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TUBING CUTTER

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Fig. 1

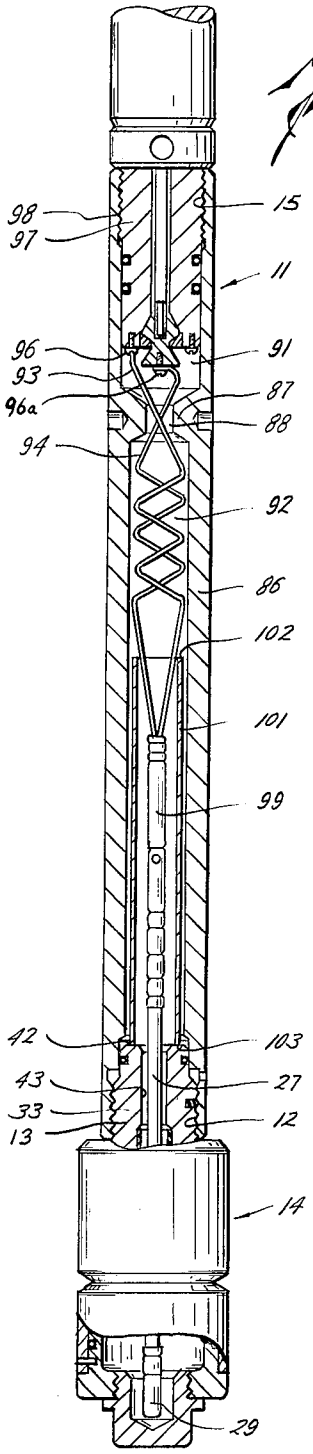
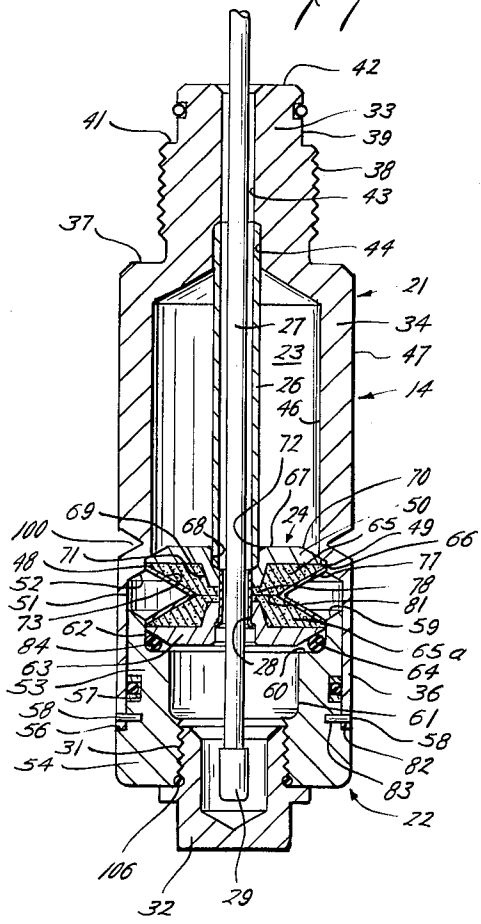


Fig. 2



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TUBING CUTTER

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This invention relates to apparatus for cutting tubing and more particularly, to a shaped charge apparatus for cutting small diameter tubing which is suspended in a well bore.

Shaped charge apparatus for cutting tubing are commonly referred to as "tubing cutters" and are used, for example, in drilling operations where it is desired to detach a bull plug or other obstruction from the lower end of a tubing in a well bore by severing the tubing above the bull plug. Tubing cutters are also used to salvage the tubing from an abandoned well or the part of the tubing above a stuck point.

Normally, tubing cutters, used in tubing for the above-described operations, are retrievable. With expendable tubing cutters which disintegrate in the well bore, it is desirable to minimize debris left in the well bore by constructing the tubing cutter so that only part of the apparatus is broken into debris with the remainder being retrievable from the well bore.

A tubing string, through which the cutter can be lowered into the well bore, often contains a pump seating nipple or landing nipple which forms a partial constriction in the tubing by reducing the size of the bore. This landing nipple may be located at a point intermediate the surface and the part of the tubing to be cut. In tubing cutters which are constructed to be partially recovered, the forces generated by an explosion of a shaped charge in the tubing cutter causes parts of the cutter which are not disintegrated to become expanded within the tubing. This expansion oftentimes prevents the retrieval of the expanded part through the landing nipple of the tubing.

Also, it is desirable that the cutter be constructed so that the debris from the disintegrated portion of the cutter is small in size and minimal in amount. Being expendable, the cost of the cutter becomes significant and therefore construction features which reduce this cost are desirable. Because of the time and expense involved in lowering the tubing cutter into a well bore it is also desirable that the arming of the cutter be reliable, ensuring the proper performance of the cutter.

It is therefore an object of this invention to provide a new and improved explosive apparatus for cutting tubing which may be easily removed from the well bore following the cutting operation.

Another object of the present invention is to provide a tubing cutter which is of a simple design and easily assembled.

Still another object of this invention is to provide an explosive charge apparatus for cutting tubing which has a simple and reliable arming operation, leaves a minimum of debris in the well bore, and which minimizes expansion of the parts of the cutter that are retrievable from the well bore.

A still further object of this invention is to provide a new and improved method and apparatus for ensuring reliable arming of a tubing cutter.

With these and other objects in view the present invention contemplates an explosive charge apparatus for severing tubing in a well bore and a method and apparatus for reliably arming the explosive charge. More particularly the apparatus includes upper and lower cylindrically shaped housing members which when assembled together provide a chamber therein for housing an explosive charge assembly. The explosive charge assembly is positively positioned in the chamber so that it is longitudinally spaced from a groove formed in one of the housing members at a distance calculated to be the expansion or bulge point in the housing upon detonation of the charge. The shaped charge assembly is held in this positive position by a resilient ring member positioned adjacent the charge assembly in the chamber which holds the charge assembly against a notch formed in the upper housing. A removable hollow plug is provided at the lower end of the lower housing and a tube is provided between the upper part of the upper housing and the shaped charge. A detonating cord may be threaded through the tube and the shaped charge so that a cap or ferrule may be crimped on the lower end of the detonating cord. The assembled apparatus may then be closed and sealed by inserting the plug in the lower housing with the hollow portion fitting over the capped detonating cord which has been threaded through the charge. A tubular shooting mandrel which threadably attaches to the upper end of the cutter has a bore for housing a connection between a firing circuit and the detonating cord. A tubular insert is positioned over the connection to prevent the connection from becoming jammed in the cutter and twisted with the threading of the cutter on the mandrel.

A complete understanding of this invention may be had by reference to the following detailed description when read in conjunction with the accompanying drawings illustrating an embodiment thereof, wherein:

FIG. 1 is a vertical sectional view of a shooting mandrel shown attached to a tubing cutter; and

FIG. 2 is a vertical sectional view of a tubing cutter embodying the invention.

Referring first to FIG. 1 of the drawings, a tubular shooting mandrel **11**, which may be suspended in any well-known manner into a well bore, is shown having an internally threaded portion **12** at its lower end. The threaded portion **12** of the shooting mandrel **11** provides an attaching means for an upper threaded end **13** of a tubing cutter **14**.

As shown in FIG. 2, tubing cutter **14** has an upper tubular housing member **21** and a lower tubular housing member **22** which form a sealed housing assembly with a hollow interior **23**. In the lower end portion of the hollow interior **23** is an annular shaped charge device **24**, the upper end portion of the hollow interior forming an expansion chamber. The expansion chamber has sufficient volumetric space to permit attenuation of shock forces generated upon detonation of the shaped charge device.

A tubular member **26** passes through the expansion chamber **23** from the upper end of the housing assembly to the shaped charge device and provides a conduit for guiding a blasting cord **27** to the shaped charge device. The blasting cord **27** also passes through a central aperture **28** in the shaped charge device **24** and its lower end is attached to a boot or ferrule **29**. The lower end of housing member **22** has an opening **31** in which a closure member **32** is threadedly and sealingly received. Closure member **32** permits access to the housing member **22** for attachment of the boot to the blasting cord after insertion into member **22**.

Upper housing member **21** has upper, intermediate and lower sections **33**, **34**, **36** the upper and intermediate sections **33**, **34** having different outer diameters to form an upwardly facing shoulder **37**. Above shoulder **37**, the upper housing section **33** has a threaded portion **38** and an uppermost portion **39** of still smaller diameter forming another upwardly facing shoulder **41**. Portion **39**, intermediate of its length, has an O-ring groove receiving an O-ring and terminates with an upwardly facing flat surface **42**.

A central, small-diameter bore **43** through upper sec-

tion 33 is counterbored at 44 and opens to the expansion chamber 23 formed in intermediate section 34. The expansion chamber 23 is formed by the wall of the housing section 34, between inner and outer wall surfaces 46, 47. The thickness of the wall being substantial to withstand explosive forces generated upon detonation of the shaped charge device without substantial distortion.

The intermediate housing section 34, at its lower end has an internal counterbored recess 48 with a conical taper 49 for seating the conically shaped, upper plate 50 of the shaped charge device 24. Below the recess 48 is still another counterbore 51 with a tapered end surface 52, the counterbore 51 forming the thin-walled lower housing section 36. The outer wall surface of lower housing section 36 has a similar diameter to the diameter of intermediate housing section 34.

The lower housing member 22 has upper and lower portions 53, 54 with different outer diameters forming a shoulder 56, the upper portion 53 being slidably received within the counterbore 51 of housing section 36 and having an O-ring in an O-ring groove 57 for sealing the housing members 21, 22 relative to one another. The shoulder 56 on housing 22 below the O-ring abuts the terminal end of housing section 36 and the housing members 21, 22 can be secured to one another by any suitable means such as pins 58. The upper end 59 of the lower housing member 22 terminates short of the tapered end surface 52 of the counterbore 51 to provide a thin-walled portion of housing section 36 adjacent to the shaped charge device 24, which portion can be easily severed by the perforating jet of the shaped charge device.

The lower housing member 22 has a central bore 61 forming a chamber and an upper counterbore 62 sized to receive a lower plate 63 of the shaped charge device 24. An O-ring 64 is also disposed between the lower plate 63 of the shaped charge device 24 and shoulder 60 formed by the counterbore 62 for reasons which will hereinafter become more apparent.

The shaped charge assembly 24 is comprised of upper and lower mirror image sub-assemblies respectively including upper and lower plates 50, 63 and shaped charge explosives 65, 65*a*. Since the sub-assemblies are identical only the upper sub-assembly will be described in detail. The plate 50 is disc shaped and is sized to be received within the counterbore 48 in the intermediate wall section 34 of the upper housing. The upper surface of the plate has a frusto-conical shaped, peripheral rim surface 70 which extends from a vertical outer edge 66 formed on the plate to a flat portion 67 extending radially from a recessed bore 68 through the center of the plate. This tapered surface 70 cooperates with the tapered surface 49 of the counterbore to center the plate 50 in the housing. The lower surface 69 of the plate is flat and extends outwardly from a central, frusto-conical surface 71 to the vertical edge 66 of the plate. The bore 28 extending through the plates of the charge device 24 has a counterbore 68 extending inwardly from the outer surface 67. Counterbore 68 is sized to receive the lower end of tube 26. A bevel 72 is formed on the upper rim of the counterbore 68.

The shaped charge explosive 65 is formed on the plate 50 to conform to the lower surface of the plate and has a lateral frusto-conical surface 73 inclined from the edge 66 of the plate toward the center of the charge. The shaped charge explosive is fitted with a thin-wall metal liner 77 which is complementary in shape to the lateral frusto-conical surface 73 formed on the charge. The explosive charge includes a central annular primer portion 78 through which the bore 28 extends. The liner, explosive and primer portion has a lower face 81 formed on a plane parallel to the upper flat surface of the plate and which fits in mirror image abutment with a face 81 on the lower-sub-assembly when they are assembled.

In the assembly of this apparatus to form a tubing cutter, the shaped charge sub-assemblies are first placed together in mirror image relation with the lower faces 81 of the liner, explosive, and primer abutting. Next, the detonating cord tube 26, which may be constructed of cardboard or other suitable material, is inserted into the counterbore 44 of the bore 43 in the upper housing section 33. The tube 26 serves to guide the detonating cord through the expansion chamber above the shaped charge device during the arming operation. The counterbore 68 of the upper plate 50 of the shaped charge device is next fitted over the depending end of the detonating cord guide tube 26 until the frusto-conical peripheral rim 70 and the vertical edge 66 of the shaped-charge assembly are fitted into the annular locating notch 43 formed in the inner bore of the intermediate wall section in the upper housing. Note that tube 26 has a length sufficiently short enough to permit positioning of the plate 50 in the recess and long enough to provide a guide between bore 43 and 28.

The resilient annular ring member 64 is next placed on the frusto-conical peripheral rim surface 70 of the lower plate 63 which forms the lower part of the shaped charge device. The lower housing member 22 is then fitted into the upper housing member with the outer wall of the lower housing member sliding within the cylindrical counterbore 51 of the thin-wall section 36 of the upper housing until a pair of holes 82 in the lower housing are aligned with the holes 83 formed through the thin-wall section of the housing section 36. The insertion of the lower housing member 22 into the upper housing 21 causes the horizontal surface 60 and a radius 84 of the counterbore 62 in the lower housing member 22 to push or compress the resilient ring member 64 against the shaped charge assembly to hold the shaped charge assembly in a fixed position against the locating notch 48 formed in the upper housing. This also permits easy alignment of the upper and lower housings 21, 22 while always ensuring proper positioning of the charge device within the housing. Pins 58 are than inserted through the holes 83 in the thin-wall section of the upper housing into the holes 82 formed into the wall of the lower housing to hold the housing members in assembly.

Referring now to FIG. 1 of the drawings a shooting mandrel 11 is shown secured to the cutter assembly 14. The shooting mandrel 11 is constructed of a tubular housing 86 which has internally threaded portions 15 and 12 on the upper and lower ends respectively thereof. A restricted portion 87 is formed in an inner bore of the housing, the restricted portion having a reduced bore 88 therethrough, to divide the housing into upper and lower bores 91 and 92.

The method of arming the tubing cutter is as follows: a pair of wires 93, 94 of a blasting cap 99 are connected to contacts 96, 96*a* formed on the ends of a well tool mandrel 97, the well tool mandrel being threaded at 98 and sized to be received within the threaded end 15 of the mandrel. Next, the blasting cord 27 is attached to the blasting cap 99. Housing 86 is passed over the blasting cap and cord and attached to mandrel 97. A tubing member 101, which may be constructed of cardboard or any other suitable material, is then inserted over the end of the detonating cord and the blasting cap and into the lower bore 92 of the mandrel until an upper edge 102 of the tube gathers the two wires 93, 94 which are connected to the upper end of the blasting cap. As the tube is further inserted into the lower bore 92, the edge 102 of the tube gathering the wires causes the cap 99 to remain suspended within the tube 101 because the residual stiffness of the wires prevents the wires from falling into the tube 101 thereby preventing the cap 99 from shifting downwardly within the tube. The lower end of the detonating cord is then threaded through the axially aligned bores 43, 28 and guide tube 26 in the tubing cutter until the detonating cord extends through and out of the threaded bore 31 of the tubing cutter lower housing. The tubing cutter 14 is then threadably secured to the lower

end of the mandrel by threading the stub on the upper housing into the mandrel 11. The operator observes, during the threading of the cutter to the mandrel, whether the lower end of the detonating cord which projects from the lower housing is twisting or rotating with the threading operation. If the detonating cord tends to rotate the operator may grasp the lower projecting end of the cord to prevent same from rotating within the tubing cutter and thereby preventing the blasting cap 99 from rotating and twisting away from the wires 93, 94 attached to the opposite end of the blasting cap. As the tubing cutter is being threaded into the lower end 12 of the mandrel the shoulder 42 formed on the stub portion of the upper housing abuts against a lower edge 103 of the tube 101 which is slidably received within the lower bore 92 of the mandrel and positions the tube within the mandrel so that the blasting cap 99 does not drift downwardly within the mandrel to become lodged in the bore 43 formed in the upper housing of the tubing cutter and thereby rotate with the tubing cutter as it is being threaded into the mandrel. After the tubing cutter has been tightened on the mandrel, any excess on the end of the detonating cord may be cut away from the detonating cord and the cap or ferrule 29 is secured or crimped to the end of the detonating cord 27 to prevent the cord from pulling back through the tubing cutter. The plug 32 having a cup-shaped recessed area and a sealing member 106 thereon is then threaded into the internally threaded end 31 of the lower housing of the tubing cutter to seal the lower end of the cutter assembly.

In the construction of the components comprising the cutter apparatus, the upper housing is preferably made of steel but could, of course, be made of other suitable materials. The lower housing, the plates in the explosive charge assembly, and the plug which is threaded into the lower housing are preferably made of a graphitized lightweight fluid tight cast iron, such as that sold under the trademark "Meehanite." More particularly, a Meehanite type GM is preferably used, this type having the properties of high compressive strength, high tensile strength, dense fine-grain structure, and a low ductility or brittleness. This material meets the requirements outlined in the following specifications:

ASTM A48–56 class 50–60, ASTM A278–56 class 60, and QQ–1–652a class 50–60. The high compressive and tensile properties of this material render the cutter assembly structurally sound when subjected to the pressures usually encountered in a well bore and the low ductility and fine grain structure properties render the cutter frangible when subjected to an explosive attack so that the charge assembly and lower housing disintegrate into small pieces which may be easily drilled through.

In the operation of this device the blasting cap is exploded by a surface controlled firing circuit connected to the cap through wires 93, 94. The firing circuit is energized by any well-known electrical firing means and includes, of course, the electrical cable suspending the cutter in the tubing. Detonation of the blasting cap 99 subsequently detones the detonating cord 27 which in turn, detonates the primer booster of the shaped charge device. The booster explosion wave travels radially outwardly through the booster to detonate the main explosive of the charge. The explosive detonates radially outwardly in a symmetrical pattern and the liner forms a cutting jet. The space between the liner and the thin section of the lower housing wall, being at atmospheric pressure, permits full development of the jet before it exits through the thin housing wall and continues outwardly to cut the tubing surrounding the cutter.

As the resulting forces generated by the explosive charge, which do not form a part of the jet, radiate from the exploding charge, they are transferred through the frangible Meehanite plates to be attenuated and dissipated in the large air space formed above the shaped charge assembly. These same resulting forces disintegrate the Meehanite plates of the charge assembly and, although partially attenuated by the air space between the shaped charge assembly and plug 32, also disintingrate the lower frangible housing and plug. The air spaces above and below the charge serve to attenuate the explosive force.

A significant feature of this invention may now be best understood by reference to FIG. 1. I have found that the severing of the thin-wall section 36 adjacent the shaped charge and the charge detonation also flares out or expands the lower end of housing section 34. Therefore, an important feature of this invention is the provision of an annular V-shaped notch 100 in the housing section 34 just above the thin-wall section 36. The notch 100 is made deep enough and spaced relative to the shaped charge so that the explosive forces also sever the intermediate wall section 34 of the upper housing at the notch 100. The severing of the upper housing section at this point removes any flared portions of housing section 34 so that housing section is easily retrieved through the usual landing nipples located within the production tubing. It can easily be determined by one skilled in the art that the position of the notch 100 relative to the shaped charge device 24 is dependent upon the amount and shape of explosive in the shaped charge assembly and is located in a straight-forward manner.

While a particular embodiment of the present invention has been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. An apparatus for suspension in a well tubing including: an upper tubular housing member having upper, intermediate, and lower wall sections about a hollow interior, said upper housing section having means adapted for securing the apparatus to a lowering device, said lower wall section having a thin-walled section, a lower tubular housing member sized for reception into said lower housing section and adapted to be telescopically received therein, said lower tubular housing member having a central opening for external access thereinto, annular shaped charge means having a bore therethrough and arranged for positioning in said upper and lower housing members to face the thin-walled section of said upper tubular housing member, the intermediate wall section of said upper housing member defining a lengthwise extending expansion chamber above said shaped charge means, a tube member extending through said expansion chamber for guiding a blasting cord therethrough from said upper housing section into the shaped charge bore, and a closure member sized for reception into said central opening in said lower housing member.

2. An apparatus for suspension in a well tubing from a shooting mandrel, and for receiving a detonating cord emanating from the lower end of the mandrel, the apparatus comprising: upper and lower tubular housing members telescopically fitted together to form an interior hollow chamber, each of said members having thin, intermediate, and thick cylindrical wall sections, said thick-walled upper housing section having a threaded portion for securing the apparatus to the shooting mandrel, said thick-walled lower housing section having a central opening providing external access therethrough, a shaped charge assembly received in said chamber and having a bore therethrough, said bore for receiving the detonating cord emanating from the lower end of the mandrel, a tube extending from said thick-walled upper housing section into the shaped charge bore for guiding the detonating cord from the thick-walled section into the shaped charge bore, said housing members having means for receiving the shaped charge assembly between the intermediate wall sections of said housing members when assembled, and a hollow plug sized for reception into said central open-

ing in said lower housing member for receiving the lower end of said detonating cord.

3. An apparatus for suspension in a well tubing from a shooting mandrel and for receiving a detonating cord emanating from the lower end of the mandrel, the apparatus comprising: upper and lower tubular housing members fitted together to form an internal hollow chamber, said upper housing member adapted for connection with the shooting mandrel, a shaped charge assembly received in said chamber and having a bore therethrough, said shaped charge assembly being held in said chamber by said lower housing member, said bore for receiving the detonating cord emanating from the lower end of the mandrel, a central opening in said lower housing member providing external access therethrough into said lower housing member, and a plug sized for reception in said central opening.

4. In an apparatus for cutting tubing wherein a shaped charge assembly having a threaded portion is threadably secured to an axially bored mandrel containing firing circuit wires, a blasting cap means, and a detonating cord, the combination of means for reliably arming the apparatus, which means comprises: a tubular sleeve received within the bore of said mandrel, said sleeve fitting over said cord and cap means with the end of said sleeve gathering said wires, a shoulder formed on the threaded portion of the shaped charge assembly, said shoulder being in abutting relationship with said sleeve for maintaining said sleeve against said wires to prevent said cap means from shifting from the mandrel into the shaped charge assembly.

5. A method of arming a shaped charge tubing cutter apparatus having threaded upper and lower end portions, the upper threaded end portion for connecting with a shooting mandrel and the lower threaded end portion having a bore adapted for closure by a plug comprising

the steps of: positioning a blasting cap means having upper and lower ends and with conductor wires extending from the upper end and detonating cord means extending from the lower end in the axial bore of the shooting mandrel which has threaded ends, positioning a tubular sleeve over the lower end of the detonating cord means, running the sleeve up on the detonating cord means and blasting cap means and into the mandrel bore until the sleeve gathers the conductor wires which extend from the upper end of the blasting cap means to support the blasting cap means within the mandrel bore, threading the detonating cord means through a bore in a shaped charge member positioned in the tubing cutter and out of the bore in the lower threaded end portion of the tubing cutter apparatus, threadably securing the shaped charge apparatus to the shooting mandrel, and pushing the lower extending end of the detonating cord means back into the tubing cutter apparatus while threading a plug into the lower end of the shaped charge apparatus.

References Cited by the Examiner

UNITED STATES PATENTS

2,873,675	2/1959	Lebourg	102—20
2,935,944	5/1960	Sweetman	102—20
3,053,182	9/1962	Christopher	102—20
3,057,295	10/1962	Christopher	102—20
3,087,369	4/1963	Butterfield	89—1
3,101,051	8/1963	Gilbert	102—20
3,139,031	6/1964	Schroter et al.	102—49
3,150,590	9/1964	Silverman	102—21
3,192,857	7/1965	Christopher	102—20

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