(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 261 119 B1**

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **27.11.91**

(51) Int. Cl.5: **B26F 3/04**, F42B 1/00, B21D 28/00

(21) Application number: **86903480.1**

(22) Date of filing: **27.05.86**

(86) International application number: **PCT/GB86/00292**

(87) International publication number: **WO 86/07000 (04.12.86 86/26)**

(54) **EXPLOSIVE CUTTING MEANS.**

(30) Priority: **28.05.85 GB 8513325**

(43) Date of publication of application: **30.03.88 Bulletin 88/13**

(45) Publication of the grant of the patent: **27.11.91 Bulletin 91/48**

(84) Designated Contracting States: **AT BE DE FR GB IT LU NL SE**

(56) References cited:
EP-A- 0 043 215
DE-A- 2 832 246
FR-A- 1 215 794
US-A- 3 076 408
US-A- 3 435 763

See also references of WO8607000

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EP 0 261 119 B1

Description

This invention relates to explosive cutting means.

It is well known in the art to use explosives to cut a target, such as a metal sheet or plate.

One well known method for explosive cutting is the so called "plaster" charge method and wherein a strip of explosive material is applied directly to the target along the intended line of cut and is detonated to generate fracture forces within the target along the intended line of cut.

Another well known method for explosive cutting is the so called "shaped charge" method and wherein a metal element, initially spaced from the target, is driven at high speed against the target along the intended line of cut by detonation of an explosive material. The metal element is deformed by the detonation and by passage through the air to the target and a blade-like high speed jet of metal strikes the target to cut the target.

Both the above methods of explosive cutting and their respective advantages and disadvantages are very will known and extensively documented and no further description thereof is required herein.

In more recent years it has been proposed that a target be cut along an intended line by producing two shock wave fronts in the target, the two shock wave fronts first entering the surface of the target simultaneously along two zones extending parallel to the intended line of cut and spaced apart with the intended line of cut mid-way between them. The two shock wave fronts pass into the target and meet along the intended line of cut and the shock waves reflected from the undersurface of the target also coincide along the intended line of cut.

It has been proposed that in such a method of cutting the shock waves first passing through the material generate compression forces along the intended line of cut whilst the reflected waves produce tension forces along the intended line of cut. In the event a target can be cut along an intended line using far less explosive material than conventional plaster charges.

For convenience the above described method of cutting by producing two spaced apart wave fronts simultaneously in the surface of the target shall be referred to as "two-wave explosive cutting" and means for producing two-wave explosive cutting shall hereinafter be referred to as "two-wave explosive cutting means".

United States Patent No. 3,076,408 discloses two-wave explosive cutting means in which a layer of explosive material is arranged in contact with the surface of a target to be cut and extends across the intended line of cut. The explosive material is detonated simultaneously at points on either side of the intended line of cut to produce the two-wave explosive cutting. This document is the basis of the preamble of claim 1.

United States Patent No. 3,435,763 discloses the two-wave explosive cutting means wherein an explosive strip is adapted to be arranged in contact with a surface of a target on either side of an intended line of cut and said strip comprises means for so controlling detonation of the material that a pair of converging re-entrant detonation fronts proceed simultaneously and symmetrically inwards to generate a Mach stem internally of the strip.

It is advantageous at this stage to differentiate between the terms "detonation front" and "shock wave front" as those terms are known in the art.

A detonation front is a front which travels through an explosive mass, from the point of initiation of the detonation, to continue the detonation of the explosive mass and therefore a detonation front can exist only within an explosive mass.

A shock wave front is generated by a detonation front at a surface or surfaces of a detonating mass and thus exists only outwardly of the explosive mass.

It should be noted that in all the prior art methods and means for two-wave explosive cutting the two shock waves are produced by controlling the configuration of the detonation fronts within the explosive material.

It will be appreciated that the speed at which the detonation front(s) pass through the explosive material is very high as also is the speed at which the shock wave fronts pass through the target. As the cut in the target is effected along the plane in which the two shock wave fronts meet any minute variation in the time of entry of the shock waves into the target, or any difference in the "balance" of the shock wave configurations, will cause the cut to deviate from the intended line of cut.

Thus, any system which relies on detonating the explosive material at a plurality of locations must be suspect in that any premature or delayed firing of any one of the detonators will result in an undesired detonation configuration with deviation from the intended line of cut. Any system which relies on barriers to periodically re-establish side edge detonation and wherein the detonation effectively proceeds independantly along the side edges of the explosive material must also be suspect. It is for this reason that prior art two-wave cutting is rarely used on long cuts, such as cuts in excess of $\frac{1}{2}$ metre.

The object of the present invention is to provide a method and means for two-wave explosive cutting which does not rely on controlling the configuration of the detonation front through the explosive charge.

According to the present invention there is provided a method for two-wave explosive cutting of a target along an intended line of cut comprising the steps of locating an explosive material to extend along the intended line of cut and on both sides of the intended line of cut and detonating said explosive material, characterised by the steps of supporting the mid-regions of the explosive material, in planes at right angles to the intended line of cut, on a shock wave delay element, shaping the explosive material to have a substantially uniform cross-section in planes at right angles to the direction of the intended line of cut with the explosive material at the side edges in each said cross-section closer to the target surface than the shock-wave delay element-supported mid-regions thereof, and detonating said explosive material to generate a detonation front in said explosive material travelling in the direction of the intended line of cut.

In one embodiment in accordance with the invention the method is characterised by the steps of shaping the cross-section of the shock wave delay element in planes at right angles to the intended line of cut to control the progression of the shock waves through said shock wave delay element to the target surface.

In one preferred embodiment the method comprises the steps of constructing the shock wave delay element of different shock wave transmission materials to control the progress of the shock waves through the shock wave delay element to the target surface.

Preferably the method comprises the steps of locating a metal element between the target and the explosive material, said metal element extending along the length of the intended line of cut and being spaced from the target surface, and providing a void in the shock wave delay element between said metal insert and the target surface.

In another embodiment the method comprises the steps of forming a void, extending in the direction of the intended line of cut, in the shock wave delay element to further delay the progression of the mid-regions of the shock wave front, in planes at right angles to the intended direction of cut, through the shock wave delay element to the target surface.

The invention also envisages a two wave-explosive cutting means comprising an elongate shock wave delay element of substantially uniform cross-section, intended to extend in the length direction of an intended line of cut, and an explosive material having its mid-regions, in planes at right angles to the intended line of cut, supported on said element.

Preferably said cutting means has its said shock wave delay element presenting a target-engaging surface and an explosive-supporting surface or surfaces facing away from said target-engaging surface, said surfaces extending in the length direction of said element.

In one embodiment the said shock wave delay element includes areas of different shock wave transmission characteristics in each cross-section of said element at right angles to the longitudinal direction of said element.

In one preferred embodiment the shock wave delay element has a greater thickness at its mid-regions than at its side edges in planes at right angles to the longitudinal direction of the said element.

Preferably the shock wave delay element is of generally triangular cross-section in planes at right angles to the longitudinal direction of the element, one major face of the element defines the target-engaging surface of the element and the other two major faces of the element define explosive-supporting surfaces of the element.

In one preferred embodiment the cross-section of the shock wave delay element is generally in the form of an isosceles triangle, with a high base to height ratio, and the base surface of said triangle comprises the target-engaging surface.

In one embodiment the said shock wave delay element includes a recess in said target-engaging surface extending along the length direction of the element and intended to straddle the intended line of cut of a target.

In a preferred embodiment a metal insert is located in said recess to extend in the length direction of the shock wave delay element and said insert is spaced from the target-engaging face of the delay element and is intended to straddle the intended line of cut.

In one embodiment, particularly suitable for cutting cylinders, the shock wave delay element is curved, in its longitudinal direction, and its two ends are joined to form a closed loop tightly embrace the target surface.

Preferably the shock wave delay element includes a magnetized element or elements.

The present invention also envisages a two-wave cutting means as defined above in combination with an initiation means.

Preferably the initiation means include a detonator and a sheet of explosive material located to detonate the explosive material on the shock wave delay element when the detonator is fired, said sheet of explosive material when detonated being arranged to detonate the explosive material on the shock wave delay element over a substantially straight detonation front at right angles to the length direction of the shock wave delay element.

The invention will now be described further by way of example with reference to the accompanying drawings in which;

Fig.1
is a diagrammatic cross section through a two-wave cutting means according to the invention,

Figs 1A, 1B and 1C
show cross sections through the cutting means illustrated in Fig 1, to the left of the centre line CL, diagrammatically illustrating the progression of the shock wave front.

Fig 2
is a diagrammatic cross section through a second two-wave cutting means.

Fig 3
is a view, similar to Fig 2, of a third two-wave cutting means

Fig 4
is a view, similar to Fig 2, showing a further two-wave cutting means according to the invention

Fig 5
is a view, similar to Fig 2, of a fifth embodiment of two-wave cutting means

Fig 6
is a view, similar to Fig 2,of a still further embodiment in accordance with the invention

Fig 7
is a perspective view showing one initiation means for the two-wave cutting means shown in Fig 2 and,

Figs 8 & 9
are plan views of two different embodiments of part of the initiation means shown in Fig 7

In the embodiment illustrated in Fig 1 an elongate shock-wave delay element 11, of rectangular cross section,rests on the surface 12a of a target 12 and a strip of explosive material 13 rests on the surface of element 11 remote from surface 12a. The element 11 has the mid-plane CL passing through its transverse cross section in the plane of the intended line of cut 14, in the target so that, in its width direction, the element 11 extends equally on either side of the line of cut 14.

The element 11 comprises, in cross section, an isosceles triangle 11a of a first material and two equal right-angle triangles 11b 11c of a second material, the first and second materials being selected to have different shock-wave transmission characteristics with the triangle 11a having the slowest transmission characteristics.

Figs 1A, 1B and 1C show cross sections of the element 11 to the left of the mid-plane CL and it will be appreciated that the shock wave fronts described with respect to Figs 1A 1B and 1C are mirror images of the shock wave fronts as will be developed in the cross section of the element 11 to the right of the plane CL.

In the embodiment shown in Fig 1A, and assuming that the first and second materials are so selected that the speed at which a shock wave front travels through the first material is one half of the speed through the second material, it will be noted that at a time "t" after detonation of the explosive material 13.

The shock wave front 15a travelling wholly through the triangle 11b will have travelled a distance D and will be progressing parallel to the surface 11. The shock wave front travelling wholly through the triangle 11a will have travelled $\frac{D}{2}$ = d and

The shock wave front 15b which has passed through the plane joining triangle 11a to triangle 11b will have travelled part way through triangle 11b and part way through 11a and will therefore be inclined to the plane of surface 12a.

Fig 1B shows the position when the shock wave has travelled to the lower-most point of triangle 11b and one half the height of triangle 11a at the mid-plane CL and it will be noted that the shock wave has a releatively straight front 15.

Assuming that the target is a metal with good shock wave transmission characteristics, Fig 1C shows the position wherein the shock wave front 15 has passed wholly into the target 12 and the inclined part 15c of said front is travelling towards the line of cut 14.

It will be appreciated that the sections and progressions of the shock wave fronts shown in Figs 1A, 1B and 1C are mirror images of the sections and progression of the shock wave fronts on the right hand side of the mid-plane CL and, when the explosive material 13 is detonated on a straight front travelling in the length direction of element 11, shock wave fronts will first enter the surface 12a of target 12 from the lowest points of triangles 11b and 11c, as viewed in Fig 1, simultaneously and the inclined shock wave fronts 15c will meet at the intended line of cut 14.

In the embodiment shown in Fig 2 a shock wave delay element 21 of elongate form, has a transverse cross-section in the form of an isosceles triangle with a high base to height ratio and the surface 21a, defined by the base, comprises the target-engaging surface of the element 21. The remaining major surfaces 21b and 21c of the element 21 comprise the explosive-supporting surfaces.

The element 21 is placed on a target 22 with its length direction extending in the direction of the intended line of cut 23 and its target-engaging surface 21a in contact with the surface 22a of the target. The target-engaging surface 21a extends equally on either side of the intended line of cut 23.

When the explosive material 24 on the explosive-supporting surfaces 21b and 21c of the element 21 is detonated so that a detonation front travels in the length direction of the element 21, the shock wave front 25 generated by the explosive material 24 travels through the shock wave delay element 11 to the surface 22a of target 22. Entry of the shock wave 25 into the target 22 is first at zones 22b, 22c where the explosive material 24 is closest to the target 22 and has the minimum delay in travelling through the element 21 and, as the height of the element 21 increases towards the plane of the intended cut 23, so the shock wave front 25 is delayed in its passage to the target 22 by the increasing thickness of element 21.

Thus, the shock wave front 25 first enters the target 22 at the two zones or regions 22b, 22c, which are equally spaced apart from the intended plane of cut 23, and the inclined shock wave fronts 25a and 25b passing through the element 21 parallel to surfaces 21b, 21c respectively travel towards one another to coincide at the plane of the intended cut 23.

In Fig 2 the shock wave fronts 25 are shown passing into a target 22 having substantially the same shock-wave transmission characteristics as the element 21.

Fig 3 shows a view similar to Fig 2, and using identical reference numerals for identical parts, the essential difference from Fig 2 being that the shock wave transmission speed for the element 21 is slower than for the target material whereby the angles of the inclined shock wave fronts 25a and 25b within the target 22 are steeper (as viewed in Fig 3) than the angle of the shock wave fronts 25a, 25b within the target 22 shown in Fig 2.

The shock wave delay element 11 of Fig 1 and the shock wave delay elements 21 of Figs 2 and 3 may be constructed from any suitable materials having the desired shock wave transmission speeds but preferably said element 11 of Fig 1 and the elements 21 of Figs 2 and 3 are constructed from rubber, synthetic rubber or plastics materials, and have sufficient flexibility to allow the respective shock wave delay elements 11 or 21 to follow non-linear contours, such as the curved surfaces of pipes and tubes.

The elements 11 and 21 may also include a soft iron core element 26 (illustrated only in Fig 2) on the mid-plane CL and extending in the length direction of the respective delay element and which can assist in holding the shock wave element in a shape imparted to follow a non-linear contour.

The elements 11 and 21 may also include magnetized material, such as magnetized particles of barium ferrite, so that the respective element 11 or 21 can magnetically adhere to the surface of a ferrous target.

The explosive material 13 of Fig 1 and 24 of Figs 2 and 3 may be secured to its respective element 11 or 22 with an adhesive material, preferably not a water-soluble adhesive.

Fig 4 illustrate a modification which can be applied to the embodiments illustrated in Figs 2 and 3. In this modification, in which like numerals have been used to designate like parts, a strip of ferrous metal 27 is bonded to the base surface of the element 21 and a strip of magnetized material 28, such as a rubber or plastics material including magnetized particles, is bonded to the metal 27 so that the composite element 11 can adhere to ferrous targets without the inclusion of magnetized particles within the element 21.

Referring now to Fig 5 it will be seen that the embodiment illustrated therein is similar to the embodiments of Fig 2 and 3, like numerals again identify like parts, with the exception that the apex of the shock wave delay element 21 is truncated and the element 21 has a central triangular cavity 30 therein the apex of which is lower-most (as viewed in Fig 5) and coincides with the intended line of cut 23 and the base of which is covered by a plate 31, e.g., of metal. The plate 31 is covered by the explosive material 24.

When the strip of explosive material 24 is detonated the plate 31 will be driven downwardly and, guided by the side walls of the cavity 30, will form a high velocity metal jet directed towards the intended line of cut 23. This jet will not cut the target 22 but will indent or recess the surface of the target 22 along the intended line of cut 23 to assist fracture of the target along said intended line of cut 23.

In the embodiment shown in Fig 6, again like parts are identified by like numerals, the shock wave delay element 21 is provided with a triangular cavity 32 which extends the length thereof and which has its base astride the intended line of cut. The cavity 32 may be metal lined if desired. It has been found in practice that the cavity 32 greatly assists focusing of the shock wave.

The shock wave delay elements 21 of Figs 5 and 6 may, in like manner to the embodiments described with reference to Figs 2 and 3 be made of rubber, synthetic rubber or plastics material so as to be flexible and said elements may include magnetized particles to enable the elements 21 of Figs 5 and 6 to adhere to ferrous targets. The plate 31 of Fig 5 may also be magnetized to assist adhesion of the insert 23 to a ferrous target.

Fig 7 shows initiating means 35 suitable for use with the explosive cutting means of any of the embodiments illustrated in Figs 2 to 6 inclusive.

The initiating means 35 comprise a support 36 of inert material shaped to conform to the shape of the exposed main faces of the explosive material 24 and which is adapted to be mounted thereon. The support 36 carries means 37 for supporting a detonator 38. The support 36 also carries on part of its surface remote from the explosive material 24, a layer of explosive material 39 which will be detonated when the detonator 38 is fired. The layer of explosive material 39 extends over one end of the support 36, as shown at 40, so as to contact the explosive material 24 when the initiating means is properly located on the explosive cutting means. The layer of explosive material 39 is substantially triangular in plan view and has incorporated therein barrier elements 41 which are so arranged that all paths from the detonator 38 to each point along the edge 40 are of substantially the same length to ensure that detonation of the explosive material 24 takes place substantially simultaneously at all points across the width thereof.

Fig 8 illustrates an array of circular barrier elements 41, for the explosive layer 39 whilst Fig 9 illustrates an array of linear barrier elements 41, both of these arrays being such as to achieve the desired object of ensuring that all paths between the point of detonation of the layer of explosive material 39 and and the edge 40 which initiates the explosive material 24 are of substantially the same length.

It will be appreciated that in all the foregoing embodiments the shock wave delay element focuses the shock wave generated by detonation of the explosive material to produce entry of the shock wave into the target first at two zones or locations equally spaced on either side of the intended line of cut whereby the classic "two-wave" cutting is achieved when the shock waves progress from said two zones to coincide at the intended line of cut.

If it is desired to cut or fracture a target along two or more intended lines of cut which are parallel to one another then explosive cutting means according to the present invention can be used in a side-by-side array or, alternatively, an explosive cutting means may be formed which comprises, in effect, a plurality of cutting means according to the present invention arranged side-by-side.

Thus, for example two-shock wave cutting means as shown in Fig 2, 3, 4, 5 or 6 could be assembled in side-by-side relationship on a common sheet to form a series of side-by-side corrugations extending across the width of a sheet, with each corrugation providing a separate two-wave explosive cutting means according to the present invention but with corrugations sharing a common sheet of explosive metal. The facility for providing multiple fractures or cuts is particularly useful when removing a section of lining from a bore or well, e.g., an oil well, since it enables the section of lining to be cut into sufficiently small pieces for either easy removal or for falling with little danger of blocking of the bore or well to the bottom of the bore or well.

In the embodiments illustrated in Figs 1 to 6 the elements 11, 21 have been described as elongate but it will be appreciated that when said elements are flexible the two-wave cutting means can be deflected to cut a target along lines other than straight lines.

The elongate shock wave delay elements described above may be easily made by conventional extrusion processes and the explosive material 24 may also be extruded to the desired cross section. Thus, the assembly of the cpmponent parts of the shock wave cutting means is simplified.

Alternatively shock wave delay elements required for cuts which cannot be made by flexing an elongate cutting means may be moulded to follow virtually any desired cut configuration. By way of example the elements may be moulded in "closed" configuration, such as a circular configuration to cut a disc from a target. Further, shapes for a cut can be built up using elongate and curved delay elements to cut, for example,a rectangular hole with curved corners.

In further embodiments the two-wave cutting means illustrated in Figs 1 to 6 inclusive may be of conical configuration, defining solids of revolution about the mid-plane (axis) CL, whereupon the shock waves will coincide at a core region passing through the target.

The invention is further described with reference to the following examples.

EXAMPLE 1

A shock wave delay element of the kind shown in Fig 2 was constructed from a composite magnetic material comprising 92.5% barium ferrite in a matrix of synthetic rubber which is sold under the registered trade mark FEROBA. This element had a density of 3.6g/cc. The cross-section of the element was an isosceles triangle having a base of 30mm and an apex of 130°. The base of the element was magnetically adhered to a plate of mild steel 7.9mm thick. To the remaining two sides of the element was applied a single strip of RDX-based plastic explosive of the kind designated SX2. This strip was 32mm wide and 3mm thick. The strip of explosive material was initiated at a point on the longitudinal axis thereof, at a distance of 40mm from the start of the intended line of cut so that the detonation front would have time to develop prior to the start of the intended line of cut. The plate was divided by a continuous and very straight fracture.

EXAMPLE 2

A shock wave delay element of the kind used in Example 1 was magnetically adhered by its base to a mild steel plate 15.3mm thick. To the other two sides of the element was applied two strips of SX2 plastic explosive, the strips each being 32mm wide and 3mm thick and being applied one upon the other to give a double thickness. When the explosive material was initiated in the same manner as in Example 1 the plate was fractured along a continuous and very straight edged line. A thick spall was projected from the rear of the plate and this spall was itself divided neatly along the line of intended cut. A particular feature of this Example was that the spall fragments exhibited straight and square outer edges. Normally, when a strip of explosive material is detonated in contact with a metal plate so as to cause a spall to be projected from the opposite side thereof, the edges of the spall fragments are ragged and somewhat tapered.

EXAMPLE 3

Two strips of SX2 plastic explosive 32mm wide and 3mm thick were folded along their longitudinal centre line so that the two sides extended at an angle of 120° to one another. The two strips were positioned one upon the other on a plate of mild steel 12,5mm thick with two longitudinal side edges of the inner strip resting upon the plate. The assembly was immersed in water so that the water filled cavity between the inner strip of explosive material and the plate to provide a shock wave delay element. The explosive was initiated centrally of one end thereof. The steel plate was divided by a fracture which coincided with the longitudinal axis of the strips of explosive material. A narrow spall approximately 11mm wide and 5mm thick was detached from the surface of the steel plate opposite to which the explosive was applied. The plate was not deformed to any visible extent beyond the fracture on that surface to which the explosive material was applied and beyond the spall on the other side. Thus the zone of visible damage did not extend laterally beyond about 5.5mm from the centre line of the fracture. This is a much narrower damage zone than usually occurs with known fracturing or cutting charges of comparable severing power.

Claims

1. A method for two-wave explosive cutting of a target along an intended line of cut comprising the steps of locating an explosive material to extend along the intended line of cut and on both sides of the intended line of cut and detonating said explosive material, characterised by the steps of supporting the mid-regions of the explosive material(13,24), in planes at right angles to the intended line of cut, on a shock wave delay element(11,21), shaping the explosive material, (13, 24) to have a substantially uniform cross-section in planes at right angles to the direction of the intended line of cut (14, 23) with the explosive material (13, 24) at the side edges in each said cross-section closer to the target surface (12a, 22a) than the shock wave delay element(11,21)-supported mid-regions thereof, and detonating said explosive material (13, 24) to generate a detonation front in said explosive material (13, 24) travelling in the direction of the intended line of cut (14, 23).

2. A method as claimed in claim 1 characterised by the steps of shaping the cross-section of the shock wave delay element (11, 21), in planes at right angles to the intended line of cut (14, 23), to control the progression of the shock waves (15a, 15b, 25a, 25b) through said shock wave delay element (11, 21) to the target surface (12a, 22a).

3. A method as claimed in claim 1 or 2, characterised by the steps of constructing the shock wave delay element (11) of different shock wave transmission materials (11a, 11b, 11c) to control the progress of the shock waves through the shock wave delay element (11) to the target surface (12a).

4. A method as claimed in any preceding claim characterised by the steps of locating a metal element (31) between the target (11, 21) and the explosive material (13, 24), said metal element (31) extending along the length of the intended line of cut (14, 23) and being spaced from the target surface (12a, 22a) and providing a void (30) in the shock wave delay element (11, 21) between said metal insert (31) and the target surface (12a, 22a).

5. A method as claimed in any preceding claim, characterised by the step of forming a void (32), extending in the direction of the intended line of cut (14, 23) in the shock wave delay element (11, 21) to further delay the progression of the mid-regions of the shock wave front, in planes at right angles to the intended direction of cut (14, 23), through the shock wave delay element (11, 21) to the target surface (12a, 22a).

6. A two-wave explosive cutting means comprising an elongate shock wave delay element (11, 21), of substantially uniform cross-section intended to extend in the length direction of an intended line of cut, and an explosive material (13, 24) having its mid-regions, in planes at right angles to the intended line of cut, supported on said element (11, 21).

7. A two-wave explosive cutting means as claimed in claim 6 characterised in that said shock wave delay element (11, 12) presents a target-engaging surface (21a) and an explosive-supporting surface or surfaces (21b, 21c) facing away from said target-engaging surface, said surfaces (21a, 21b and 21c) extending in the length direction of said element (11, 21).

8. A two-wave explosive cutting means as claimed in claim 6 or 7, characterised in that said shock wave delay element (11) includes areas (11a, 11b, 11c) of different shock wave transmission characteristics in each cross-section of said element (11) at right angles to the longitudinal direction of said element (11).

9. A two-wave explosive cutting means as claimed in claims 6,7, or 8, characterised in that the shock wave delay element (21) has a greater thickness at its mid-regions than at its side edges in planes at right angles to the longitudinal direction of the said element.

10. A two-wave explosive cutting means as claimed in claim 7, 8 or 9, characterised in that the shock wave delay element (21) is of generally triangular cross section in planes at right angles to the longitudinal direction of the element (21) and one major face (21a) of the element (21) defines the target-engaging surface of the element and the other two major faces (21b, 21c) of the element define explosive-supporting surfaces of the element (21).

11. A two-wave explosive cutting means as claimed in claim 10 and wherein, the triangular cross section of the element (21) is generally in the form of an isosceles triangle, with a high base to height ratio, and the base surface of said triangle comprises the target-engaging surface (21a).

12. A two-wave explosive cutting means as claimed in claim 6, 7, 8, 9, 10 or 11 characterised in that said shock wave delay element (11, 21) includes a recess (30 or 32) in said target-engaging surface (21a) extending along the length direction of the element (11, 21) and intended to straddle the intended line of cut (14, 23) of a target (14, 23).

13. A two-wave explosive cutting means as claimed in claim 12, characterised in that a metal insert (31) is located in said recess (30) to extend in the length direction of the shock wave delay element (11, 21) and said insert (31) is spaced from the target-engaging face of the delay element (11, 21) and is intended to straddle the intended line of cut (14, 23).

14. A two-wave explosive cutting means as claimed in any one of claims 6 to 13 inclusive, in which the shock wave delay element (11, 21) is curved, in its longitudinal direction, and its two ends are joined to form a closed loop.

15. A two-wave explosive cutting means as claimed in any one of claims 6 to 14 inclusive characterised in that the shock wave delay element includes a magnetized element (28) or elements.

16. A two-wave explosive cutting means as claimed in any one of claims 6 to 15, in combination with an initiation means (35 to 41).

17. A two-wave cutting means as claimed in claim 16 and characterised in that the initiation means include a detonator (38) and a sheet of explosive material (40) located to detonate the explosive material on the shock wave delay element (11, 21) when the detonator is fired, said sheet of explosive material (40) when detonated being arranged to detonate the explosive material (13, 24) on the shock wave delay element (11, 21) over a substantially straight detonation front at right angles to the length direction of the shock wave delay element (11, 21).

Revendications

1. Procédé de coupe par explosion à deux ondes d'une cible selon une ligne de coupe prévue comportant les étapes consistant à placer une matière explosive le long de la ligne de coupe prévue et sur les deux côtés de la ligne de coupe prévue et à faire exploser ladite matière explosive, caractérisé par les étapes consistant à supporter les régions médianes de la matière explosive (13,24), dans des plans perpendiculaires à la ligne de coupe prévue, sur un élément (11,21) retardateur d'onde de choc, à conformer la matière explosive (13,24) de façon à avoir une section transversale sensiblement uniforme dans des plans perpendiculaires à la direction de la ligne de coupe (14,23), la matière explosive (13,24) étant sur ses bords latéraux dons chaque section transversale plus proche de la surface (12a,22a) de la cible que les régions médianes supportées par l'élément (11,21) retardateur d'onde de choc, et à faire exploser ladite matière explosive

(13,24) de façon à engendrer un front d'explosion dans ladite matière explosive (13,24) se déplaçant dans la direction de la ligne de coupe prévue (14,23).

2. Procédé selon la revendication 1, caractérisé par les étapes consistant à conformer la section transversale de l'élément (11,21) retardateur d'onde de choc dans des plans perpendiculaires à la ligne de coupe prévue (14,23) de façon à commander la progression des ondes de choc (15a,15b,25a,25b) à travers ledit élément retardateur d'onde de choc (11,21) jusqu'à la surface de cible (12a,22a).

3. Procédé selon la revendication 1 ou 2, caractérisé par les étapes consistant à construire l'élément (11) retardateur d'onde de choc dans différentes matières (11a,11b, 11c) de transmission d'onde de choc de manière à commander la progression dos ondes de choc à travers l'élément (11) retardateur d'onde de choc jusqu'à la surface de cible (12a).

4. Procédé selon l'une quelconque des revendications précédentes, caractérisé par les étapes consistant à placer un élément de métal (31) entre la cible (12,22) et la matière explosive (13,24), ledit élément de métal (31) s'étendant sur la longueur de la ligne de coupe prévue (11,23) et étant espacé de la surface de cible (12a,22a) et à prévoir un vide (30) dans l'élément (11, 21) retardateur d'onde de choc entre ledit insert de métal (31) et la surface de cible (12a,22a).

5. Procédé selon l'une quelconque des revendications précédentes, caractérisé par l'étape consistant à former un vide (32) s'étendant dans la direction de la ligne de coupe prévue (14,23) dans l'élément (11,21) retardateur d'onde de choc de façon à encore retarder la progression des régions médianes du front d'onde de choc, dans des plans perpendiculaires à la direction de coupe prévue (14,23), à travers l'élément (11,21) retardateur d'onde de choc jusqu'à la surface de cible (12a,22a).

6. Dispositif de coupe par explosion à deux ondes, comprenant un élément allongé (11,21) retardateur d'onde de choc, ayant une section transversale sensiblement uniforme destinée à s'étendre dans la direction longitudinale d'une ligne de coupe prévue, et une matière explosive (13,24) ayant ses régions médianes, dans des plans perpendiculaires à la ligne de coupe prévue, supportées sur ledit élément (11,21).

7. Dispositif de coupe par explosion à deux ondes selon la revendication 6, caractérisé en ce que ledit élément retardateur d'onde de choc (11,21) présente une surface (21a) de contact de cible et une surface ou des surfaces (21b,21c) de support d'explosif dirigées à l'opposé de ladite surface de contact de cible, lesdites surfaces (21a,21b et 21c) s'étendent dans la direction longitudinale dudit élément (11,21).

8. Dispositif de coupe par explosion à deux ondes, selon la revendication 6 ou 7, caractérisé en ce que ledit élément (11) retardateur d'onde de choc comprend des zones (11a,11b,11c) ayant des caractéristiques de transmission d'onde de choc différentes dans chaque section transversale dudit élément (11) perpendiculaire à la direction longitudinale dudit élément (11).

9. Dispositif de coupe par explosion à deux ondes, selon l'une des revendications 6, 7 ou a, caractérisé en ce que l'élément (21) retardateur d'onde de choc présente une épaisseur supérieure dans ses régions médianes que sur ses bords latéraux, dans des plans perpendiculaires à la direction longitudinale dudit élément.

10. Dispositif de coupe par explosion à deux ondes, selon les revendications 7, 8 ou 9, caractérisé en ce que l'élément (21) retardateur d'onde de choc est de section transversale globalement triangulaire, dans des plans perpendiculaires à la direction longitudinale de l'élément (21), et en ce qu'une grande face (21a) de l'élément (21) définit la surface de contact de cible de l'élément tandis que les deux autres grandes faces (21b,21c) de l'élément définissent les surfaces de support d'explosif de l'élément (21).

11. Dispositif de coupe par explosion à deux ondes, selon le revendication 10, et dans lequel la section transversale triangulaire de l'élément (21) est globalement en forme de triangle isocèle avec un rapport élevé de la base à la hauteur, la surface de base dudit triangle comprenant la surface (21a) de contact de cible.

12. Dispositif de coupe par explosion à deux ondes, selon les revendications 6, 7, 8, 9, 10 ou 11, caractérisé en ce que ledit élément (11,21) retardateur d'onde de choc comporte une cavité (30 ou 32) dans ladite surface (21a) de contact de cible s'étendant dans la direction longitudinale de l'élément (11,21) et destinée à

chevaucher la ligne de coupe prévue (14,23) d'une cible (12,22).

13. Dispositif de coupe par explosion à deux ondes, selon la revendication 12, caractérisé en ce qu'un insert métallique (31) est placé dans ladite cavité (30) pour s'étendre dans la direction longitudinale de l'élément (11,21) retardateur d'onde de choc et en ce que ledit insert (31) est à une certaine distance de la face de contact de cible de l'élément de retard (11,21) et est destiné à chevaucher la ligne de coupe prévue (14,23).

14. Dispositif de coupe par explosion à deux ondes, selon l'une quelconque des revendications 6 à 13, dans lequel l'élément (11,21) retardateur d'onde de choc est courbe, dans sa direction longitudinale, ses deux extrémités étant reliées pour former une boucle fermée.

15. Dispositif de coupe par explosion à deux ondes, selon l'une quelconque des revendications 6 à 14, caractérisé en ce que l'élément d'onde de choc comprend un ou des éléments (28) magnétisés.

16. Dispositif de coupe par explosion à deux ondes, selon l'une quelconque des revendications 6 à 15, en combinaison avec un dispositif d'amorçage (35 à 41).

17. Dispositif de coupe à deux ondes, selon la revendication 16, et caractérisé en ce que le dispositif d'amorçage comprend un détonateur (38) et une feuille de matière explosive (40) placée de manière à faire exploser la matière explosive sur l'élément retardateur d'onde de choc (11,21) quand le détonateur est actionné, ladite feuille de matière explosive (40) lorsqu'elle explose étant agencée pour faire exploser la matière explosive (13,24) sur l'élément (11,21) retardateur d'onde de choc sur un front de détonation sensiblement rectiligne perpendiculaire à la direction longitudinale de l'élément (11,21) retardateur d'onde de choc.

Patentansprüche

1. Verfahren zum Zweiwellen-Explosionsschneiden eines Gegenstands entlang einer gewünschten Trennlinie, umfassend die folgenden Schritte: Anordnen eines Sprengstoffes, so daß er entlang der gewünschten Trennlinie und zu beiden Seiten der Trennlinie verläuft, und Detonieren dieses Sprengstoffes, gekennzeichnet durch die folgenden Schritte:
Haltern der Mittenbereiche des Sprengstoffs (13, 24) in rechtwinklig zu der gewünschten Trennlinie verlaufenden Ebenen auf einem Stoßwellenverzögerungselement (11, 21), Formen des Sprengstoffs (13, 24) derart, daß sein Querschnitt in rechtwinklig zu der Richtung der gewünschten Trennlinie (14, 23) verlaufenden Ebenen im wesentlichen gleichförmig ist, wobei der Sprengstoff (13, 24) an den Seitenrändern in jedem Querschnitt näher an der Oberfläche (12a, 22a) des Gegenstands liegt als seine von dem Stoßwellenverzögerungselement (11, 21) gehalterten Mittenbereiche, und Detonieren des Sprengstoffs (13, 24) zur Erzeugung einer Detonationsfront in dem Sprengstoff (13, 24), die sich in Richtung der gewünschten Trennlinie (14, 23) fortbewegt.

2. Verfahren nach Anspruch 1,
gekennzeichnet durch den Schritt der Formung des Querschnitts des Stoßwellenverzögerungselements (11, 21) in rechtwinklig zu der gewünschten Trennlinie (14, 23) verlaufenden Ebenen, um die Ausbreitung der Stoßwellen (15a, 15b, 25a, 25b) durch das Stoßwellenverzögerungselement (11, 21) zur Oberfläche (12a, 22a) des Gegenstands zu kontrollieren.

3. Verfahren nach Anspruch 1 oder 2,
gekennzeichnet durch den Schritt des Aufbaus des Stoßwellenverzögerungselements (11) aus verschiedenen Stoßwellendurchlaßmaterialien (11a, 11b, 11c), um die Ausbreitung der Stoßwellen durch das Stoßwellenverzögerungselement (11) zur Oberfläche (12a) des Gegenstands zu kontrollieren.

4. Verfahren nach einem der vorhergehenden Ansprüche,
gekennzeichnet durch die folgenden Schritte: Anordnen eines Metallteiles (31) zwischen dem Gegenstand (11, 21) und dem Sprengstoff (13, 24), wobei sich das Metallteil (31) entlang der Länge der gewünschten Trennlinie (14, 23) erstreckt und von der Oberfläche (12a, 22a) des Gegenstands beabstandet ist, und Vorsehen eines Hohlraumes (30) in dem Stoßwellenverzögerungselement (11, 21) zwischen dem Metallteil (31) und der Oberfläche (12a, 22a) des Gegenstands.

5. Verfahren nach einem der vorhergehenden Ansprüche,
gekennzeichnet durch den Schritt der Formung eines Hohlraumes (30) in dem Stoßwellenverzögerungselement (11, 21), der in Richtung der gewünschten Trennlinie (14, 23) verläuft, um die Ausbreitung der Mittenbereiche der Stoßwellenfront in rechtwinklig zu der ge-

wünschten Trennrichtung (14, 23) verlaufenden Ebenen durch das Stoßwellenverzögerungselement (11, 21) zur Oberfläche (12a, 22a) des Gegenstands weiter zu verzögern.

6. Zweiwellen-Explosionsschneidvorrichtung, umfassend ein langgestrecktes Stoßwellenverzögerungselement (11, 21) mit im wesentlichen gleichförmigem Querschnitt, das sich in Längsrichtung einer gewünschten Trennlinie erstreckt, und einen Sprengstoff (13, 24), dessen Mittenbereiche in rechtwinklig zu der gewünschten Trennlinie verlaufenden Ebenen auf dem Stoßwellenverzögerungselement (11, 21) abgestützt sind.

7. Zweiwellen-Explosionsschneidvorrichtung nach Anspruch 6,
dadurch gekennzeichnet, daß das Stoßwellenverzögerungselement (11, 21) eine Gegenstands-Anlagefläche (21a) und eine Sprengstofftragfläche oder -flächen (21b, 21c) aufweist, die von der Gegenstands-Anlagefläche (21a) weg gerichtet sind, wobei diese Flächen (21a, 21b und 21c) in Längsrichtung des Stoßwellenverzögerungselements (11, 21) verlaufen.

8. Zweiwellen-Explosionsschneidvorrichtung nach Anspruch 6 oder 7,
dadurch gekennzeichnet, daß das Stoßwellenverzögerungselement (11) Bereiche (11a, 11b, 11c) mit unterschiedlichen Stoßwellendurchlaßcharakteristiken in jedem Querschnitt des Stoßwellenverzögerungselements (11) unter rechten Winkeln zu der Längsrichtung des Elementes (11) aufweist.

9. Zweiwellen-Explosionsschneidvorrichtung nach einem der Ansprüche 6, 7 oder 8,
dadurch gekennzeichnet, daß das Stoßwellenverzögerungselement (21) in unter rechten Winkeln zu seiner Längsrichtung verlaufenden Ebenen, in seinen Mittenbereichen dicker als an seinen Seitenrändern ist.

10. Zweiwellen-Explosionsschneidvorrichtung nach einem der Ansprüche 7, 8 oder 9,
dadurch gekennzeichnet, daß das Stoßwellenverzögerungselement (21) in rechtwinklig zu seiner Längsrichtung verlaufenden Ebenen im allgemeinen Dreiecksquerschnitt hat und daß eine Hauptfläche (21a) des Stoßwellenverzögerungselements (21) seine Gegenstands-Anlagefläche bildet und die beiden anderen Hauptflächen (21b, 21c) des Elementes (21) Sprengstofftragflächen des Stoßwellenverzögerungselements (21) bilden.

11. Zweiwellen-Explosionsschneidvorrichtung nach Anspruch 10, wobei der Dreiecksquerschnitt des Stoßwellenverzögerungselements (21) im allgemeinen die Form eines gleichschenkligen Dreiecks mit einem großen Verhältnis von Grundlinie zu Höhe hat und daß die Grundfläche des Dreiecks die Gegenstands-Anlagefläche (21a) aufweist.

12. Zweiwellen-Explosionsschneidvorrichtung nach einem der Ansprüche 6, 7, 8, 9, 10 oder 11,
dadurch gekennzeichnet, daß das Stoßwellenverzögerungselement (11, 21) in der Gegenstands-Anlagefläche (21a) eine Ausnehmung (30 oder 32) hat, die entlang der Längsrichtung des Stoßwellenverzögerungselements (11, 21) verläuft und die gewünschte Trennlinie (14, 23) eines Gegenstands übergreifen soll.

13. Zweiwellen-Explosionsschneidvorrichtung nach Anspruch 12, dadurch gekennzeichnet, daß in der Ausnehmung (30) ein Metalleinsatz (31) so angeordnet ist, daß er in Längsrichtung des Stoßwellenverzögerungselements (11, 21) verläuft, und daß der Einsatz (31) von der Gegenstands-Anlagefläche des Stoßwellenverzögerungselements (11, 21) beabstandet ist und die gewünschte Trennlinie (14, 23) übergreifen soll.

14. Zweiwellen-Explosionsschneidvorrichtung nach einem der Ansprüche 6 bis 13 einschließlich, bei der das Stoßwellenverzögerungselement (11, 21) in seiner Längsrichtung gebogen ist und seine beiden Enden zur Bildung einer geschlossenen Schleife verbunden sind.

15. Zweiwellen-Explosionsschneidvorrichtung nach einem der Ansprüche 6 bis 14 einschließlich,
dadurch gekennzeichnet, daß das Stoßwellenverzögerungselement ein magnetisiertes Element (28) oder magnetisierte Elemente enthält.

16. Zweiwellen-Explosionsschneidvorrichtung nach einem der Ansprüche 6 bis 15, in Kombination mit einer Zündeinrichtung (35-41).

17. Zweiwellen-Explosionsschneidvorrichtung nach Anspruch 16, dadurch gekennzeichnet, daß die Zündeinrichtung einen Detonator (38) und einen Sprengstoff-Flächenkörper (40) aufweist, der so positioniert ist, daß er den Sprengstoff auf dem Stoßwellenverzögerungselement (11, 21) zur Detonation bringt, wenn der Detonator gezündet wird, wobei der Sprengstoff-Flächenkörper (40) bei der Detonation so angeordnet ist, daß er den Sprengstoff (13, 24) auf dem Stoßwellenverzögerungselement (11, 21) über eine im wesentlichen geradlinige Detonationsfront rechtwinklig zur Längsrichtung des Stoßwellenverzögerungselementes (11, 21) detoniert.

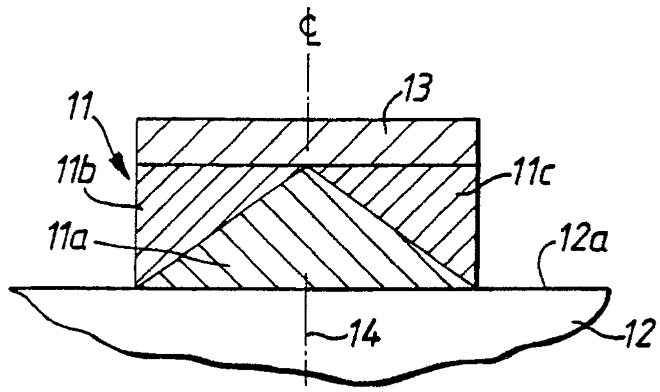


FIG.1.

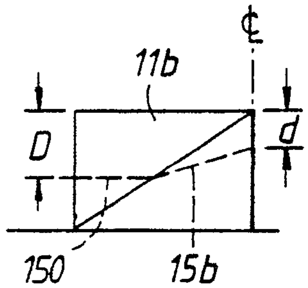


FIG.1A.

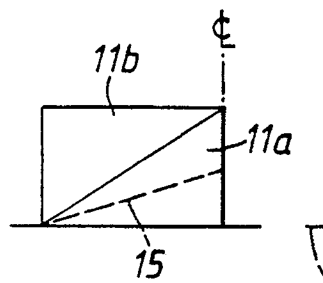
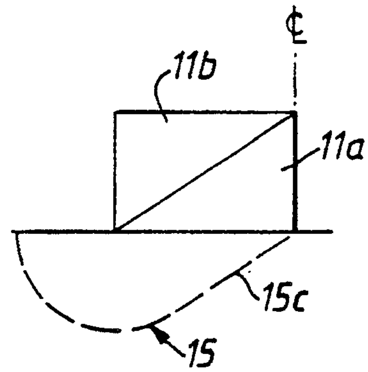


FIG.1B.



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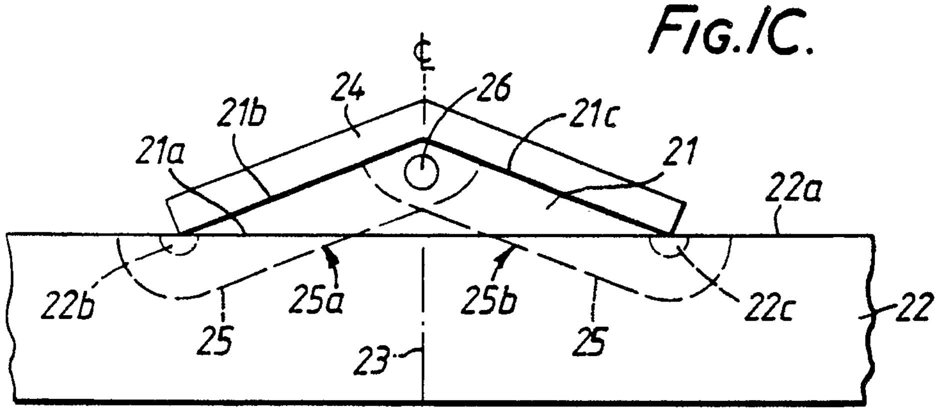

FIG.2.

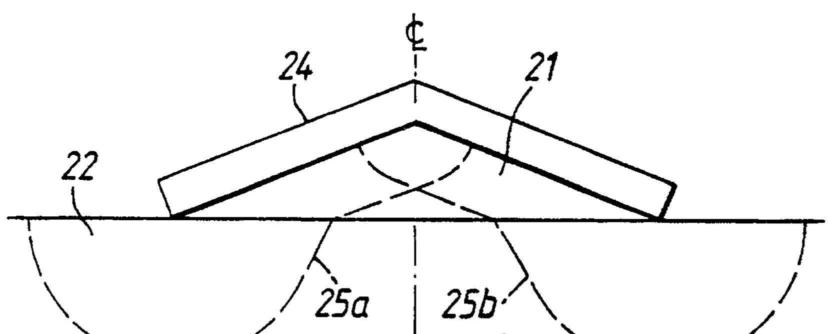

FIG.3.

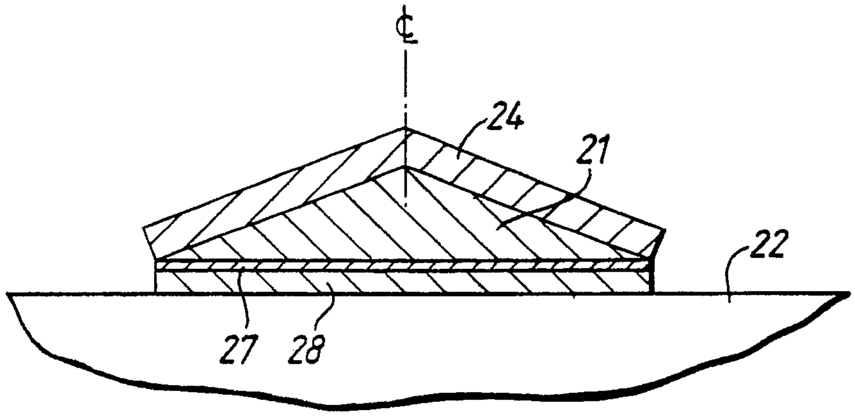

FIG.4.

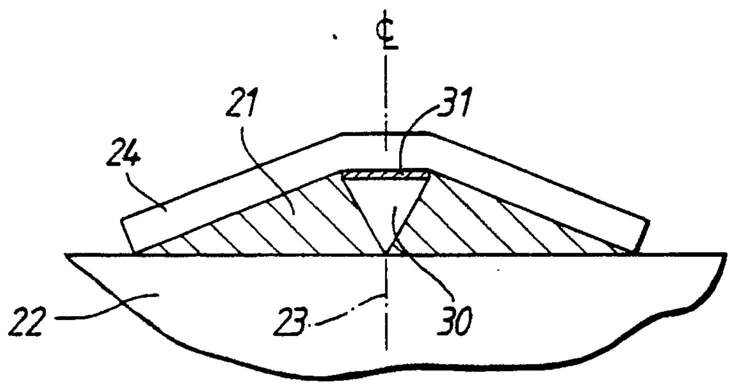

FIG.5.

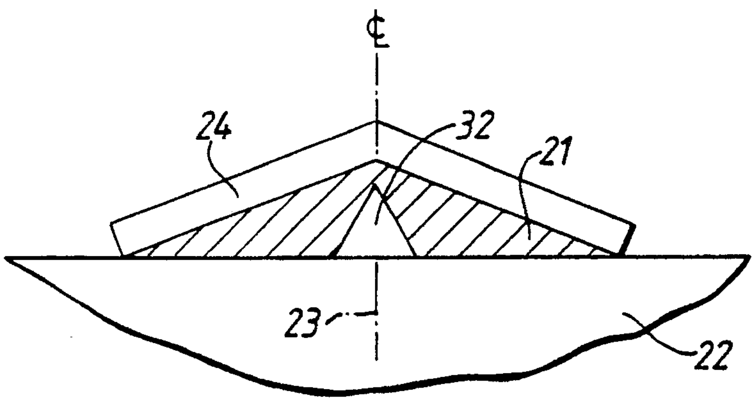

FIG.6.

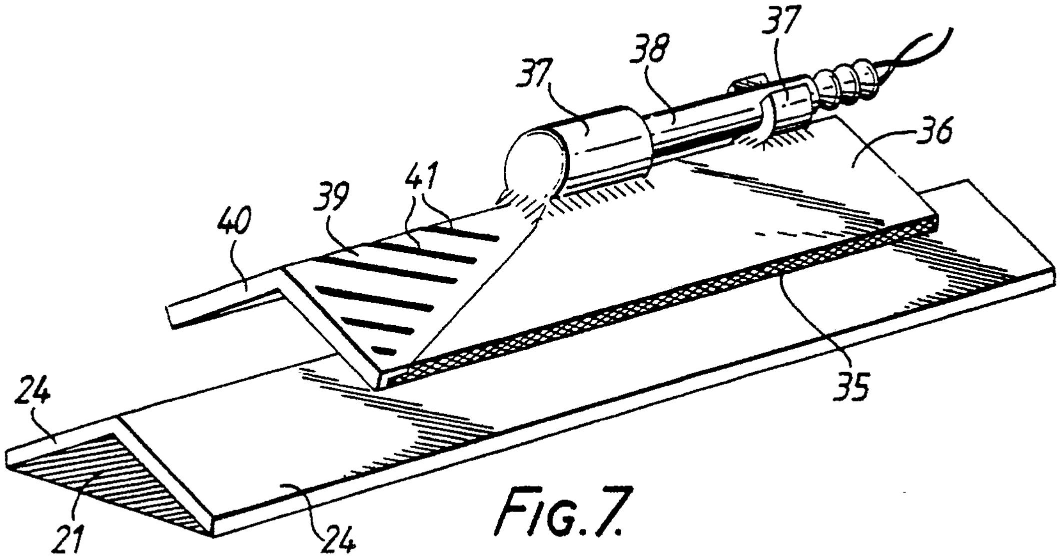

FIG.7.

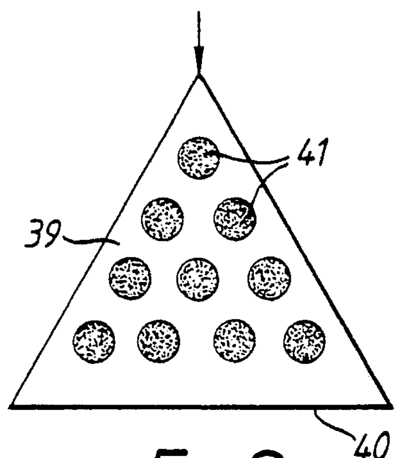

FIG.8.

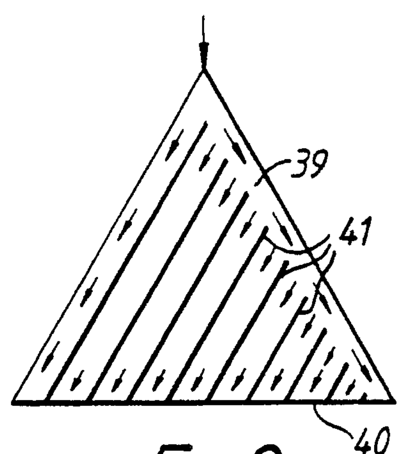

FIG.9.