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APPARATUS FOR CUTTING HOLES IN WELL CASING

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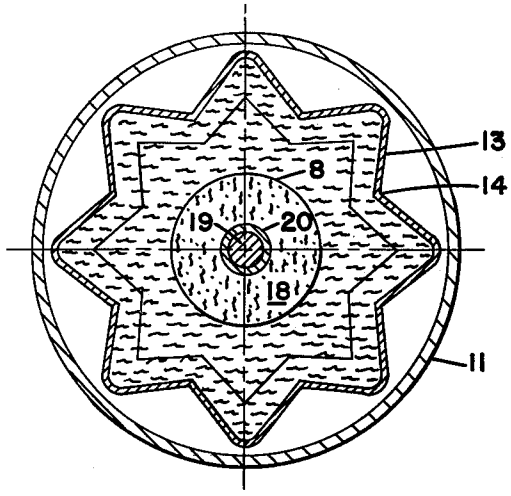


Fig. 2

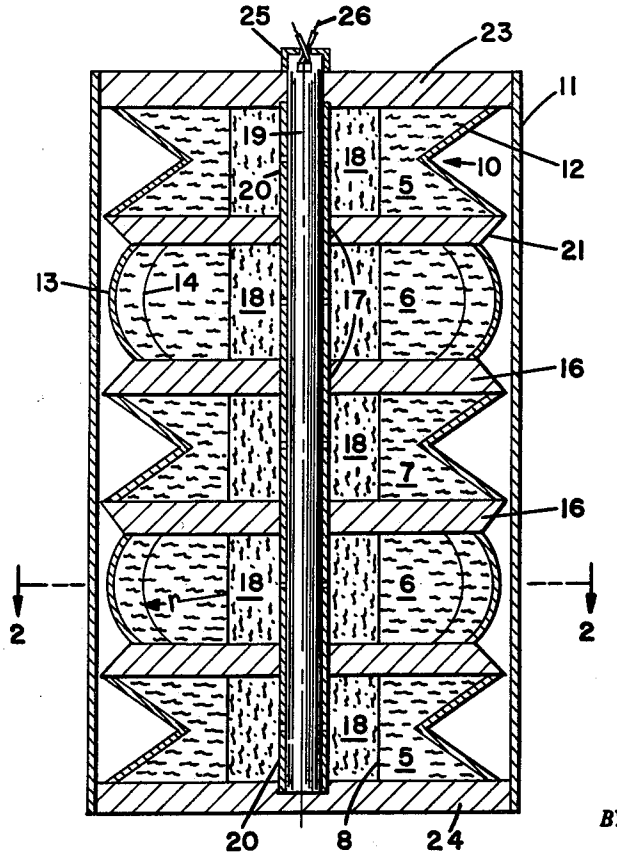


Fig. 1

Blake M Caldwell
George C. Howard
INVENTORS.

BY L. Goodwin
ATTORNEY

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APPARATUS FOR CUTTING HOLES IN WELL CASING

George C. Howard, Tulsa, Okla., and Blake M. Caldwell, Arlington, Tex.; said George C. Howard assignor to Pan American Petroleum Corporation, a corporation of Delaware, and said Blake M. Caldwell assignor, by mesne assignments, to Welex, Inc., Fort Worth, Tex., a corporation of Delaware

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13 Claims. (Cl. 102—20)

This invention relates to an apparatus for cutting holes in well casing. More specifically, this invention relates to an improved apparatus for cutting windows in a casing string disposed in a well.

The removal of sections of casing from a casing string in a well is sometimes required for the purpose of producing the well, for producing a window through which a drill can bypass the bottom of an old hole and drill into lower formations, and the like. Various methods have been proposed for producing such windows including the removal of sections of casing by dissolving the casing in strong acid solutions, by milling, and by melting the casing with a chemical heating agent such as thermite. These methods, in general, are expensive and time consuming and, furthermore, often do not produce a satisfactory window through which a well can be sidetracked.

It is, therefore, an object of this invention to provide an improved apparatus for cutting windows in a string of casing within a well. A more specific object of this invention is to provide an apparatus including a detonating explosive which can be lowered into a cased well to cut a section of the casing into a multiplicity of small segments which can be withdrawn from the well through the casing and thus removed from the window section so that a drill can be run through the window and the well can be sidetracked. A still more specific object of this invention is to provide a detonating explosive charge with a generally cylindrical surface having grooves which tend to concentrate the force of the explosion along intersecting lines. These and other objects of this invention will become apparent from the following description in which:

Figure 1 is a cross-sectional view of a detonating explosive showing a means for producing intersecting high velocity jets; and

Figure 2 is a cross-sectional view taken on the line 2—2 of Figure 1.

This invention in brief thus comprises an apparatus including a multiplicity of co-axial annular sections wherein alternate sections have transverse peripheral grooves and are adapted to produce high velocity linear jets which intersect each other at intervals so that when the apparatus is disposed in a well casing and detonated, the casing is cut into lattice-like sections which are sufficiently small to be removed through the casing. Referring now to Figure 1 of the drawings, the detonating explosive which may be any high density, high velocity explosive such as penta-erythritol tetranitrate (PETN), trinitrotoluene (TNT), or mixtures thereof such as pentolite (50 percent PETN and 50 percent TNT) is molded into short annular sections 5, 6, and 7 having an axial dimension of between about ½ and about 2 inches, typically 1¼ inches. An axial hole 8 is desirably left in the center of the annular sections to provide space for a detonating fuse, a booster shot, or both. The outer surface or periphery of each annular section of detonating explosive is grooved to produce a concentrated or focused beam of hot gases which, as is well known in this art, will penetrate steel,

rock, or the like to a substantial distance. In the outer or end sections 5, the periphery preferably has a circumferential groove 10. Additionally, alternate section 7 of the explosive has a similar circumferential groove. These grooves may be angular, i.e., V-shaped, and desirably have an angle at the apex of about 10–100° to concentrate the beam into a very thin circular beam or jet before the gases from the detonatnig explosive reach the protective case 11. The more acute angles are desirable since the focal length is shorter. The apex angle of the groove is correlated with the distance between the bottom of the groove and the case 11 such that the beam of gases is formed before the gases strike the case or an intermediate material such as liquid or solid between the case and the casing or well wall. An apex angle of about 60° is generally preferred.

The detonating explosive may be formed into this shape by various means, but preferably a shaped charge liner 12 which consists of a thin ring is used to provide a mold into which the detonating explosive is cast. The upper and lower surfaces of the annular section may be plane, or in some cases other configurations well-known to those skilled in the art may be substituted. The outside surface or periphery of the explosive naturally conforms to the shape of the liner. While the liner or concentrator and thus the groove in the periphery of the detonating explosive may be angular as shown, it will be apparent that other configurations well-known to those skilled in the art may be substituted. The two sides of the groove are usually symmetrical, but some irregularity is permissible. The frustro-spherical sections 6, constituting the central or symmetrical frustums of spheres, disposed between these circumferentially grooved annular sections 5 and 7 are constructed in a manner somewhat similar to the circumferentially grooved sections and generally have about the same overall dimensions. The outer surface or periphery of these intermediate sections 6 are grooved with the axis of the groove preferably at an angle of about 90° to the circumferential grooves. That is, the grooves in the intermediate sections 6 are desirably axial or longitudinal whereas the grooves in the outside and alternate sections are desirably circumferential. This leaves the ends of the pipe or casing relatively smooth. The grooves in the intermediate sections in addition to being longitudinal are curved so that the high velocity jets issuing therefrom tend to be lengthened or flared lengthwise in an axial direction whereby they intersect the jets on either side issuing from the circumferentially grooved sections 5 and 7. While the apex of the longitudinal groove 14 may be arcuate having a radius r of about the same length or shorter than the radius of the sections, any geometric or even an irregular shape may be employed, provided only that the shape must be convex so that the jets are flared lengthwise to intersect the circular jet produced by the adjacent alternate explosive charges. Any number of longitudinal grooves 14 may be provided in the intermediate sections 6. Typically, between about 3 and about 12 are used, the only limitation being that the distance between is desirably substantially less than the diameter of a casing which is to be cut. The angle of the sides of the grooves is in the same range as the corresponding angle in the circumferentially grooved sections. These intermediate sections are also molded preferably by filling a pre-formed shaped charge liner 13 with a detonating explosive. This liner 13, like liner 12, consists usually of a thin metallic ring, for example, an iron, aluminum, copper, or brass ring, which in the case of liner 13 is in the general form of a frustum of a sphere, namely the center symmetrical section of a sphere.

Any number of circumferentially grooved sections of detonating explosive may be used provided that a section of the same or a similar detonating explosive having

means for producing axially flared jets is located between each pair of such sections. Typically, a sufficient number of alternate sections of each type is assembled axially to provide a length of from about 1 to about 25 feet or more. These two types of sections may be assembled adjacent each other, but preferably a non-detonating spacer **16** is provided between adjacent sections. This spacer may be made of metal such as iron, brass, or the like, but preferably it is made from a readily drillable material such as lead, plastic, rubber, fiber, or the like. Each spacer has an axial bore **17** of between about 3/16 inch to about ½ inch, preferably about 5/16 inch. By this arrangement, when the various detonating explosive sections are formed, a booster **18** such as tetryl or the like may be cast or formed as a core inside the cylindrical sections. The spacers **16** have a diameter substantially equal to the inside diameter of the case **11**. The thickness may be varied over a substantial range. Typically, the spacers may be made from Bakelite or other plastic sheets having a thickness of between about 1/16 and about 1 inch. Spacers made from 3/16 inch Masonite have been found quite satisfactory. These spacers appear to strengthen or enforce the jets on either side so that, particularly in combination with the flared longitudinal jets, the tendency of the vertical and horizontal jets to interfere is overcome and the small lattice-like casing sections do not remain joined at the corners. The spacers are sometimes beveled on the outer edge **21** with the bevel on the side adjacent to the intermediate or vertical cutter sections **6**. The surfaces of the bevels are desirably substantially perpendicular to the tangent of the base of grooves **14** at the ends of the grooves. The elongated longitudinal jets can be formed by this means without distortion of the gas by contact with a solid before the gas reaches the focal point.

The booster **18** may be ignited by a detonating fuse or the like. In the preferred embodiment a fuse or detonating cord **19** such as Primacord or Cordeau having cap means (not shown) to initiate detonation may be inserted in tube **20**. The tube is placed in the apparatus between the upper head **23** and the lower head **24** so that a fuse and a seal **25** can be inserted after the charges are assembled. Suitable electrical conductors **26** may be connected via the supporting cable (not shown) to a generator or the like at the surface as a means of initiating the explosion of the Primacord, the booster, and/or the detonating explosives.

While for the purpose of illustration the grooves in the periphery of alternate sections of the detonating explosive have been made circumferential and the grooves in the periphery of intermediate sections have been made axial or longitudinal so that the jets form right angle parallelograms, it will be apparent that other configurations wherein two or more lines of jets are at different angles may in some cases be more desirable. Regardless of the angle or angles between the lines of jets, however, it has been found that in order to cut a casing window and leave the lattice-like casing segments in pieces which are completely separated from adjoining pieces, at least one line of the intersecting jets must be flared lengthwise at an arc having a greater curvature than that of the regular surface of the charges. That is, the tendency of two lines of jets to leave the casing sections connected near the intersecting cuts can be overcome by making, for example, the vertical grooves convex outwardly whereby the jets from the intermediate sections are forced to intersect the horizontal or circumferential jets. It will also be apparent that while the apparatus has been described in the preferred embodiment as a series of generally annular sections of detonating explosive cast in separate metallic liners, various other types of liners can sometimes be employed. These and various other modifications can, therefore, be made in the apparatus without departing from the spirit of the invention. The invention is thus to be construed to be limited only by the scope of the appended claims.

We claim:

1. An apparatus for cutting a window in casing by cutting a section of said casing into small segments which can be removed from said window through said casing comprising a generally cylindrical explosive having at least two sets of substantially parallel grooves in the periphery thereof, each groove being substantially symmetrical about a plane which passes through its apex and is substantially normal to the surface of said explosive, said planes of said sets of grooves intersecting to form in said periphery lattice-like grooves for concentrating the force of said explosive into linear jets along intersecting lines, the first of said sets being curved convex outwardly between the other of said sets, said first set being curved sufficiently so that a line in said plane of one of said grooves in said first set and perpendicular to the bottom of such groove intersects said plane of a groove in another set of said grooves to flare lengthwise said linear jets from said first set of grooves between said intersecting lines of another set and cause said linear jets from the respective sets of said grooves to intersect within said casing, and means to detonate said explosive.

2. An apparatus for cutting a window in casing by cutting a section of said casing into small segments which can be removed from said window through said casing comprising a generally cylindrical explosive having a first set and a second set of substantially parallel grooves in the periphery thereof, each groove being substantially symmetrical about a plane which passes through its apex and is substantially normal to the surface of said explosive, said planes of said sets of grooves intersecting to form lattice-like grooves at about right angles, said second set of parallel grooves being in segments shorter than the distance along said planes between adjacent pairs of said first set of parallel grooves, each groove in said second set of parallel grooves being curved convex outwardly at the ends so that a line in said plane of said groove perpendicular to the bottom of said groove intersects within said casing said plane of at least one groove in said first set of said grooves, whereby the jets produced by one of said sets of grooves upon detonation of said explosive intersect within said casing the jets produced by the other of said sets of grooves, and means to detonate said explosive.

3. In an apparatus for cutting a window in casing and the like a series of axially aligned generally annular sections of a detonating explosive, alternate sections of said series having a circumferential groove in the periphery thereof, the sections between said alternate sections having central frustro-spherical surfaces with a multiplicity of longitudinal grooves therein, and said sections being spaced along their common axis so that the jets produced by said sections between said alternate sections intersect within said casing the jets produced by said alternate sections.

4. An apparatus for cutting a window in casing and the like comprising a series of axially aligned generally annular sections of a detonating explosive, alternate sections of said series having a circumferential groove in the periphery thereof, intermediate sections of said series having a central frustro-spherical surface with a multiplicity of longitudinal grooves therein, said alternate sections and said intermediate sections being spaced along their common axis so that the jets produced by said intermediate sections intersects within said casing the jets produced by said alternate sections, said alternate sections and said intermediate sections each having an axial bore therein, a booster disposed in said bore, and means to detonate said booster.

5. An apparatus according to claim 4 wherein spacers are provided between each of said alternate and said intermediate sections of detonating explosive.

6. An apparatus according to claim 5 wherein said spacers are beveled on the outer edge on the side adjacent said intermediate sections whereby the jets from said in-

termediate sections may be flared and intersect the jets from said circumferential sections.

7. In an apparatus for cutting a window in casing by cutting a section of said casing into small segments which can be removed from said window through said casing comprising a generally cylindrical explosive, a multiplicity of circumferential grooves in the surface of said explosive, and a multiplicity of segmented longitudinal grooves in said surface between pairs of said circumferential grooves, said segmented longitudinal grooves being curved convex outwardly between said pair of circumferential grooves so that upon detonation of said explosive the linear jets produced by said segmented longitudinal grooves intersect within said casing the jets produced by said circumferential grooves.

8. An apparatus according to claim 7 wherein said circumferential grooves are spaced a distance not substantially greater than the diameter of said generally cylindrical explosive.

9. In an apparatus for cutting a window in casing by cutting said casing into small segments which can be removed from said window through said casing including a generally cylindrical explosive having at least two sets of substantially parallel grooves in the periphery thereof, each groove being substantially symmetrical about a plane which passes through its apex and is substantially normal to the surface of said explosive, one set of said grooves intersecting the other set of said grooves for concentrating the force of said explosive into two sets of linear jets along intersecting lines, and means for detonating said explosive, the improvement comprising curving at least one of said sets of grooves convex outwardly so that a line in said plane of a groove within one of said sets of grooves and perpendicular to the bottom of said groove intersects within said casing said plane of a groove of the other of said sets of grooves and flares lengthwise the segments of at least one of said sets of linear jets between said intersecting lines whereby each of said casing segments is completely severed from adjacent segments.

10. An apparatus according to claim 1 wherein liners are placed in said grooves.

11. An apparatus according to claim 1 wherein said explosive is cast in a thin metallic liner having depressions in the surface conforming to said grooves.

12. An apparatus according to claim 2 wherein said first set of parallel grooves is circumferential and said second set of parallel grooves is substantially longitudinal of said generally cylindrical explosive.

13. An apparatus according to claim 2 wherein the parallel grooves in each of said first set and said second set are spaced a distance not substantially greater than the diameter of said generally cylindrical explosive.

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