Aug. 14, 1956 C. W. GRANDIN 2,758,543

CUTTING METHOD AND APPARATUS

Filed April 10, 1950

2 Sheets-Sheet 1

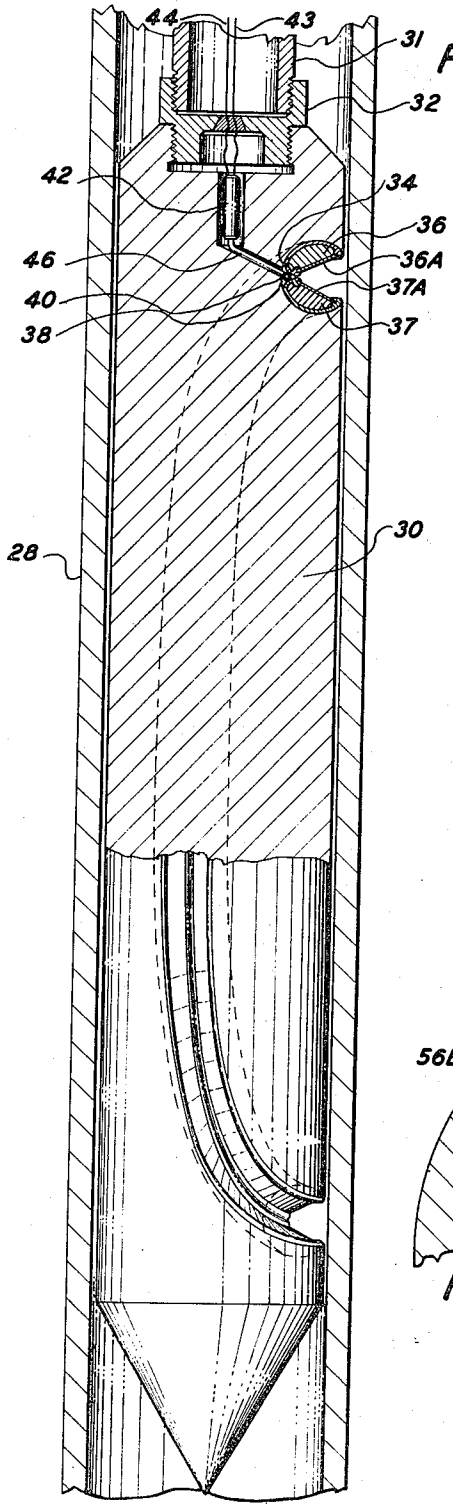


FIG. 6.

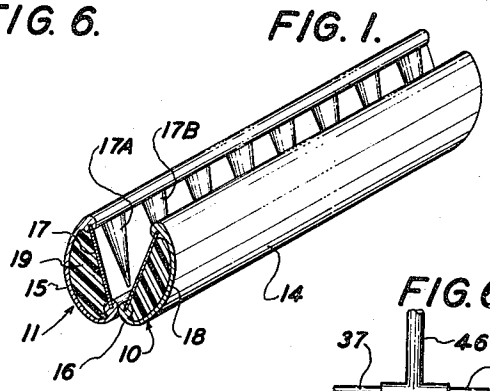


FIG. 1.

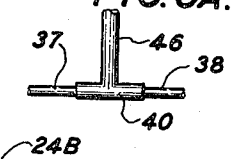


FIG. 6A.

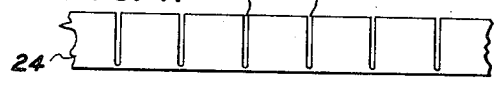


FIG. 4.

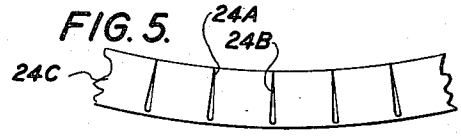


FIG. 5.

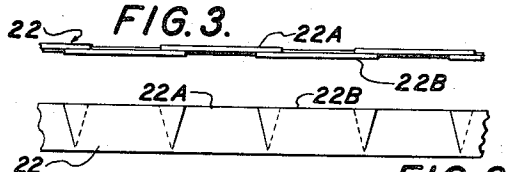


FIG. 3.

FIG. 2.

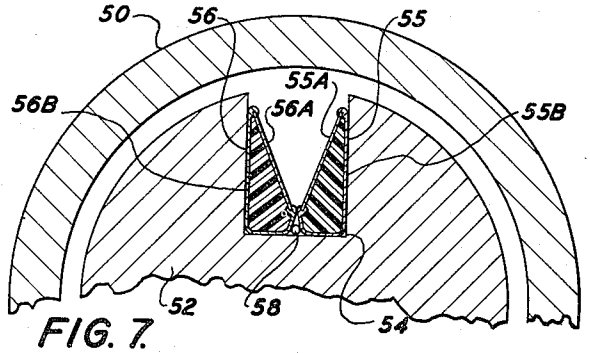


FIG. 7.

INVENTOR.
CLARENCE W. GRANDIN

BY

James B. Christie

ATTORNEY

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CUTTING METHOD AND APPARATUS

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FIG. 10.

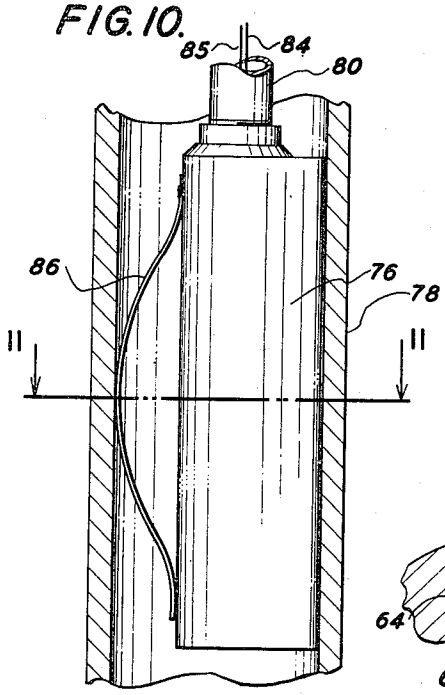


FIG. 9A.

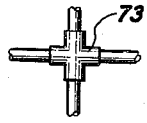


FIG. 9.

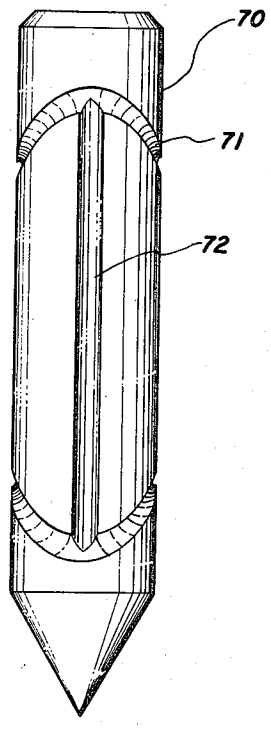


FIG. 8.

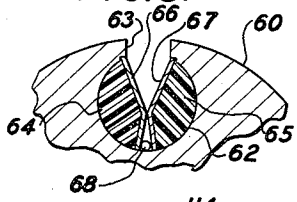


FIG. 11.

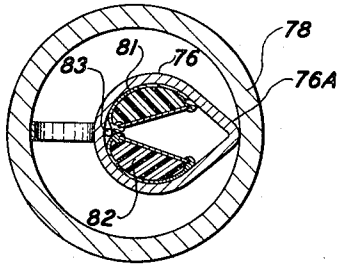


FIG. 12.

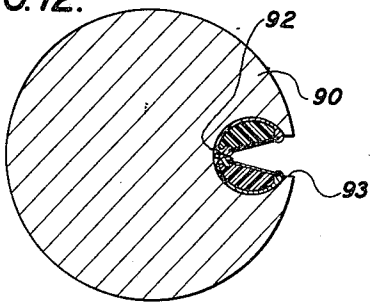


FIG. 13.

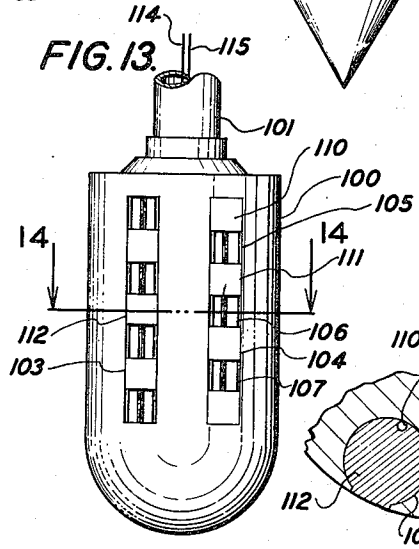
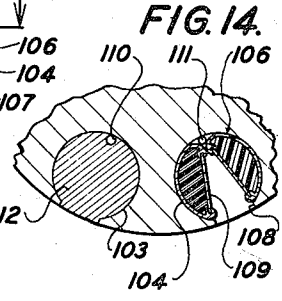


FIG. 14.



INVENTOR.
CLARENCE W. GRANDIN

BY

James D. Christie

ATTORNEY

United States Patent Office

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CUTTING METHOD AND APPARATUS

Clarence W. Grandin, Altadena, Calif.

Application April 10, 1950, Serial No. 154,925

13 Claims. (Cl. 102—21.6)

This invention relates to the use of explosives for cutting metals, minerals, etc., and more particularly to improvements in methods and apparatus for cutting such materials by means of explosive generated shock waves.

It has long been known that if an explosive pellet is detonated on say a metal surface, an outline of the pellet will be engraved in the metal. This phenomenon is brought about by the action of concentrated shock waves on the metal surface and is known as the Monroe Effect. It has also been found that if a small cavity is formed in the explosive charge opening toward the metal surface, the effect of the explosion on the metal will be magnified. The explanation is advanced that this cavity in the explosive pellet brings about a greater concentration of the shock waves before they strike the metal, resulting in an appreciable velocity increase and a consequent greater effect on the metal.

This principle has found practical use in casing perforators wherein a conical explosive pellet having a conical cavity in its base is positioned adjacent a wall of the casing with the cavity opening toward the casing. On detonation such a pellet will blow a hole through the casing. In conventional perforators a series of such pellets are successively detonated to produce a plurality of perforations in the casing. I have now found methods and apparatus for utilizing the Monroe Effect to cut metals, minerals or other hard materials in any desired pattern or outline as distinguished from merely blowing a hole in the material. A feature of the invention is the simplicity and the economy of the apparatus and the speed with which it functions to cut metal either on a straight, curved or closed line and in any desired pattern.

As an illustration of an application of the invention, there is a certain locality in California penetrated by numerous oil wells which is subject to periodic subsurface cleavage. When such cleavage or slippage occurs in the underlying strata, wells extending through this strata are severed so that the upper portion of the well is displaced laterally from several inches to several feet from the lower portion of the well. Such occurrence, of course, immediately stops production in these wells and it is necessary to whipstock from the upper section to again meet the lower section of the well. To do this the casing in the upper section must be cut away to the extent necessary to allow a drill bit and drill string to proceed at an angle through the side of the casing and at a predetermined location. Conventional gun or explosive perforators are not adapted for this use since the small holes produced by such equipment are totally inadequate for cutting away a segment of the casing which must be many feet in length. However, with the apparatus of my invention as hereinafter described, I am enabled to cut away a section of the casing of any desired shape and of sufficient size to permit a drill bit and drill string to pass through it in the whipstocking operation.

The foregoing is only one example of the many uses of the apparatus of the invention which is adapted to cut

metal tubes or plates, mineral formations, etc., in any desired line or shape.

Accordingly, the invention contemplates apparatus for cutting hard materials comprising an elongated charge of explosive, means forming an elongated cavity of triangular cross section extending from end to end of the charge, and detonating means extending from end to end of the charge adjacent the vertex of the cavity. In a preferred embodiment, the charge comprises two elongated explosive pellets, each pellet being substantially cylindrical in shape with a flat side extending from end to end, means holding the two pellets in longitudinal abutment adjacent one edge of each of the flat sides with the sides diverging from each other to include an angle of from about 30° to 45° so as to form the aforementioned elongated cavity of triangular cross section, and detonating means extending the length of and between the adjoining pellets adjacent the line of contact therebetween and opposite the cavity.

A feature of the invention is the means defining the flat sides on the otherwise substantially cylindrical pellets. I have found that best results are achieved if this means comprises a separate thin metal liner forming one wall of each pellet with the two liners converging toward the vertex of the triangular cavity defined by the liners. The cutting action is more efficient if the liners are not formed integrally with each other and are in no way attached to each other at the vertex of the cavity. However, it is also within the contemplation of the invention to employ an integral body of explosive and to form the necessary cavity by means of a single metal trough of triangular section instead of the separate liners.

An important part of the invention resides in the fact that these liners are flexible in all directions so that the elongated pellets may be bent in any desired shape without materially affecting the shape of the cavity, which is preferably held within the angular limits mentioned above to achieve optimum results. Various means for attaining this flexibility in the metal liners are illustrated in the accompanying drawing as hereinafter described.

The invention also contemplates a method of cutting hard materials by means of explosives which comprises disposing an explosive charge adjacent the material to be cut and in the form of an elongated ribbon extending along the line to be cut and having a cavity of triangular section extending from end to end of the charge and opening toward the material, and detonating the charge progressively by means of a cordeau extending the length of the charge on the side opposite the material to be cut and in the shortest possible path.

The invention will be more clearly understood by reference to the following detailed description thereof taken in conjunction with the accompanying drawings in which:

Fig. 1 is a prospective view of one form of the invention comprising two juxtaposed pellets and showing one type of flexible liner;

Fig. 2 is an elevation of another type of flexible liner;

Fig. 3 is a top view of the liner of Fig. 2;

Fig. 4 is an elevation of a third type of flexible liner;

Fig. 5 is an elevation showing the method of forming the liner of Fig. 4;

Fig. 6 is a section through a piece of tubular metal pipe showing one form of the apparatus of the invention wherein the elongated explosive pellets are mounted in a cylindrical carrier adapted to be suspended within the pipe;

Fig. 6A is an elevation of a cordeau junction as used in the apparatus of Fig. 6;

Fig. 7 is a transverse section through a modified form of the apparatus of Fig. 6;

Fig. 8 is a transverse section through still another modification of the apparatus of Fig. 6;

Fig. 9 is an elevation of a carrier similar to that shown in Fig. 6;

Fig. 9A is an elevation of a cordeau junction as used in the carrier of Fig. 9;

Fig. 10 is a vertical section through a piece of tubular pipe showing another type of carrier;

Fig. 11 is a transverse section taken on the line **11—11** of Fig. 10;

Fig. 12 is a transverse section through a carrier showing an alternative means of mounting the explosive charge therein;

Fig. 13 is an elevation of a carrier and explosive assembly used for forming a plurality of spaced holes rather than a continuous cut in an object; and

Fig. 14 is a transverse section taken on the line **14—14** of Fig. 13.

Referring to Fig. 1 of the drawing, there is shown a pair of elongated pellets **10, 11**, each pellet being substantially cylindrical in form as defined by flexible casings **14, 15** with one flat face defined by liners **16, 17**, respectively, held along their opposite edges in the respective casings. Explosive charges **18, 19** are enclosed within the respective casings and liners.

It is to be understood that the invention does not depend upon the use of a flexible casing, as for example the case **14**, since the explosive charge may be packed into a groove formed in a carrier as will be explained hereinafter. However, from a manufacturing standpoint it is expedient to form the pellets by extrusion, in which case a casing is indicated to confine the pellet before it is mounted in such a carrier.

The liners **16, 17** comprise thin metal strips of say approximately .070 inch in thickness, which as mentioned above are sealed along their longitudinal edges in the enclosing casing.

The elongated pellets **10, 11** are used in substantially the illustrated form and orientation by inserting them in an appropriate carrier grooved to receive the two pellets, or by otherwise binding them together so that the pellets will abut adjacent the lower edge of the metal liners and so that the liners will diverge to include an angle of from about 30° to about 45°. In this manner an elongated cavity of triangular cross section is formed between the abutting pellets.

To make the apparatus of the invention universally applicable it is necessary that it be flexible in all directions, and that any bend therein will not appreciably alter the included angle between the liners. To accomplish this the metal liners are so constructed that they are flexible both transverse and parallel to the plane of their major surfaces. In the embodiment shown in Fig. 1, this is accomplished by forming the liners, as for example the liner **17**, with a plurality of semi-conical undulations **17A, 17B**, etc. These undulations act as expansion joints which permit the liner **17** to be bent along its major axis within the limits defined by the transverse protrusion of the undulations.

Figs. 2 and 3 show in elevation and plan view respectively another form of liner having the necessary flexibility along its major axis. Liner **22**, shown in Figs. 2 and 3, is formed from a flat circular or curvilinear annular strip of metal which is cut radially from the outer toward the inner periphery at comparatively short intervals and the metal is then bent along its major axis into a straight strip as illustrated so that adjoining sections **22A, 22B** overlap, being displaced laterally from the uncut edge to permit the overlapping. When the liner **22** is bent in the plane of the paper, the V shaped overlaps will either spread or contract, depending upon the direction of curvature.

Another liner **24** is illustrated in elevation in Fig. 4 and is provided with a series of transverse partial slots **24A, 24B**, etc., which permit the liner to be bent along its major axis. To form the liner **24**, a curvilinear strip of metal **24C**, as shown in Fig. 5, is slotted at **24A, 24B**, etc., the slots being generally triangular in shape so that

when the strip **24C** is straightened to form the liner **24**, the sides of the slots **24, 24B** will be substantially parallel to each other.

Any type of flexible metal liner may be used in the practice of the invention, the three types illustrated in Figs. 1 to 5 comprising only three of the many possible means of achieving the necessary flexibility. Also where a single metal trough is used to replace the separate liners, as mentioned above, it is also preferably flexible. Such flexibility of a trough may be achieved if desired in the same manner shown in Figs. 1—5.

In using the apparatus of the invention for cutting a hole in a well casing in the manner described in the foregoing example, the explosive charge, preferably comprising two separate pellets, is carried in an elongated carrier adapted to be suspended by means of a cable or oriented on a drill string at the proper point in the casing.

Such apparatus is shown in elevation in Fig. 6 as disposed in a casing section **23**. A substantially cylindrical carrier **30** is mounted on the lower end of a drill string **31** by means of an appropriate bushing **32** threaded respectively to the carrier and the drill string. A curvilinear groove **34** is formed in the carrier and for the particular application mentioned is ellipsoidal in outline. Two elongated explosive pellets **36, 37**, say of the type shown in Fig. 1, and having flexible metal liners **36A, 37A**, are mounted in a continuous ribbon in the groove **34** so that opposite ends of the two pellets abut somewhere along the groove, as for example approximately at the upper extremity of the groove. An elongated detonating cordeau **38** is retained in the space between the two pellets and substantially adjacent the point of abutment of the two pellets with opposite ends of the cordeau being fastened in a junction **40** (Fig. 6A). An electric blasting cap **42** is mounted in the carrier and is connected by leads **43, 44** through the drill string **31** to a power source at the surface. The blasting cap is connected by a section of cordeau **46** to the junction **40**. The junction contains a booster to ignite the abutting ends of the cordeau **38** responsive to the ignition of the section **46** of the cordeau. The detonation is propagated in both directions from the junction **40** around the groove **34** and since the ignition of the cordeau proceeds at an equal rate to the propagation of the explosive force itself there can be no premature detonation anywhere along the explosive ribbon. When the explosive ribbon constituting the two pellets **36, 37** is detonated, the shock waves break through the relatively thin, dense metal liner, converge in the intervening cavity, and are directed outwardly against the casing at a rate approximately twice that of either of the shock waves. The casing is cut along the line of the groove **34**, the metal in the cut section remaining intact but falling inside and down the casing.

The carrier groove need not be curvilinear in section as shown in Fig. 6, nor do the explosive pellets need to be substantially cylindrical in section. Fig. 7 is a transverse section through a metal pipe **50** and a carrier **52** similar to the carrier **30** shown in Fig. 6. The carrier **52** is provided with a groove **54** which is rectangular in section and two explosive pellets **55, 56** are mounted in juxtaposition in the groove **54** with metal liners **55A, 56A**, respectively, defining a cavity of triangular section and with the pellet casings **55B, 56B**, respectively, defining an opposing wedge shaped cavity through which a cordeau **58** is carried. The device shown in Fig. 7 will function in the same manner as that shown in Fig. 6.

It is not necessary as mentioned above that the explosive charge be retained in a flexible casing, although this is a practice expedient from a manufacturing standpoint. Fig. 8 is a section similar to Fig. 7 showing a carrier **60** having a groove **62** cast therein and opening through a slot **63**. In this embodiment powder is packed in the groove to form two bodies **64, 65**, which are separated by flexible metal liners **66, 67**, respectively. The liners are shaped to define a cavity of triangular cross section, as in the foregoing embodiments, and a smaller separation

between the powder charges below the cavity for carrying a cordeau 68. The liner 66 for example may be of any of the types shown in Figs. 1 to 5 except that each leg of the liner as viewed in the section of Fig. 8 will be cut or formed to have the semi-conical undulations, the transverse grooves or the overlapping sections so that the whole liner may be bent along its major axis.

As explained above the liners may be formed integrally as a trough of triangular section in which case there need be no separation of the explosive charge beneath the vertex of the trough. Separate liners are preferred, however, for the reason that a fraction of the explosive charge is dissipated in collapsing a trough type liner.

In the apparatus as shown in Fig. 6 having a single curvilinear continuous groove, an ellipsoidal segment of the casing 28 will be cut from the main body of the casing, this segment being elliptic in shape if flattened into a single plane. It has been found that such an integral piece when removed from the casing may be of such size and shape as to prevent it from falling down the casing and out of the way of the whipstocking or directional drilling operation. This may be accomplished by using an apparatus as shown in elevation in Fig. 9. In Fig. 9 a carrier 70 is provided with a first groove 71 to receive an explosive ribbon comprising two pellets as described and adapted to cut an ellipsoidal section out of a casing, and a second groove 72 extending from the upper to the lower extremity of the groove 71 and likewise adapted to carry an explosive ribbon of the type described. When the ribbon in this carrier is detonated it will cut a section of the casing conforming in shape to the section cut by the apparatus of Fig. 6, but at the same time it will cut this section in half so that the two pieces may more readily fall to the bottom of the hole. Even though the path from the upper to the lower extremity of groove 71 is shorter along groove 72 than along groove 71, there is no premature detonation of the charge at the lower extremity of groove 71 because the grooves join substantially perpendicularly to each other. In the same manner, additional slots of any desired configuration may be included in a carrier to cut the removed section into any number of smaller fragments.

In Fig. 9A there is shown a junction 73 of the type used in the carrier of Fig. 9 to join the cordeau leading from the blasting cap to both ends of the cordeau lying along groove 71 and one end of the cordeau lying in groove 72.

Upon occasion it is necessary or desirable to cut a well casing or other object in the presence of fluid or gas under pressure. In such an event it is important to exclude such fluid or gas from the cavity defined by the two explosive pellets, since the superatmospheric pressure would interfere to a certain extent with the formation and propagation of the necessary shock waves. Apparatus for use in such circumstances is shown in elevation in Fig. 10 as disposed in a length of pipe, the pipe being shown in sectional elevation in Fig. 10 and in transverse section in Fig. 11 which is taken on the line 11—11 of Fig. 10. Referring to Figs. 10 and 11, a carrier 76 is suspended in a pipe 78 by a supporting tube 80, which in the case of an oil well might well be the drill string. Unlike the carriers shown in Fig. 6 through 9 the carrier 76 is tubular and is shaped to carry two explosive pellets 81, 82, the pellets being of the type heretofore described, and a detonating cordeau 83. Viewed in section in Fig. 11 the carrier is generally cylindrical with a protrusion 76A extending the length of the carrier and aligned with the cavity between the two explosive pellets. The protruding side 76A of the carrier acts as a standoff fixing the distance between the pellets and the side wall of the pipe 78 and is of such shape as to permit the proper propagation and combination of the shock waves from the two pellets 81, 82, and at the same time sealing these pellets against fluid or gas pressure existing within the pipe 78. A leaf spring 86 is mounted on the outside of the carrier 76 diametrically opposite the protruding side 76A urging the carrier against the inner wall of the pipe 78. The means of igniting the detonating cordeau 86 with a blasting cap may be the same as that shown in Fig. 6, the blasting cap being connected to a power source at the surface by electrical leads 84, 85, which are shown at the top of Fig. 10.

The carrier shown in Fig. 6 is of an expendable type. With the groove 34 formed in the manner shown, the carrier will be destroyed by detonation of the explosive. In many cases this is not objectionable as when the carrier is constructed of wood or other expendable material. However, in some instances it may be desirable to construct a carrier adapted for reuse. Such a carrier is shown in section in Fig. 12. Carrier 90 shown in Fig. 12 is constructed of metal and has a channel 92 cast therein and opening through a slot 93 in a wall of the carrier. It will be noted that the channel 92 in the carrier 90 differs from the channel 34 in the carrier 30 of Fig. 6 in that it is inset, leaving a relatively thick metal lip between the channel and the outer wall of the carrier as compared to the feather lip defining the groove 34 in the carrier of Fig. 6. It is this feather lip which prevents repeated use of the carrier of Fig. 6, since the lip is fractured when the explosive ribbon is detonated. By constructing a carrier as shown in Fig. 12 with a relatively thick overhanging or defining lip, sufficient shear strength is obtained to withstand the side effects of the explosive charge and as a consequence the carrier may again be used by placing new explosive ribbons in the channel 92.

The apparatus thus far described adapts itself for use in cutting continuous lines or elongated patterns. It is often desirable to perforate a pipe or piece of metal with a plurality of separate holes. This also can be accomplished in accordance with my invention, and apparatus for doing this is illustrated in elevation in Fig. 13 and in transverse section in Fig. 14. Referring to these figures there is shown a carrier 100 adapted to be suspended, say inside of a well casing, by a tube 101 which is conveniently the drill string. The carrier 100 is provided with two parallel grooves 103, 104, shaped as the groove 92 in the apparatus of Fig. 12. Alteratively, the grooves 103, 104 may be shaped with a feather edge as in the apparatus of Fig. 6. In this embodiment, several short sections 105, 106, 107 of explosive ribbon consisting in each case of two pellets 108, 109 as shown in Fig. 14 are placed in the grooves and are separated by sections 110, 111, 112, etc. of an inert material such as diatomaceous earth, clay, asbestos, or the like. Cordeaus 110, 111 are carried through channels 103, 104, respectively, passing through the inert material as well as the short sections of explosive ribbon.

The two lengths 110, 111, of cordeau are simultaneously ignited by means of a blasting cap (not shown) imbedded in the carrier and connected by wires 114, 115 to a remote power source. To properly operate a perforator of this type it is absolutely essential that the explosive charges be separated by inert material so that the shock waves generated by each charge will converge in the cavity of that charge issuing from the carrier as a combined blast unaffected by lateral displacement of the charge or by predetonation responsive to previous detonation of other charges. If the inert material were omitted, the separate explosive charges would have enough lateral freedom to substantially reduce the focus of the combination shock waves. Although the perforator of Fig. 13 is shown as including a pair of parallel longitudinal channels, perforation may be achieved with any shape channel or carrier by the simple expedient of interspersing inert material between separate sections of explosive. Attention is called to the fact that the cordeau travels in the shortest possible path between successive sections of charge so that there can be no premature detonation of the charges.

The explosive ribbon comprising the two flexible pel-

lets, as for example in the apparatus of Fig. 1, may be used apart from any carrier by simply taping or otherwise affixing the ribbon onto a material to be cut. In such a case some means, preferably other than the means used to apply it to the surface to be cut, is provided to hold the two pellets in the proper abutting and diverging relationship. Conveniently, the carrier shown in Fig. 10 can be used for this purpose, this carrier being flexible to about the same extent as the explosive ribbon, or in the alternative, a flexible casing, or clips may be used to clip the two explosive pellets together in the desired orientation.

In the apparatus of the invention the collapse of the detonation wave fronts in the elongated cavity is so confined that streams of gas are projected from the cavity with approximately twice the speed of a single wave front. For this reason ordinary commercially available 100% blasting gelatin is quite sufficient to do the cutting, although no such results could be obtained from a single charge of the gelatin acting by itself.

I claim:

1. Apparatus for cutting hard materials comprising a pair of elongated flexible explosive pellets, each pellet having a flat side extending from end to end, means holding the two pellets in longitudinal abutment adjacent one edge of the flat sides with the sides diverging from each other to form an elongated cavity of triangular cross section between the pellets, and detonating means extending the length of and between the pellets.

2. Apparatus for cutting hard materials comprising a pair of elongated flexible explosive pellets, each pellet having a flat side extending from end to end, means holding the two pellets in longitudinal abutment adjacent one edge of the flat sides with the sides diverging from each other to include an angle of from about 30° to about 45° so as to form an elongated cavity of triangular cross section between the pellets, and detonating means extending the length of and between the pellets.

3. Apparatus for cutting hard materials comprising a pair of elongated flexible explosive pellets, each pellet having a flat side defined by separate thin metal liners extending from end to end, means holding the two pellets in longitudinal abutment adjacent one edge of the metal liners with the liners diverging from each other to include an angle of from about 30° to about 45° so as to form an elongated cavity of triangular cross section between the pellets, and detonating means extending the length of and between the pellets.

4. Apparatus for cutting hard objects in a predetermined pattern comprising a carrier, an elongated receptacle formed in the carrier conforming to said predetermined pattern, an elongated explosive charge disposed in said receptacle and consisting of juxtaposed discrete elongated pellets, means defining a cavity between said pellets of triangular cross section extending from end to end of the charge with the cavity opening toward said object, and detonating means extending the length of the charge in the receptacle.

5. Apparatus according to claim 4 wherein the means defining a cavity in said charge comprises a pair of elongated flexible metal liners held within said receptacle in disconnected and substantially abutting relationship and in contact with said charge.

6. Apparatus for cutting a hard object along a predetermined line comprising a carrier, an elongated receptacle in the carrier conforming in shape to said predetermined line, a pair of elongated explosive pellets disposed in said receptacle, each pellet having a flat side extending from end to end thereof, the two pellets being held in the receptacle in abutting relationship along an edge of said sides with the sides diverging outwardly to form an elongated cavity of triangular cross section between and extending from end to end of the pellets, and detonating means extending from end to end between the pellets.

7. Apparatus according to claim 6 wherein said carrier comprises a solid member of a length in excess of the length covered by said predetermined line, and said receptable comprises a channel formed in said member and opening longitudinally on the outside of the member, the pellets being disposed in said channel with said cavity opening toward the channel opening.

8. Apparatus according to claim 6 wherein said carrier comprises a tubular member generally cylindrical in form with a longitudinal protrusion in the wall thereof, the pellets being retained in the carier with the cavity opening toward said protrusion, and means holding the tubular member with said protrusion in contact with the object to be cut.

9. Apparatus for cutting hard materials comprising a pair of elongated flexible explosive pellets, each pellet having a flat side defined by separate thin imperforate metal liners extending from end to end, means holding the two pellets in longitudinal abutment adjacent one longitudinal edge of the metal liners and with the liners diverging from each other to include an angle from about 30° to 45° so as to form an elongated cavity of triangular cross section between the pellets, and detonating means extending the length of and between the pellets exterior of the cavity and adjacent the apex thereof.

10. Apparatus for cutting hard objects in a perforated pattern comprising a carrier, a plurality of explosive bodies supported by the carrier for disposal adjacent the object to be cut and spaced from each other by bodies of inert material, each explosive body being formed of a pair of discrete longitudinally extending pellets each having a flat side and each pair being in longitudinal abutment at the edges of the flat sides, the flat sides forming an apex the length of the body which opens toward the object to be perforated, and detonation means extending from body to body, traversing each body along the side of the apex away from the object to be perforated.

11. Apparatus for cutting hard materials comprising a pair of discrete strings of explosive each string consisting of a body of explosive enclosed in an elongated tubular casing having one flat flexible metal wall, support means confining the strings in abutment along one edge of the respective flat metal walls with the walls diverging from such abutment to define an elongated cavity of triangular cross-section opening toward the exterior of the support means, and detonating means extending the length of and between the strings adjacent the line of abutment of the strings.

12. Apparatus according to claim 11 wherein said support means for confining the strings comprises a carrier, an elongated channel in the carrier opening through a wall of the carrier, the strings being positioned in said channel with the elongated cavity opening toward the opening of said channel.

13. Apparatus according to claim 11 wherein said support means for confining the explosive charge comprises an elongated tubular member shaped to receive and retain the strings and having a longitudinal protrusion in diametric alignment with said cavity.

References Cited in the file of this patent

UNITED STATES PATENTS

2,399,211	Davis	Apr. 30, 1946
2,415,814	Davis	Feb. 18, 1947
2,440,568	Arter	Apr. 27, 1948
2,494,256	Muskat	Jan. 10, 1950
2,506,836	Kaltenberger	May 9, 1950
2,513,233	Byers	June 27, 1950
2,543,057	Porter	Feb. 27, 1951
2,587,243	Sweetman	Feb. 26, 1952
2,587,244	Sweetman	Feb. 26, 1952
2,638,323	Bannon	May 12, 1953