Specifically, a "torpedo bumper" type of detonating mechanism is employed in the Figure 5 construction to fire the cap or ignition element **18***a* and thus eliminate the necessity for extending circuit conductors from the cutting device to the top of the borehole. In brief, this mechanism comprises an upwardly spring biased firing pin **26** adapted to be struck a hammer blow by a firing plunger **27** which is slidably supported within a tube **28** projecting upwardly from the dome of the cover **22**. Normally, the lower end of the plunger **27** is maintained away from the top of the firing pin **26** by means of a light coil spring **29** which is telescoped over the plunger **27** and extends between the head **27***a* of this plunger and the flanged upper end **28***a* of the tube **28**.

In the operation of this firing mechanism, a weight (window weights are commonly used) is lowered into the borehole after the cutting device **12** is in position and such weight is dropped a short distance to engage the head **27***a* of the plunger **27**. This plunger in moving downward strikes the firing pin **26** to ignite the detonating cap and thus detonate the explosive charge **17**. From this point on, the cutting device functions in the exact manner explained above with reference to the embodiment of the invention illustrated in Figures 1, 2, and 3 of the drawings.

Referring now more particularly to Figures 6 to 9, inclusive, of the drawings, the present invention is there illustrated in its embodiment in a cutting device **30** particularly adapted for use in cutting drill string or the stem **31***a* of a drill bit **31** which has become stuck at the bottom of a borehole **32** in the process of being drilled into the earth's crust. As will be understood, the drill bit **31** is carried at the lower end of a drill string **33** which extends upward and out of the borehole **32** to have rotary motion imparted thereto by the usual driving mechanism of a conventional rotary rig schematically illustrated at **34**. In accordance with conventional practice, the drill string **33** is sectionalized in character, being comprised of a number of sections **33***a* which are added section by section as the depth of the borehole increases.

In brief, the cutting device **30** comprises an explosive cutting unit **35** which is supported within an elongated open wire cage **36** having rings **37** and **38** at the top and bottom ends thereof for receiving the drill string **33**. As best shown in Figures 7, 8, and 9 of the drawings, the cutting unit **35** comprises an annular body of explosive material **39** having a center opening for receiving the drill string and stem **31***a* of the drill and having a continuous V-shaped cavity **39***a* around the inner edge thereof for directionalizing toward the drill stem **31***a* the explosive forces developed upon detonation thereof. The explosive material, such, for example, as 90 per cent gelatin, manufactured by E. I. du Pont de Nemours and Company, Inc., is confined within a sheet metal structure, which comprises annular top and bottom plates **40** and **41**, an edge ring **42** and an inner doughnut-shaped element **43**. The latter element is provided with annularly related walls **43***a* which closely line the V-shaped cavity **39***a* of the explosive body **39** and terminate in annular parts **43***b* and **43***c* which act as stand-off means for maintaining the mouth of the cavity spaced at least a predetermined distance from the drill stem **31***a*. If desired, the doughnut-shaped element **43** may be closed at its inner side by means of a ring **44** to define a chamber facing the cavity **39***a* which may be evacuated to enhance the degree of directionalization and concentration of the explosive forces developed upon detonation of the material **39** in the manner explained above.

Here also, the angle defined by the V-related walls may range from 45 to 60 degrees and all metal parts of the unit **35** are preferably formed of brass or copper to reduce the likelihood of inadvertent detonation of the material **39**.

For the purpose of detonating the explosive material **39**, an ignition element in the form of a length of Primacord **45** is wrapped around the outer edge of this body

in contact therewith within the ring **42**. The ends of the Primacord **45** are brought out through an opening **40***a* in the plate **40** and extend into contact with a detonating cap schematically indicated at **46** mounted upon the plate **40** at the upper side thereof. This cap is equipped with the usual ignition elements which may be electrically energized from a remote point over a pair of circuit conductors **47**. Specifically, these conductors may form a part of a cable for lowering the cutting device **30** into the borehole **32** and are connected at the surface of the earth to a detonator **14***a* of the conventional electric impulse type.

In employing the cutting device **30** to cut the drill stem **31***a* of the bit **31** located at the bottom of the borehole **32**, the upper section **33***a* of the drill string is uncoupled from that portion of the drill string **33** disposed in the borehole, following which the cutting device **30** is telescoped over the upper end of the drill string with this string extending through the aligned openings in the cutting unit **35** and the upper and lower cage rings **37** and **38**. The cable may now be used to lower the device **30** into the borehole **32** by sliding the same downwardly along the drill string **33** until it comes to rest against the enlarged head of the drill bit **31**. With the device **30** in this position, the cutting unit **35** thereof obviously surrounds the stem **31***a* of the bit. Accordingly, by utilizing the detonator **14***a* to energize the ignition element of the cap **46** over the circuit conductors **47**, the Primacord **45** may be ignited to effect detonation of the explosive material **39**. In this regard it will be understood that the characteristics of Primacord are such that the explosive material **39** is almost instantaneously ignited at all points around the outer perimeter of the explosive body. The resulting directionalized explosive forces developed in a manner which will be clearly apparent from the above explanation, are all directed inwardly toward the drill bit stem **31***a* and have the effect of cleanly shearing this stem into two parts. It will be noted that due to the annular construction of the cutting unit **35** the explosive forces strike the stem **31***a* simultaneously from all directions so that twisting or distortion of the unsevered portions of the stem is minimized. After the stem **31***a* is thus divided into two parts, the drill string **33** may be readily withdrawn from the borehole **32** and the drill stem segment remaining at the end thereof removed. Obviously, the borehole may be extended to a lower depth by drilling around the stuck bit **31** in the usual manner.

From the foregoing explanation, it will be understood that the present invention affords a reliable and economical solution to the problem of cutting an elongated metallic element such, for example, as casing or the stem of a drill bit, disposed at substantial depths in a borehole in the earth. Not only are the devices illustrated in the drawings and described above of simple and economical construction, but they also are very easy to use and their action to produce the desired results is instantaneous.

While different embodiments of the invention have been described, it will be understood that various modifications may be made therein which are within the true scope and spirit of the invention as defined in the appended claims.

I claim:

1. Apparatus for severing an elongated element extending longitudinally of a borehole in the earth, comprising a disk-like body of explosive material having a cavity extending around one edge thereof for directionalizing toward said elongated element the explosive forces developed upon detonation of the material, a metal structure providing a liner for said cavity and including means providing a sealed stand-off space between said cavity and the adjacent surface of said elongated element, means for lowering said structure and body of explosive material into the borehole to position said cavity opposite said elongated element at the desired point of severance therealong, said last-named means including a plurality of side members and spacing rings defining an open wire cage of substantial length which substantially fills the borehole, means for positioning said metal structure intermediate the ends of said side members with said disk-like body of explosive material in a position extending transversely of said borehole as said cage is lowered into said borehole, and means for detonating said explosive material from the earth's surface.

2. Apparatus for severing an elongated element extending longitudinally of a borehole in the earth, comprising a disk-like body of explosive material having a cavity extending around one edge thereof for directionalizing toward said elongated element the explosive forces developed upon detonation of the material, a sheet metal structure completely enclosing said body of explosive material and provided with a liner for said cavity, said structure also including means cooperating with said liner to provide a sealed annular stand-off space between said cavity and the adjacent surface of said elongated element, means for lowering said structure and body of explosive material into the borehole to position said cavity opposite said elongated element at the desired point of severance therealong, said last-named means including a plurality of side members and spacing rings defining a disposable open wire cage of substantial length which substantially fills the borehole, means for positioning said metal structure intermediate the ends of said side members with said disk-like body of explosive material in a position extending transversely of said borehole as said cage is lowered into said borehole, and means for detonating said explosive material from the earth's surface.

3. Apparatus for severing an elongated element extending longitudinally of a borehole in the earth, comprising a disk-like body of explosive material having a cavity extending around one edge thereof for directionalizing toward said elongated element the explosive forces developed upon detonation of the material, a sheet metal structure completely enclosing said body of explosive material and provided with a liner for said cavity, said structure also including means cooperating with said liner to provide a sealed annular stand-off space between said cavity and the adjacent surface of said elongated element, means for lowering said structure and body of explosive material into the borehole to position said cavity opposite said elongated element at the desired point of severance therealong, said last-named means including a plurality of side members connected at their ends to a pair of spacing rings to define a disposable open wire cage of substantial length which substantially fills the borehole, said side members having recesses intermediate the length thereof adapted to receive the spaced edges of said metal structure for positioning said structure with said disk-like body of explosive material in a position extending transversely of said borehole as said cage is lowered into said borehole, a detonating cord extending at least part way around the non-cavitied edge of said disk-like body of explosive material within said metal structure, and means for detonating said cord from the earth's surface, thereby to detonate said explosive material.

4. Apparatus for severing an element of a drill string extending longitudinally of a borehole in the earth and disposed at approximately the center of the borehole, comprising an annular body of explosive material having a center opening for receiving said element and provided with a cavity around the inner edge thereof for directionalizing toward said element the explosive forces developed upon detonation of said explosive material, a metal structure providing a liner for said cavity and including means providing a sealed stand-off space between said cavity and the adjacent surface of said element, means for lowering said structure and body of explosive material into the borehole to position said cavity opposite said element at the desired point of severance therealong, said last-named means including a plurality of side members and spacing rings defining an open wire cage of substantial length which substantially fills the borehole, means for positioning said metal structure intermediate the ends of said side members with said annular body of explosive material in a position extending transversely of said borehole as said cage is lowered into said borehole, and means for detonating said explosive material from the earth's surface.

5. Apparatus for severing an element of a drill string extending longitudinally of a borehole in the earth and disposed at approximately the center of the borehole, comprising an annular body of explosive material having a center opening for receiving said element and provided with a cavity around the inner edge thereof for directionalizing toward said element the explosive forces developed upon detonation of said explosive material, a sheet metal structure completely enclosing said body of explosive material and provided with a liner for said cavity, said structure also including means cooperating with said liner to provide a sealed annular stand-off space between said

cavity and the adjacent surface of said element, means for lowering said structure and body of explosive material into the borehole to position said cavity opposite said element at the desired point of severance therealong, said last-named means including a plurality of side members and spacing rings defining a disposable open wire cage, the intermediate portions of said side members being positioned adjacent the walls of said borehole and said spacing rings loosely embracing said drill string, means for positioning said metal structure intermediate the ends of said side members with said annular body of explosive material in a position extending transversely of said borehole as said cage is lowered into said borehole, and means for detonating said explosive material from the earth's surface.

6. Apparatus for severing an element of a drill string extending longitudinally of a borehole in the earth and disposed at approximately the center of the borehole, comprising an annular body of explosive material having a center opening for receiving said element and provided with a cavity around the inner edge thereof for directionalizing toward said element the explosive forces developed upon detonation of said explosive material, a sheet metal structure completely enclosing said body of explosive material and provided with a liner for said cavity, said structure also including means cooperating with said liner to provide a sealed annular stand-off space between said cavity and the adjacent surface of said element, means for lowering said structure and body of explosive material into the borehole to position said cavity opposite said element at the desired point of severance therealong, said last-named means including a plurality of side members having intermediate portions positioned adjacent the walls of said borehole and terminating in converging end portions, a pair of spacing rings connecting the end portions of said side members to define a disposable open wire cage, said spacing rings being adapted loosely to embrace said drill string, means for positioning said metal structure intermediate the ends of said side members with said annular body of explosive material in a position extending transversely of said drill string as said cage is lowered into said borehole, and means for detonating said explosive material from the earth's surface.

7. Apparatus for severing an element of a drill string extending longitudinally of a borehole in the earth and disposed at approximately the center of the borehole, comprising an annular body of explosive material having a center opening for receiving said element and provided with a cavity around the inner edge thereof for directionalizing toward said element the explosive forces developed upon detonation of said explosive material, a metal structure completely enclosing said body of explosive material and provided with a liner for said cavity, said structure also including means cooperating with said liner to provide a sealed annular stand-off space between said cavity and the adjacent surface of said element, means for lowering said structure and body of explosive material into the borehole to position said cavity opposite said element at the desired point of severance therealong, said last-named means including a plurality of side members and spacing rings defining a disposable open wire cage, the intermediate portions of said side members being positioned adjacent the walls of said borehole and said spacing rings being adapted loosely to embrace said drill string, said side members having recesses in the intermediate portions thereof adapted to receive the spaced edges of said metal structure for positioning said structure with said annular body of explosive material in a position extending transversely of said borehole as said cage is lowered into said borehole, a detonating cord extending at least part way around the outer non-cavitied edge of said annular body of explosive material within said metal structure, and means for detonating said cord from the earth's surface, thereby to detonate said explosive material.

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