This invention relates to apparatus for cutting or severing oil well tubing and the like, which apparatus is frequently referred to in the industry as a tubing cutter.

Another object of the invention is to provide a tubing cutter that may be transported and handled without undue hazard.

Another object of the invention is to provide a tubing cutter that is simple to manufacture and assemble and easily to use in the field.

The foregoing objects of the invention are achieved, in general, in apparatus for cutting oil well tubing and the like which includes a vertical, cylindrical, sealed housing having pressure-resistant top, bottom and side walls, and means for lowering the housing in oil well tubing. A shaped explosive charge is mounted within the housing, the charge having a circular, horizontal cross-section and an outwardly-opening, annular, lined cavity formed in the outer periphery thereof and being adapted upon being fired to produce a radially expanding planar cutting jet. The shaped explosive charge is mounted in the housing and oriented to direct the planar jet laterally to cut the housing and the surrounding well tubing. Means is provided for firing the charge from the surface of the earth.

In accordance with one aspect of the invention, the side wall of the housing opposite the annular, lined cavity of the shaped explosive charge provides a horizontal, annular groove opening inwardly of the housing and having a thin section bounding the outer periphery of the groove. It is through this thin section that the planar jet cuts and proceeds outwardly to sever the tubing. The groove may be so formed as to cooperate with the shaped explosive charge to provide the requisite stand-off in which the cutting jet may properly form. The walls of the groove may be inclined to aid in reducing flaring of the tubing, as will be explained more fully as the description proceeds.

In another aspect of the invention, the shaped charge is located a substantial distance below the top wall of the housing whereby the housing and the shaped charge define therebetween a substantially unobstructed space providing an expansion chamber for products of the explosion that do not directly impact the jet, in which respect the energy of such products is effectively dissipated to minimize damage to the well tubing and casing. Such expansion chamber may be provided either above or below the shaped charge and within the housing, or expansion chambers may be provided both above and below the shaped charge.

Advantageously, a tubing cutter may include the invention in both of the foregoing aspects with more than merely additive advantages.

The invention will be described with greater particularity, and other of its aims, objects and advantages will be brought out in the following detailed description taken in connection with the drawings.

In the drawings:

FIG. 1 is an axial sectional view of the lower portion of a well tool assembly including an exemplary tubing cutter device embodying the principles of the invention;

FIG. 2 is a detailed axial section view of the cutter device shown in FIG. 1;

FIG. 3 is a sectional view along the line 3-3 of FIG. 2;

FIG. 4 is a detailed axial sectional view of another form of cutter device in accordance with the invention; and

FIG. 5 is a sectional view along the line 5-5 of FIG. 4.

Referring to FIG. 1, the assembly therein shown has a cutter head generally designated by the numeral 10. The cutter head is threadedly connected at its upper end to a hinging head 11. The latter is secured to an adapter sub 12 which is attached to a conventional casing collar locator 13, only the lower end of the latter component being indicated in FIG. 1. In accordance with common practice, the casing collar locator is suitably connected to a rope socket (not shown) to which is attached the...
usual conductor cable (not shown) by which the apparatus is lowered into the well tubing to be severed and by which firing current is delivered to the apparatus.

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through the passage as shown in FIG. 1 wherein the detonating fuse, such as a Primacord fuse, is indicated by the reference numeral 51.

Referring to FIG. 2, it is seen that the outside diameter of the booster element 49 is the same as the outside diameter of the end plate boxes 46. It is also seen that the two end plates 42 and 43 with the booster element sandwiched therebetween form a spool-shaped container lower for the annular shaped explosive charge elements designated 52 and 53, respectively. The lower and upper shaped charge elements 52 and 53 are identical to each other. Each such element has a main explosive charge 54, of compressed waxed RDX for example. The outer peripheral face 55 of each main explosive charge element is lined with an inert annular liner section 56. The liner sections 56 are of truncated conical form and abut each other at their inner peripheries, flaring outwardly from each other to provide an annular cavity of V-shaped vertical cross-section.

The cartridge 40 may be fabricated and assembled along the following lines. Wax molded granular cyclonite is compressed in a suitable die into one of the conical liner sections 56 to form a lined pellet of the shape indicated in the drawings. The lined main charge pellet thus formed is cemented to one of the end plates 42 and 43 along the surface of the lower end plate. The booster element 49 is placed on and cemented to the cylindrical portion 46 of the end plate along the upper surface 59. A second lined main charge pellet with an end plate cemented thereto is inverted over the lower element and booster charge and is cemented along the contacting surfaces. The cartridge, thus formed lower and upper, lined main unitary explosive component that may be readily inserted in the housing of the cutter.

The housing is counterbored upwardly from the bottom, the counterbore having a diameter equal to that of the cartridge 40. A shoulder 60 is thus formed on the side wall of the housing against which the upper beveled rim of the cartridge is seated. The parts are so dimensioned that the upper surface of the cylindrical portion 35 of the plug 34 retains the cartridge in the position indicated in FIGS. 1 and 2.

With reference to FIG. 1, it will be seen that the side wall section of the housing is provided with an annular groove 61 opposite the annular lined cavity of the cartridge 40. The groove is symmetrical about a horizontal plane passing medially through the cartridge 40. The upper half of portion 56 along the outer face 62 intersecting a downwardly and outwardly sloping face 63 which in turn intersects a vertical cylindrical face 64 defining a thin wall section 65 that faces the vertex of the lined cavity of the shaped charge. The bottom half of the groove is a mirror image of the upper half. It will be seen that the outer rims of the liner sections 56 abut the side wall of the housing immediately above and below the edges of the groove 61. Such contact of the liner with the side wall of the housing improves the performance of the cutting jet over a jet formed by a device in which the liner is not laterally supported around the rims.

A fuse tube 66 of aluminum or the like extends between the cartridge 40 and the top wall 52 of the housing, the lower end of the tube being received in the recess 48 of the plate 43 and the upper end of the tube being received in a recess 67 formed in the top wall of the housing. The cylindrical boss 30 of the cutter head is provided with an axial bore 68 through which a part of the explosive train extends.

The top of the detonating fuse 51 is crimped into the bottom of a fuse booster 69, as shown in FIG. 1. The upper end of the booster is seated above the top of the cylindrical boss 30 into contact with the bottom of the electric blasting cap 26, the top of the fuse booster being wrapped with friction tape 70 to hold the booster in place.
In assembling the apparatus, the fuse tube 66 is first inserted into the cutter head and the cartridge 40 is then inserted into the head through the open bottom. The plug 34 is then positioned and secured in place by means of the screws 37. An O-ring 71 is employed to seal the plug to the side wall section of the cutter head. This completes the assembly of the cutter head. So much of the apparatus is usually assembled in the charge manufacturing plant. It will be noted that the cutter head assembly in this condition has no blasting cap or other sensitive means for detonating the explosive component of the cutter head; hence, the assembly is relatively safe and may be shipped and handled with a minimum of hazards.

In the field and preparatory to use of the apparatus in a well, the firing head assembly 11 is secured to the adapter 12 by the screws 16. The firing head is equipped with the blasting cap 26 and rigged for firing. A suitable length of detonating cord 51 is provided with a fuse booster 69 and inserted to the inner head as shown in FIG. 1, the top of the fuse booster being taped in place as indicated at 70. Thereafter, the cutter head is threaded into the firing head and the apparatus is ready to be lowered into the tubing of an oil well for severing the tubing.

The apparatus is lowered in the well and located with the cartridge 40 opposite the side where the tubing is to be severed. The firing circuit is energized from the surface of the earth to explode the blasting cap 26. The blasting cap fires the fuse booster 69 which, in turn, detonates the primer 52. When the detonating wave reaches the annular booster element 49, the latter is detonated. The explosion wave travels radially outwardly through the booster 49 to detonate the main charge elements 52 and 53 in a symmetrical manner. The explosion wave travels outwardly in the main charge and attacks and detonates the liner elements 56 to provide a horizontal planar cutting jet traveling radially outwardly in the plane of the vertex of the lined shaped charge cavity. The planar cutting jet impinges upon the thin section 65 of the side wall of the cutter head and severs the bottom of the cutter head from the top along a circular cut that usually takes out the entire thin section 65 between the upper inclined groove face 63 and the lower inclined groove face 72. The cutting jet has enough residual energy to continue outwardly to cut the surrounding tubing opposite the groove 61. It will be understood that this upper head fits within the tubing with only enough clearance to permit the tool to be run into the tubing without becoming lodged therein.

When the cutter is fired, the lower severed section of the housing, including the side wall section below the thin web 65 and the plug 34, falls with the severed section of the tubing to the bottom of the well and may later be removed if desired. The upper section of the housing 10 above the thin web 65 remains substantially intact and it, together with the tool parts thereafter including the firing head, is withdrawn from the well. The upper section of the housing may be unscrewed from the firing head and discarded and the firing head may be reloaded and equipped with a fresh cutter head for another cutting operation.

With the cutter apparatus of the present invention, as shown in FIGS. 1 to 3, tubing is severed without producing any objectionable flare in the end of the tubing above the cutter head. The tubing is cleanly and smoothly parted from the well with no tendency to become lodged due to a flared bottom. The lower section of tubing that is severed from the upper section is generally found to have an upper end that is slightly flared; however, it may ordinarily be retrieved from the well without difficulty using conventional fishing tools.

It will be seen that the shaped charge cartridge 40 is located a substantial distance below the top wall of the housing to leave a substantially unobstructed space in the housing above the shaped charge. This space serves as an expansion chamber into which the upwardly moving parasitic products of the explosion of the shaped charge may expand and to a large extent dissipate their energy. Such energy, being absorbed within the upper section of the housing, is prevented from acting on the tubing being severed to build up a parasitic explosion above the cut. By the expression "parasitic products of explosion" is meant those products of the explosion that do not directly enter the cutting jet.

The material and thickness of the housing walls above the groove 61 are selected in relation to the explosive forces involved, to withstand such forces and to remain intact when the charge is fired. The housing walls above the groove are sufficiently strong to also contain the explosive forces produced by the detonating fuse 51 extending axially through the chamber.

The thin wall section 65 is strong enough to withstand well pressure at the deepest location at which the tool is expected to be used; however, it is purposely kept as thin as possible so that only a minimum of energy is taken away from the jet as the latter cuts through the thin wall section. Thus, the jet retains the largest possible quantity of energy for the useful work of cutting the tubing.

The downwardly and outwardly sloping upper face 63 of the groove 61 has been found beneficial in minimizing flaring of the tubing above the cut. It is thought that the downward slope of the face 63 directs some of the parasitic products of explosion downwardly and away from the cut.

The groove 61 provides an annular stand-off space in which the planar cutting jet may properly form before reaching the thin wall section 65.

The embodiment of the invention shown in FIGS. 1 to 3 is especially proportioned for use in tubing of 2 3/4 inches by 3 1/2 inches and has a horizontal planar cutting jet at the O.D. of the cutter head is 2 7/8 inches. The I.D. of the housing above the cartridge 40 is 1 5/8 inches and the I.D. of the counterbored portion of the housing at the lower end thereof is 2 3/8 inches. The height of the expansion chamber beneath the housing and above the cartridge 40 is 2 1/4 inches. The width of the groove 61 at the inner wall of the housing is 3/16 inch and the thickness of the thin wall section 65 is 3/8 inch. The height of the thin wall section is 3/8 inch. The inclined groove faces 63 and 72 are disposed at approximately 30 degrees to the horizontal; however, this angle may vary within practical limits from approximately 20 degrees to approximately 60 degrees. Of course, other sizes of tubing cutters may be made to cut larger or smaller tubing.

In FIGS. 4 and 5 there is shown another form of the invention in many respects similar to that shown in FIGS. 1 to 3. The cutter head of FIGS. 4 and 5 is identical to that shown in FIGS. 1 to 3 from the level of the bottom of the cartridge up. In the cutter head shown in FIGS. 4 and 5, the housing side wall portion 73 is extended for a substantially distance below the bottom of the cartridge 40 and is provided with a bottom closure plug 34' to form a second expansion chamber 74 between the cartridge and the plug. The expansion chamber 74 is of substantially the same size as the expansion chamber above the cartridge 40'.

The cartridge 40' is supported against the shoulder 60' and opposite the groove 61' by support means including a length of aluminum tubing 75, the top end of which is received in the recess 48' of the cartridge and the lower end of which rests in a cup 76 brazed to a spider 77 having radial leaf-spring legs that engage the top of the plug 34' to resiliently urge the tube and cartridge 40' into the illustrated position.

The fuse booster 69' and detonating fuse 51' are similar to the corresponding components shown in FIGS. 1 to 3. However, the fuse 51' may extend downward through the cartridge 40' and through the lower tube 75 to the bottom thereof. The fuse portion below the cartridge
serves upon detonation to destroy the tube 75, whereby less large debris is produced.

In use, the cutter head of FIGS. 4 and 5 is connected to a firing head such as the firing head 11 of FIG. 1 and to the other necessary equipment for lowering the cutter head into a well. The assembled tool is fired from the surface of the earth as described with reference to FIGS. 1 to 3. The formation of the horizontal planar cutting jet takes place as described hereinbefore. The jet cuts through the thin wall section 65 to sever the tubing surrounding the cutter head in a manner analogous to that described hereinbefore.

With the cutter head of FIGS. 4 and 5, having expansion chambers within the housing both above and below the cartridge, the vertical parasite products of the explosion of the cartridge 49' and the products of explosion of the fuse 51' are absorbed and shielded from the tubing being severed to a greater extent than with a cutter head having only a single expansion chamber above the cartridge. Thus, significantly less damage is done to the portions of the tubing above and below the cut. The flaring of the lower severed section of tubing immediately below the cut is less pronounced than with the device of FIGS. 1 to 3, and the flaring of the upper section of the tubing is inconsequential.

I claim:

1. A device for severing pipe in an oil well bore and the like comprising:
   (a) a short cylindrical, non-frangible, pressure-resistant housing including a hollow body portion and a separate end plug sealingly closing the lower end of said body,
   (b) said body portion having a thick annular side wall and a thick top wall integral therewith,
   (c) said top wall having a central, upstanding cylindrical boss integral therewith,
   (d) said boss providing an axial opening therethrough adapted to receive a detonating fuse therein,
   (e) the lower section of said side wall having a counterbore therein terminating a substantial distance below said top wall and providing a downwardly-facing shoulder,
   (f) said side wall providing a horizontal annular groove opening inwardly of said housing and having a thin section bounding the outer periphery of the groove,
   (g) said groove being located subjacent and close to said shoulder in the counterbored portion of said body,
   (h) a generally cylindrical, shaped explosive charge cartridge slidingly received in said counterbore with the upper edge of the cartridge seated against said shouder and the lower edge of said cartridge abutting the wall of said counterbore below said groove,
   (i) said cartridge having a main charge of explosive material having an outwardly-opening, annular, lined cavity facing said thin section and adapted upon being fired to produce a radially expanding planar cutting jet adapted to cleanly sever said side wall at said thin section,
   (j) said cartridge providing an axial opening therethrough adapted to receive a portion of a detonating fuse,
   (k) said housing and said cartridge defining therebetween a substantially unobstructed space above said cartridge providing an expansion chamber for the parasite products of said cartridge resulting from detonation thereof,
   (l) the walls of said body above said groove being of sufficient thickness and strength to remain intact and to be substantially undistorted when said cartridge is fired,
   (m) a rigid, fuse-receiving tube connecting the axial opening in said boss with the axial opening in said cartridge, said tube extending axially through said expansion chamber above said cartridge, and
   (n) means retaining the upper edge of said cartridge firmly seated against the shoulder in the counterbored portion of said body.
2. A device for severing pipe in an oil well bore and the like comprising:
   (a) a short cylindrical, non-frangible, pressure-resistant housing including a hollow body portion and a separate end plug sealingly closing the lower end of said body,
   (b) said body portion having a thick annular side wall and a thick top wall integral therewith,
   (c) said top wall having a central, upstanding cylindrical boss integral therewith,
   (d) said boss providing an axial opening therethrough adapted to receive a detonating fuse therein,
   (e) the lower section of said side wall having a counterbore therein terminating a substantial distance below said top wall and providing a downwardly-facing shoulder,
   (f) said side wall providing a horizontal annular groove opening inwardly of said housing and having a thin section bounding the outer periphery of the groove,
   (g) said groove being located subjacent and close to said shoulder in the counterbored portion of said body,
   (h) a generally cylindrical, shaped explosive charge cartridge slidingly received in said counterbore with the upper edge of the cartridge seated against said shoulder and the lower edge of said cartridge abutting the wall of said counterbore below said groove,
   (i) said cartridge having a main charge of explosive material having an outwardly-opening, annular, lined cavity facing said thin section and adapted upon being fired to produce a radially expanding planar cutting jet adapted to cleanly sever said side wall at said thin section,
   (j) said cartridge providing an axial opening therethrough adapted to receive a portion of a detonating fuse,
   (k) said housing and said cartridge defining therebetween a substantially unobstructed space above said cartridge providing an expansion chamber for the parasite products of said cartridge resulting from detonation thereof,
   (l) the walls of said body above said groove being of sufficient thickness and strength to remain intact and to be substantially undistorted when said cartridge is fired,
   (m) a rigid, fuse-receiving tube connecting the axial opening in said boss with the axial opening in said cartridge, said tube extending axially through said expansion chamber above said cartridge, and
   (n) the upper surface of said end plug abutting the lower surface of said cartridge to retain the cartridge firmly seated against the shoulder in the counterbored portion of said body.
3. A device for severing pipe in an oil well bore and the like comprising:
   (a) a short cylindrical, non-frangible, pressure-resistant housing including a hollow body portion and a separate end plug sealingly closing the lower end of said body,
   (b) said body portion having a thick annular side wall and a thick top wall integral therewith,
   (c) said top wall having a central, upstanding cylindrical boss integral therewith,
   (d) said boss providing an axial opening therethrough adapted to receive a detonating fuse therein,
   (e) the lower section of said side wall having a counterbore therein terminating a substantial distance below said top wall and providing a downwardly-facing shoulder,
   (f) said side wall providing a horizontal annular groove opening inwardly of said housing and having a thin section bounding the outer periphery of the groove,
(g) said groove being located subjacent and close to said shoulder in the counterbored portion of said body,
(h) a generally cylindrical, shaped explosive charge cartridge slidingly received in said counterbore with the upper edge of the cartridge seated against said shoulder and the lower edge of said cartridge abutting the wall of said counterbore below said groove,
(i) said cartridge having a main charge of explosive material having an outwardly-opening, annular, lined cavity facing said thin section and adapted upon being fired to produce a radially expanding planar cutting jet adapted to cleanly sever said side wall at said thin section,
(j) said cartridge providing an axial opening therethrough adapted to receive a portion of a detonating fuse,
(k) said housing and said cartridge defining substantially unobstructed spaces above and below said cartridge for the parasitic products resulting from detonation thereof,
(l) the walls of said body above said groove being of sufficient thickness and strength to remain intact and to be substantially undistorted when said cartridge is fired,
(m) a rigid, fuse-receiving tube connecting the axial opening in said boss with the axial opening in said cartridge, said tube extending axially through said expansion chamber above said cartridge, and
(n) support means extending across the expansion chamber below said cartridge engaging said end plug and said cartridge to retain the upper edge of the cartridge firmly seated against the shoulder in the counterbored portion of said body.

4. A device for severing pipe in an oil well bore and the like comprising:
(a) a short cylindrical, non-frangible, pressure-resistant housing including a hollow body portion and a separate end plug sealingly closing the lower end of said body,
(b) said body portion having a thick annular side wall and a thick top wall integral therewith,
(c) said top wall having a central, upstanding cylindrical boss integral therewith,
(d) said boss providing an axial opening therethrough adapted to receive a detonating fuse therein,
(e) the lower section of said side wall having a counterbore therein terminating a substantial distance below said top wall and providing a downwardly-facing shoulder,
(f) said side wall providing a horizontal annular groove opening inwardly of said housing and having a thin section bounding the outer periphery of the groove,
(g) said groove being located subjacent and close to said shoulder in the counterbored portion of said body,
(h) a generally cylindrical, shaped explosive charge cartridge slidingly received in said counterbore with the upper edge of the cartridge seated against said shoulder and the lower edge of said cartridge abutting the wall of said counterbore below said groove,
(i) said cartridge having a main charge of explosive material having an outwardly-opening, annular, lined cavity facing said thin section and adapted upon being fired to produce a radially expanding planar cutting jet adapted to cleanly sever said side wall at said thin section,
(j) said cartridge providing an axial opening therethrough adapted to receive a portion of a detonating fuse,
(k) said housing and said cartridge defining therebetween a substantially unobstructed space above said cartridge providing an expansion chamber for the parasitic products of said cartridge resulting from detonation thereof,
(l) the walls of said body above said groove being of sufficient thickness and strength to remain intact and to be substantially undistorted when said cartridge is fired,
(m) a rigid, fuse-receiving tube connecting the axial opening in said boss with the axial opening in said cartridge, said tube extending axially through said expansion chamber above said cartridge, and
(n) means including a spring acting against said end plug retaining the upper edge of said cartridge firmly seated against the shoulder in the counterbored portion of said body.

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