July 6, 1965 G. B. CHRISTOPHER 3,192,857

WELL TUBING CUTTING DEVICE

Filed Oct. 8, 1962 2 Sheets-Sheet 1

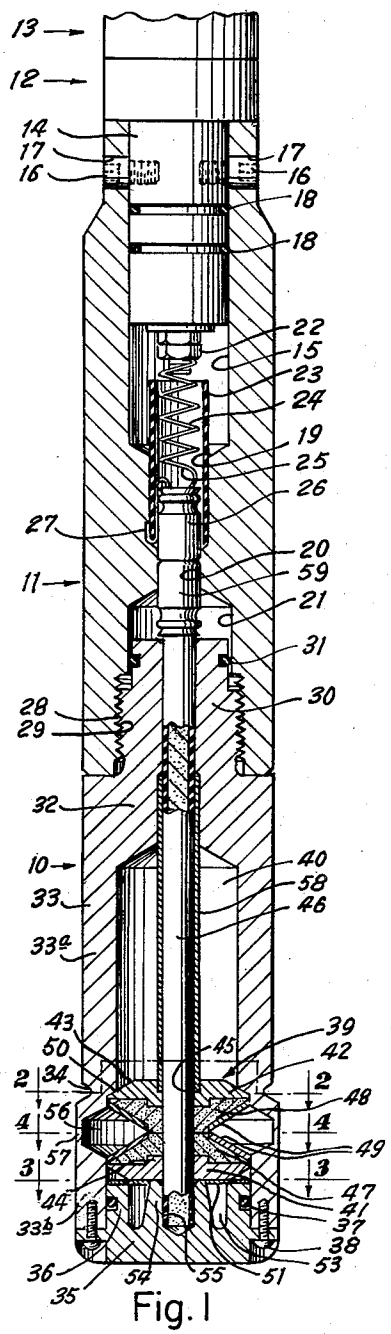


Fig. 1

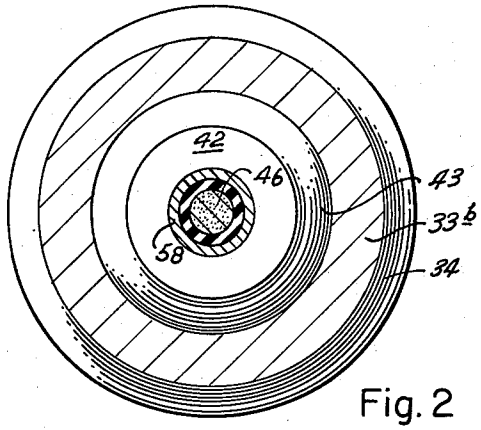


Fig. 2

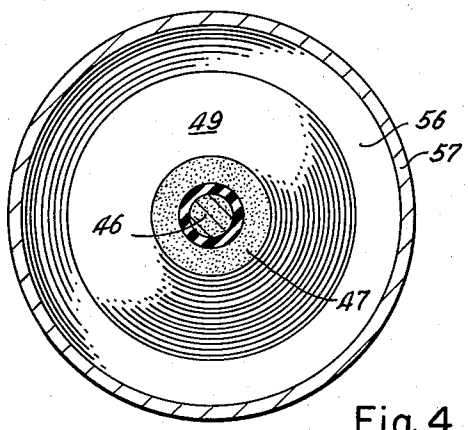


Fig. 4

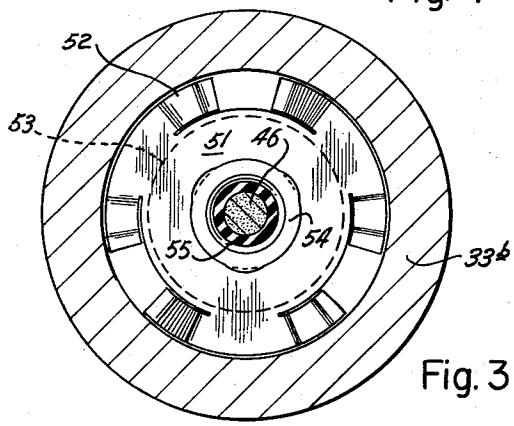


Fig. 3

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WELL TUBING CUTTING DEVICE

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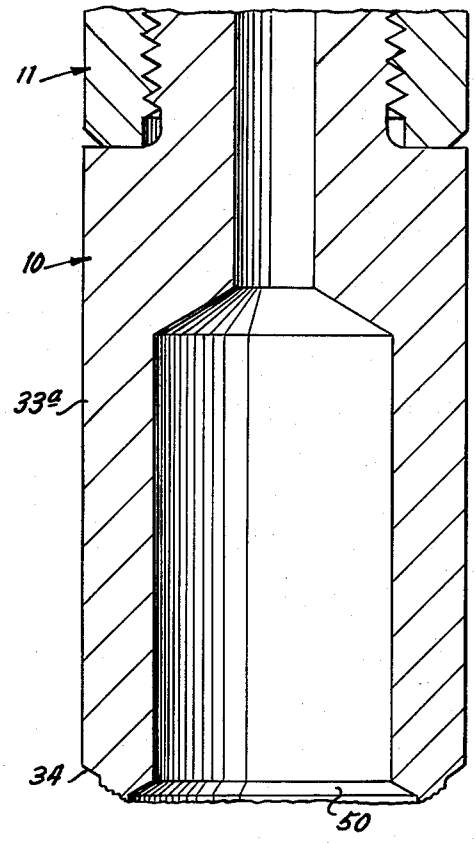


Fig.5

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WELL TUBING CUTTING DEVICE

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4 Claims. (Cl. 102—20)

This invention relates to a device for severing well tubing and the like by means of an annular shaped explosive charge.

Permanent type well completion techniques often require that the lower end of a tubing string be equipped with a guide shoe, bull plug, valve or other equipment which closes or restricts the end of the tubing. To complete the well using a through-tubing perforating gun, it is necessary that the obstruction be removed from the lower end of the tubing.

Other occasions often arise where it is desirable to cut well tubing in place, such as where the tubing has become stuck in the well, cannot be released from a packer, or the casing has collapsed on the tubing.

A large part of the tubing cutting operations conducted in recent years has utilized devices that may be run into the well on the end of an electric wireline. A pressure-resistant housing is used which contains an annular shaped explosive charge that, upon detonation, produces a planar cutting jet that is directed radially outwardly from the housing to cut through the tubing walls. The explosive load is carefully sized to insure that the tubing is cut through without causing any damage to the surrounding casing. One commercially successful form of a tubing cutting device which minimizes the flaring or splitting and outward bending of the cut tubing is disclosed in my copending application for United States Letters Patent, Serial No. 766,343, filed October 9, 1958, for "Apparatus for Cutting Oil Well Tubing and the Like," now Patent No. 3,057,295. The invention disclosed in this application is directed to improvements in the tubing cutter disclosed in my foregoing copending application.

In conducting tubing cutting operations, it is sometimes necessary that the retrievable portion of the tubing cutter housing pass through landing nipples installed in the tubing having a smaller inside diameter than the tubing. The slight flaring of the retriveable upper portion of the housing produced by the planar jet at the cut end of the housing has caused difficulty in retrieving the housing through close fitting nipples. Also, the severed, non-retrievable, lower end portion of the housing of the tubing cutter described in my foregoing copending application remains intact in the well and may bridge the opening in the lower portion of the cut tubing and interfere with subsequent down-hole work.

Therefore, it is an object of this invention to provide a tubing cutting device having a housing with a retrievable portion that will easily pass through close fitting openings after the device has been fired.

Another object of this invention is to provide a tubing cutting device that has a housing, a portion of which is retrievable, that is adapted to shear transversely with a minimum of flaring of the retrievable portion of the housing.

A further object of this invention is to provide a tubing cutting device with a housing having a non-retrievable lower portion adapted to be broken into several pieces by detonation of the shaped explosive charge.

The foregoing objects of the invention are achieved, in general, in a device for severing well tubing and the like which includes a short cylindrical, pressure-resistant housing including a hollow body portion. A separate end plug may sealingly close the lower end of the body. The body portion has a thick annular side wall and a thick top wall, which may be integral therewith. The side wall provides a first horizontal annular groove, preferably located in the exterior surface of the lower portion thereof. The side wall provides a second horizontal annular groove in the interior surface of the lower portion thereof immediately below the first annular groove. The side wall has a thin section bounding the outer periphery of the second groove. The body portion below the first annular groove has an outside diameter that is greater than the body portion above the first annular groove. A generally cylindrical, shaped explosive charge, having a main charge of explosive material with an outwardly-opening, annular, lined cavity in the periphery thereof, is mounted facing the thin section of the side wall. The charge is adapted upon firing to produce a radially expanding planar cutting jet adapted to sever the side wall at the thin section. Means are provided to maintain the cartridge in a fixed position with the cavity facing the thin section. The top wall and the cartridge provide openings therethrough adapted to receive a portion of a detonating fuse. The housing and the cartridge define therebetween a substantially unobstructed space above the cartridge providing an expansion chamber for containing upwardly acting forces produced upon detonation of the cartridge. The body is adapted to be cleanly severed transversely at the first annular groove by detonation of the cartridge. The side walls of the body above the first annular groove are of sufficient thickness and strength to remain intact and to be substantially undistorted after the cartridge is fired.

In accordance with another aspect of the invention, the separate end plug is provided with an axial bore and an annular groove surrounding the bore in the top surface thereof.

The foregoing objects and aims, and other objects and attendant advantages, will be set forth in detail in the following description of the invention 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 cutting device embodying the principles of the invention;

FIG. 2 is an enlarged sectional view along line 2—2 of FIG. 1;

FIG. 3 is an enlarged sectional view along line 3—3 of FIG. 1;

FIG. 4 is an enlarged sectional view along line 4—4 of FIG. 1; and

FIG. 5 is an enlarged sectional view of the retrievable body portion of the tubing cutting device of FIG. 1 after the shaped charge cartridge has been fired.

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 firing 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.

The adapter sub 12 has an axially depending, cylindrical projection 14 fitted snugly within a cylindrical bore 15 formed in the upper end of the firing head. Allenhead cap screws 16—16, threaded into the depending projection 14 and passing through holes 17—17 in the firing head, securely fasten the firing head to the adapter sub. O-rings 18—18 seal the firing head to the projection 14 and prevent ingress of well fluids into the bore 15.

The firing head has an axial bore 19 of reduced diam-

eter communicating with the bottom of the bore **15**. Another bore **20** of still further reduced diameter extends axially downwardly from the bore **19** to communicate with a recess **21** extending axially upwardly from the bottom of the firing head.

An electrical contact member **22** is insulatedly supported by the projection **14** at its lower end and is electrically connected by insulated conductors (not shown) extending upwardly through the assembly to the wire of the conductor cable. An insulating sleeve **23**, of resilient material such as rubber, is inserted in the bore **19**. The sleeve frictionally supports a metallic spring **24** that makes contact at its upper end with the contact member **22** and is electrically connected at its lower end to the terminal wire **25** of an electric blasting cap **26**. The other terminal wire **27** of the blasting cap is grounded to the assembly by having its free end looped under the bottom of the insulating sleeve **23** and pressed into contact with the wall of the bore **19**. It will be noted that the blasting cap is in part supported in the assembly by the walls of the bore **20**.

The recess **21** of the firing head has internal threads **28** at its lower end which mate with the external threads **29** provided on the cylindrical boss **30** of the cutter head **10**. An O-ring **31** seals the boss within the recess **21** of the firing head to prevent intrusion of well fluids.

The cutter head **10** has a top wall **32** and an annular cylindrical side wall **33**. The upper portion **33***a* of the side wall **33** has a diameter slightly smaller than the lower portion **33***b* of the side wall which is below a generally V-shaped first annular groove **34** provided in the exterior of the side wall **33**. The open lower end of the housing is closed by an end plug **35** having a cylindrical portion **36** that makes a sliding fit inside the lower end of the housing. An O-ring **37** is received in a groove provided in the periphery of the cylindrical portion of the plug to provide a seal with the interior of the lower portion **33***b* of the side wall. Drive screws **38** received in aligned openings provided in the edge of the plug **35** and the bottom of the lower portion **33***b* of the side wall attach the plug to the side wall.

A shaped explosive charge cartridge **39** is mounted within the chamber **40** of the cutter head. As described in my aforementioned copending application, the chamber **40** provides an expansion chamber into which the upwardly acting gases generated by the detonating cartridge may expand and be confined. The forces so generated are absorbed and contained by the chamber **40** and the heavy side wall **33** to prevent the energy from acting on the cut tubing end to flare or split the bottom end of the cut tubing. The cartridge includes identical lower and upper end plates **41** and **42** which are circular in horizontal cross-section. The outer edge of each plate is beveled as shown at **43** in FIGS. 1 and 2. Each end plate has an inwardly-projecting cylindrical portion or boss **44** providing a thickened central section for the end plate. Each end plate provides an axial opening **45** to receive a portion of a detonating fuse **46**, such as Primacord. The main shaped explosive charge is formed from lower and upper annular elements designated **47** and **48**, respectively. Each element is made of a detonating explosive material, such as compressed waxed RDX for example. The outer peripheral face of each element is inwardly inclined and is lined with an inert liner section **49**. The inner edges of the liner sections abut at the bottom of the generally V-shaped groove formed by the outwardly flaring faces of the two explosive elements. The cartridge **39** is assembled by gluing together two half-sections. Each half-section consists of an end plate, a compressed explosive element, and a liner section which has previously been assembled into a unitary assembly. A top view of such a half-section of the cartridge **39** is shown in FIG. 4. The explosive elements provide axial openings aligned with the openings in the end plates to receive the detonating fuse **46**.

The inside diameter of the chamber **40** adjacent the lower portion **33***b* of the wall **33** is enlarged slightly by counterboring to provide a shoulder **50** that is opposite the groove **34** in the exterior of the side wall **33**. The cartridge **39** is received in the counterbored portion of the cutter head and is seated against the shoulder **50**. A cylindrical diaphragm spring **51**, positioned between the top surface of end plug **35** and the bottom surface of the lower end plate **41**, maintains the cartridge **39** firmly seated against the shoulder **50**. Referring to FIG. 3, it is seen that the spring **51** has a number of cut-out, upturned spring fingers **52** which engage the bottom of the lower end plate to maintain the cartridge in a fixed position. The end plug **35** has a deep annular groove **53** in the top surface thereof which defines a cylindrical center portion **54** of the plug. This center portion **54** has an axial bore **55** which receives the end of the detonating fuse **46**. The bore extends to about the same depth in the plug as does the groove **53**. A fuse tube **58** extends from the top wall **32** through chamber **40** to the top of the upper end plate to guide the detonating fuse through the openings **45** in the end plates into the bore **55**.

Referring now to FIG. 1, the lower portion **33***b* of the side wall provides a second annular, generally U-shaped groove **56** in the interior surface thereof immediately below the first exterior annular groove **34**. The groove **56** is opposite the annular lined cavity of the cartridge **39** and is symmetrical about a horizontal plane passing medially through the cartridge. The bottom of the groove defines a thin wall portion **57** in the lower section **33***b* of the side wall. This thin wall portion of the cutter head is made only thick enough to withstand hydrostatic pressures expected to be encountered in a well bore so that it may be readily cut by the planar jet with a minimum of energy absorption.

The cutter head **10** can be made of any material having sufficient strength whereby the entire assembly will resist the amount of hydrostatic pressure expected to be encountered in a well bore and which material will provide sufficient strength for the upper wall section **33***a* and top wall **32** to remain intact and to be substantially undistorted by the detonation of the shaped charge explosive cartridge. The heads can be made by rough machining from alloy steel stock, followed by heat treating and final machining. Satisfactory cutter heads can also be fabricated from castings of "Ductile Iron," a close grain cast iron.

The cutter head **10** is usually assembled at a manufacturing facility and shipped to the field for use as a complete unit. In assembling the device, a blasting cap **26** is positioned in the bore **20** in firing head **11** and its lead wires connected, one to post **22** and the other to ground. An exact length of detonating fuse **46** is cut and a booster cap **59** is crimped on one end thereof. The length of fuse is inserted into the opening in the top wall and cylindrical boss **30** of the cutter head and pushed in until the end hits the bottom of the bore **55** in the end plug **35**. An O-ring **31** is placed around the boss **30** and the cutter head is then screwed into the firing head **11**. When the threads are made up, the upper end of booster cap **59** butts against the lower end of the blasting cap **26** to provide a detonating train that may be fired from the earth's surface. The firing head is connected to the adapter sub **12** and through it to the casing collar locator **13** and the conductor cable (not shown) by which the completely assembled apparatus is lowered into a string of tubing.

In operation, the cutter head is positioned in the tubing at the depth it is desired to sever the tubing. A switch (not shown) on the earth's surface is closed to supply electric current to fire the blasting cap **26** which, in turn, fires the booster cap **59**, detonating fuse **46** and cartridge **39**. The shaped explosive charge cartridge detonates and forms a horizontal planar cutting jet traveling outwardly in the plane of the vertex of the lined

shaped charge cavity. The jet severs the thin wall section **57** and continues outwardly to cut the surrounding tubing.

When the explosive sections **47–48** of the cartridge detonate, the side wall **33** is broken off transversely with little or no outward flaring at the apex of the V-shaped first annular groove **34**. The side wall generally breaks along a line extending between the apex of the groove **34** and the point defined by the intersection of the surfaces of the counterbored interior side wall and the shoulder **50**. The force of the explosion breaks the ring portion of the case lying between the first exterior annular groove **34** and second interior annular groove **56** into a number of separate pieces. As may be seen in FIG. 5, provision of the groove **34** in the exterior of the wall **33** prevents any slight irregular edge portions of the broken end of the cutter head from extending past the outline of the upper portion **33***a* of the side wall.

The force of the detonation of the cartridge also breaks the larger diameter, lower portion **33***b* of the side wall into several small pieces. The annular groove **53** and the axial bore **55** in the end plug provide lines of weakness to enhance break up of this portion of the device. The portion of the detonating fuse received in the bore **55** contributes substantially to break-up of the end plug. The end plug is preferably made of a frangible material such as cast iron. Thus, it is seen that all of the portions of the cutter head below the first annular groove **34** are broken into pieces which are small enough to fall through the severed tubing without any danger of bridging in the tubing. The cutter head upper side wall portion **33***a* remains intact and substantially undistorted. The retrievable portions of the device, owing to their small diameter, are easily brought back through close fitting seating nipples that may be present in the tubing.

The embodiment of the invention shown in FIG. 1 is especially proportioned for severing $2\frac{1}{16}$ O.D., 0.156" wall, 1.721" I.D. tubing and is retrievable back through an Otis S type seating nipple with a 1.625 I.D. The O.D. of the upper portion **33***a* of the side wall is 1.442". The O.D. of the lower portion **33***b* of the side wall is 1.564". The height of the housing is $4\frac{19}{32}$" (without end plug) and the height of the chamber **40** is $2\frac{13}{16}$" measured from the bottom of the housing. The chamber **40** is $\frac{15}{16}$" I.D. above the shoulder **50**; the counterbored portion of the chamber which receives the cartridge is 1.093" I.D. The lower portion **33***b* of the side wall is 1.050" in height. The side walls of groove **34** are illustrated as including a 60° angle but other angles may function just as satisfactorily. The apex of the groove **34** defines a circle having a 1.317" diameter. The diameter of the groove **56** is 1.346" and the thin wall section **57** has a thickness of 0.050". The groove **53** and the bore **55** in the end cap **35** are both 0.318" deep. The cartridge **39** contains 4.0 grams of waxed RDX explosive with ¼ of one percent graphite. The annular elements of the explosive are compressed with a force of 12½ tons.

From the foregoing description of the invention, it will be obvious to persons skilled in the art to make various modifications thereto and it is understood that such modifications are included within the spirit and scope of the invention as defined by the appended claims.

I claim:

1. A device for severing well tubing and the like comprising:

(a) a short cylindrical, 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 side wall providing a single first horizontal annular groove in the exterior surface of the lower portion thereof;

(d) said side wall providing a second horizontal annular groove in the interior surface of said lower portion thereof immediately below said first annular groove and said side wall having a thin section bounding the outer periphery of said second groove;

(e) said body portion below said first annular groove having an outside diameter greater than the body portion above said first annular groove;

(f) a generally cylindrical, shaped explosive charge cartridge having a main charge of explosive material with an outwardly-opening, annular, lined cavity in the periphery mounted facing said thin section of said side wall and adapted upon being fired to produce a radially expanding planar cutting jet adapted to sever said side wall at said thin section;

(g) said cartridge being positioned within said hollow body portion to place the upper surface of said main charge of explosive material in a horizontal plane lying between said first and second annular grooves;

(h) means maintaining said cartridge in said position within said hollow body portion;

(i) said top wall and said cartridge providing axial openings therethrough adapted to receive a portion of a detonating fuse;

(j) said housing and said cartridge defining therebetween a substantially unobstructed space above said cartridge providing an expansion chamber for upwardly acting forces produced upon detonation of said cartridge;

(k) said body adapted to be cleanly broken transversely at said first annular groove by detonation of said cartridge whereby said body portion above said first annular groove will remain at substantially the same diameter as before detonation of said cartridge; and

(l) the side wall of said body above said first annular groove being of sufficient thickness and strength to remain intact and to be substantially undistorted after said cartridge is fired.

2. A device for severing well tubing and the like comprising:

(a) a short cylindrical, 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 side wall providing a single first horizontal annular groove in the exterior surface of the lower portion thereof;

(d) said side wall providing a second horizontal annular groove in the interior surface of said lower portion thereof immediately below said first annular groove and said side wall having a thin section bounding the outer periphery of said second groove;

(e) said body portion below said first annular groove having an outside diameter greater than the body portion above said first annular groove;

(f) a generally cylindrical, shaped explosive charge cartridge having a main charge of explosive material with an outwardly-opening, annular, lined cavity in the periphery mounted facing said thin section of said side wall and adapted upon being fired to produce a radially expanding planar cutting jet adapted to sever said side wall at said thin section;

(g) said cartridge being positioned within said hollow body portion to place the upper surface of said main charge of explosive material in a horizontal plane lying between said first and second annular grooves;

(h) means maintaining said cartridge in said position within said hollow body portion;

(i) said top wall and said cartridge providing axial openings therethrough adapted to receive a portion of a detonating fuse;

(j) said housing and said cartridge defining therebetween a substantially unobstructed space above

said cartridge providing an expansion chamber for upwardly acting forces produced upon detonation of said cartridge;

(k) said body adapted to be cleanly broken transversely at said first annular groove by detonation of said cartridge whereby said body portion above said first annular groove will remain at substantially the same diameter as before detonation of said cartridge;

(l) the side wall of said body above said first annular groove being of sufficient thickness and strength to remain intact and to be substantially undistorted after said cartridge is fired; and

(m) said body portion below said first annular groove and said separate end plug being adapted to be broken into several pieces by detonation of said cartridge, and the end portion of a detonating fuse.

3. A device for severing well tubing and the like comprising:

(a) a short cylindrical, 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 side wall providing a single first horizontal annular groove in the exterior surface of the lower portion thereof;

(d) said side wall providing a second horizontal annular groove in the interior surface of said lower portion thereof immediately below said first annular groove and said side wall having a thin section bounding the outer periphery of said second groove;

(e) said body portion below said first annular groove having an outside diameter greater than the body portion above said first annular groove;

(f) a generally cylindrical, shaped explosive charge cartridge having a main charge of explosive material with an outwardly-opening, annular lined cavity in the periphery mounted facing said thin section of said side wall and adapted upon being fired to produce a radially expanding planar cutting jet adapted to sever said side wall at said thin section;

(g) said cartridge being positioned within said hollow body portion to place the upper surface of said main charge of explosive material in a horizontal plane lying between said first and second annular grooves;

(h) means maintaining said cartridge in said position within said hollow body portion;

(i) said top wall and said cartridge providing axial openings therethrough adapted to receive a portion of a detonating fuse;

(j) said housing and said cartridge defining therebetween a substantially unobstructed space above said cartridge providing an expansion chamber for

upwardly acting forces produced upon detonation of said cartridge;

(k) said body adapted to be cleanly broken transversely at said first annular groove by detonation of said cartridge whereby said body portion above said first annular groove will remain at substantially the same diameter as before detonation of said cartridge;

(l) the side wall of said body above said first annular groove being of sufficient thickness and strength to remain intact and to be substantially undistorted after said cartridge is fired; and

(m) said separate end plug providing an axial bore adapted to receive an end portion of a detonating fuse and an annular groove surrounding said bore in the top surface of said plug to provide lines of weakness whereby detonation of said cartridge and fuse breaks said end plug into several small pieces.

4. A device for severing well tubing and the like comprising:

(a) a vertically elongated, hollow, hermetically sealed, pressure-resistant housing;

(b) said housing having an upper cylindrical portion and a lower cylindrical portion of larger diameter than said upper cylindrical portion, said lower portion being integral with and coaxial with said upper portion, said housing providing a single exterior, annular groove defined between said upper and lower portions, said groove being coaxial with said upper and lower portions and having a diameter less than the diameter of either portion;

(c) an annular, shaped explosive charge positioned in said housing coaxially with said housing portions and said groove, located immediately below said groove to project its jet circumferentially through the side wall of said lower housing portion, and adapted upon being detonated to produce a clean break in said housing horizontally through said groove without producing any substantial increase in the diameter of said upper cylindrical portion of said housing; and

(d) means for firing said shaped explosive charge.

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