United States Patent [19]

Lagofun

[11] **3,873,786**

[45] **Mar. 25, 1975**

[54] **EXPLOSIVE TYPE SWITCH WITH CIRCUIT SERVING MEANS**

[75] Inventor: **Guy Lagofun,** Tarbes, France

[73] Assignee: **Etat Francais represente par Le Delegue ministeriel pour L'armement,** Paris, France

[22] Filed: **May 8, 1973**

[21] Appl. No.: **358,407**

[30] **Foreign Application Priority Data**

June 26, 1972 France 72.22959

[52] **U.S. Cl.** **200/61.08**

[51] **Int. Cl.** **H01h 35/00**

[58] **Field of Search** .... 200/61.08; 89/1 B; 102/28 R, 28 EB, 31, 32, 70.02 R, 70.2 A; 337/142, 401, 413, 416; 83/639

[56] **References Cited**

UNITED STATES PATENTS

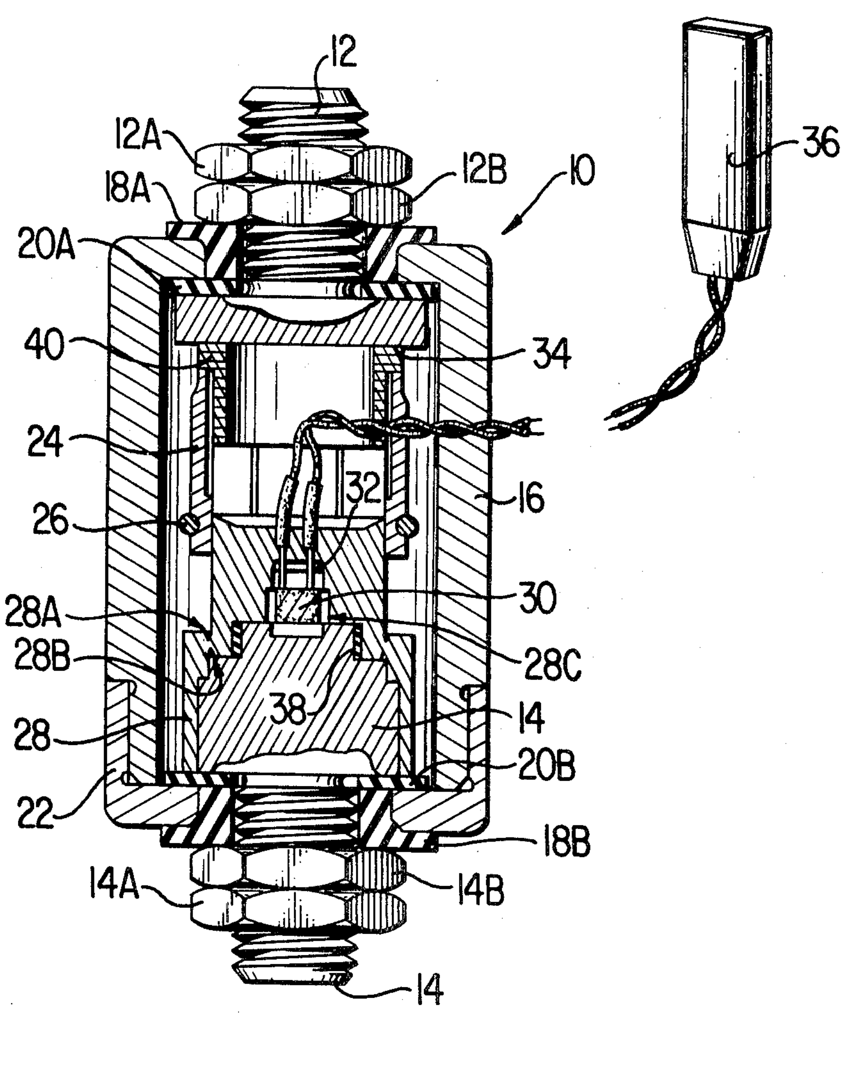
2,365,364	12/1944	Temple	83/639
2,929,892	3/1960	Blomgren	200/61.08 X
3,277,255	10/1966	Mattsson et al.	200/61.08
3,393,605	7/1968	Parnell	89/1 B
3,640,169	2/1972	Rosenthal	83/639
3,732,129	5/1973	Martin	102/28 EB X
3,742,859	7/1973	Finnegan et al.	102/24 R X
3,745,276	7/1973	McPherson	200/61.08

Primary Examiner—James R. Scott
Attorney, Agent, or Firm—Larson, Taylor & Hinds

[57] **ABSTRACT**

A severing device is provided for severing a mechanical element such as a strip, bar or the like using pure shear forces generated by ignition of an explosive charge having an energy per unit of mass of more than 1,000 joules/gram and a detonation speed of over 3,000 ms. In a first ultra-high speed, high amperage circuit breaker embodiment of the invention, the mechanical element comprises a cylindrical portion and an annular portion which extends outwardly therefrom, the internal diameter of the annular portion being approximately equal to that of the cylindrical portion and a fracture initiator in the form of opposed grooves having the same diameter is located in the area joining the two portions. The explosive charge, along with a firing unit therefor, is located in a recess in the cylindrical portion of the element to be severed.

8 Claims, 4 Drawing Figures



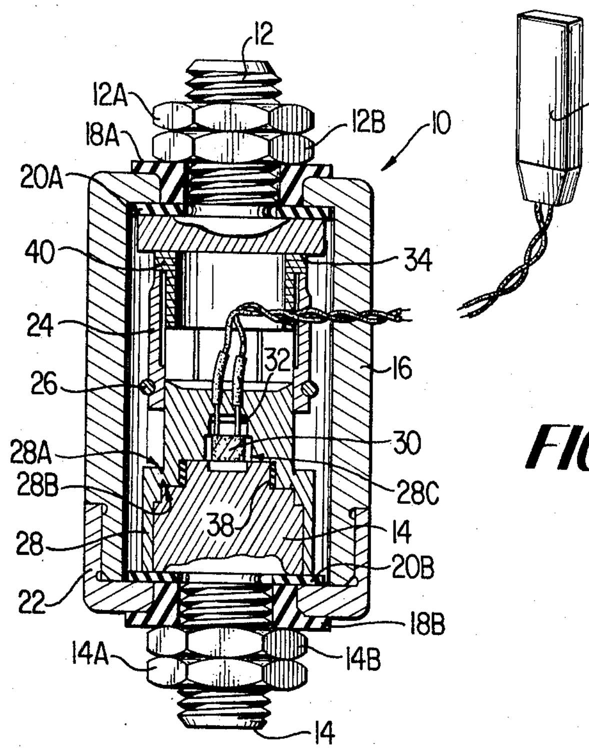

12
12A
12B
10
18A
20A
36
40
34
24
16
26
32
30
28A
28B
28C
38
14
28
20B
22
18B
14A
14B
14

FIG 1

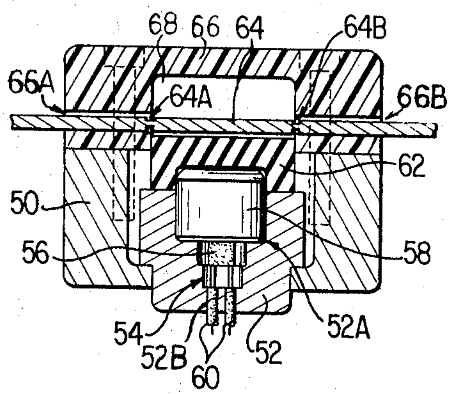

68
66
64
64B
66A
64A
66B
62
50
58
56
54
52A
52B
52
60

FIG 2

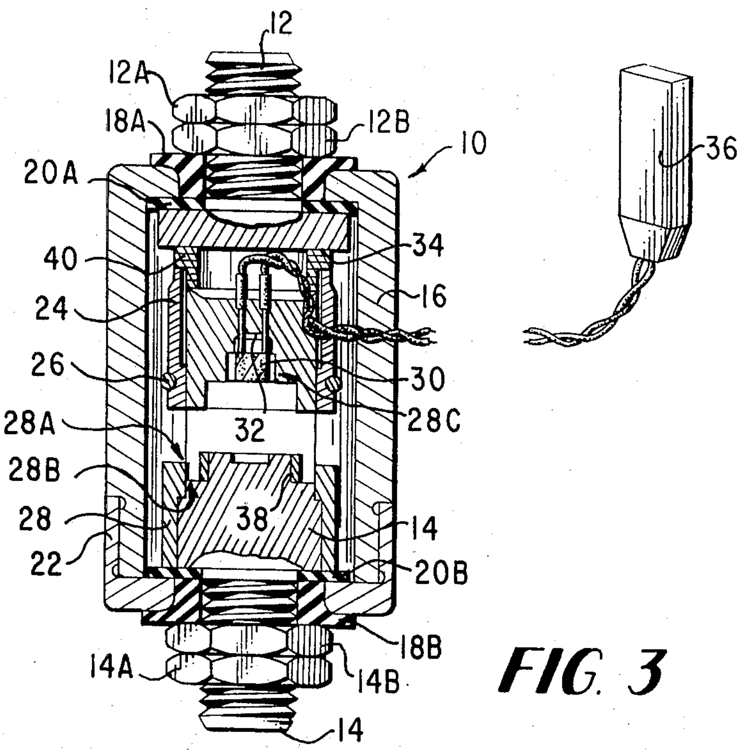

12
12A
18A
12B
10
20A
36
40
34
24
16
26
30
28A
32
28C
28B
38
28
14
22
20B
18B
14A
14B
14

FIG. 3

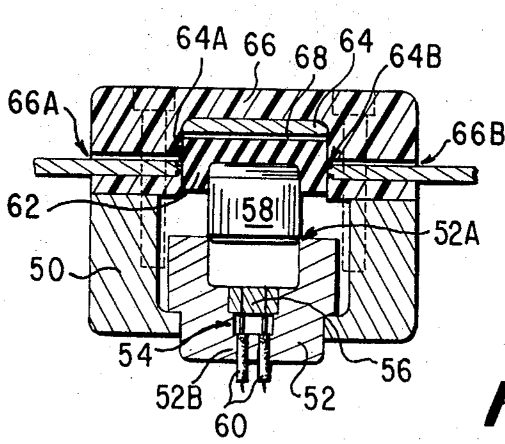

64A
66
68
64
64B
66A
66B
62
58
52A
50
54
56
52B
52
60

FIG. 4

EXPLOSIVE TYPE SWITCH WITH CIRCUIT SERVING MEANS

FIELD OF THE INVENTION

The invention relates to a method and apparatus for severing a mechanical element, such as a wire, bar, strip or the like, using the energy of an explosive.

BACKGROUND AND SUMMARY OF THE INVENTION

The invention concerns severing or shearing an element or part which is introduced into a chamber together with an explosive charge the latter of which causes a shear pressure to be exerted on the element to be severed either directly, or indirectly through an intervening member, by means of the expanding gases released by the explosion of the charge.

The invention provides a number of important advantages as compared with the prior art. For example, in accordance with one aspect of the invention, severing of the mechanical element, and, in a preferred embodiment, displacement of the severed portion of the element over a predetermined distance, takes place within a period of approximately 10^{-4} seconds from the instant a firing signal is initiated. A further important feature of the invention is that devices built in accordance therewith vary from one another in response time only by a matter of microseconds. These high performance features of the invention, which, to the knowledge of the applicant, have not been heretofore obtainable, provide new utilization possibilities and enable the use of high power explosives which are normally difficult to use industrially. Further, these explosives can be put to use without damage to the device or the need for special protection. In accordance with a further aspect thereof, the invention is adapted for use in devices of limited size such as circuit-breakers for electrical installations. Other purposes or uses of the invention are set forth in, or will be apparent from, the description of two embodiments of the invention set forth hereinbelow.

In accordance with the invention, a element or part to be severed is subjected to pure shear stresses caused by the explosion of explosive materials having a useful energy per unit mass of over 1,000 joules/gram (j/g), and preferably between 2,000 and 5,000 j/g, and a rate of detonation of over 3,000 ms., preferably between 7,000 and 8,000 ms. The explosive materials are arranged or housed in a recess which opens onto a delimited surface of the element to be severed, or a movable part which bears directly or indirectly on the element to be severed, so that the initial volume of the gas from the explosion is at least equal to the volume covered by the delimited surface adjacent to the charge housing during the useful displacement of the severed portion of the element, or of the movable part.

The severing method and apparatus of the invention utilizes the extraordinary effectiveness of pure shear so as to limit as much as possible the energy and time required. To explore this point further, if it be assumed, for example, that Δa is the elastic slip caused by a shear force T corresponding to, for a given cross section, the shear rupture stress P, the relevant relationships can be expressed by the formula $\Delta a/a = P/G$, where a is the thickness of the part and G is the cross-sectional modulus of elasticity or, more accurately, the shear modulus ($G = 0.38\ E$ where E = Young's Modulus). For soft

brass, P = 350 Newtons/mm^2(N/mm^2) and G = 40,000 N/mm^2 and, thus, assuming that the quantity $P\Delta a/a$ remains constant during shearing $\Delta a/a \approx 1.10^{-2}$. It will be appreciated that shear will be achieved as soon as the crystals have been displaced in the plane of the shear to a distance $\approx (a)(10^{-2})$, the shear energy being given by the expression (T) (a) (10^{-2}) where T is the breaking load.

The shear process of the invention is extremely rapid because of the short distance the shear forces act. Shearing is initiated as soon as the shear stress exceeds a particular threshold and hence it is desirable to reach this threshold as rapidly as possible. To this end, an explosive material is utilized which has a high rate of propagation and a high energy per unit mass as set forth above. Examples of such explosives are those known commercially as "Hexogen," "Octogen," "Pentrite," "Tetryl," "Trinitrotoluene" and the like. Such explosives ensures that prior to any geometrical change in the severing device due to displacement of the part to be severed, the gas pressure acting directly or indirectly on this part is raised within a time of less than one microsecond to a level higher than that corresponding to the shear threshold and is maintained at this level for the time necessary for the shearing process to take place.

In order to prevent any damage to, or deterioration of, the severing device as a result of the use of an explosive having a high rate of detonation and high internal energy, it is important that the major portion of this energy be used rapidly in the shear process and in the attendant displacement of the sheared part. This consideration dictates that, firstly, the sheared part be given the lowest possible mass consonant with effective operation and secondly, that the severing device be configured such that the efficiency of conversion of the internal energy of the explosive into mechanical and kinetic energy is as high as possible.

According to research conducted by applicant, the desired results discussed above can be achieved when the initial volume offered to or available to the explosive gases prior to any movement taking place is, at most, equal to the volume swept by the gases during the useful displacement of the sheared part. This initial volume can, at least, equal the covolume of the explosive material and this is a reason why, as discussed above, it is advantageous to use an explosive which has a high energy per unit of mass and a high rate of propagation.

According to a first embodiment of the invention, an ultra-high speed, high amperage circuit breaker is provided wherein the element to be severed comprises a cylindrical portion and a coaxial annular portion, the internal diameter of the annular portion being approximately equal to the external diameter of the cylindrical portion, means for initiating fracture, in the form of opposed grooves of the same diameter, being located in the area or zone where the cylindrical and annular portions of the element to be severed are joined together. The cylindrical and annular portions are connected to respective terminals and the cylindrical portion is adapted to house the explosive charge and a firing unit therefor.

In a second embodiment, the element to be severed is a conductive strip or bar which extends through an insulating cover of a metal housing. A conductive member located within the housing itself houses the explosive charge, a firing unit for the charge and a metal anvil which is displaced by explosion of the charge. An insulating member located between the anvil and the conductive bar is displaced with the anvil to a position between the ends of the bar, after the bar is severed, to prevent flashover.

Other features and advantages will be set forth in, or apparent from, the detailed description of the preferred embodiments found hereinbelow.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view, partially in section and partially broken away, of an ultra-high speed, high amperage circuit breaker in accordance with a first embodiment of the invention; and

FIG. 2 is a view similar to FIG. 1 of an ultra-high speed, high amperage circuit breaker in accordance with a second embodiment of the invention;

FIG. 3 is a view similar to that of FIG. 1 showing the circuit breaker of FIG. 1 in the actuated position thereof; and

FIG. 4 is a view similar to that of FIG. 2 showing the circuit breaker of FIG. 2 in the actuated position thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, the invention is illustrated as incorporated in an ultra-high speed, high amperage circuit breaker, which is generally denoted **10.** Circuit breaker **10** includes upper and lower electrical terminals **12** and **14** which are adapted to be connected to the appropriate leads or conductors of the electrical system in which the relay is to be included. Terminal **12** is mounted on a metallic body member or casing **16** by mounting nuts **12A** and **12B** and is insulated from body member **16** by a set of first and second insulating washers **18A** and **20A**. Terminal **14** is mounted on a metallic cap member **22** by a pair of mounting nuts **14A** and **14B** and is insulated from cap member **22** by a further set of first and second insulating washers **18B** and **20B**. An electrical contact **24**, which is electrically connected to terminal **12**, is formed by sectors cut out of a cylinder and held together by an annular spring **26.**

A metal fracture member or part **28** which is coaxial with, and is screwed, onto terminal **14**, frictionally engages contact **7** when cap member **22** is screwed onto body member **16.** Fracture member **28** is provided with grooves **28A** and **28B** which serve as so-called "fracture initiators", grooves **28A** and **28B** providing beginnings for the fracture and defining and limiting the area in which the shear stresses are to act. Fracture member **28** also includes a recess **28C** which serves as a housing for an explosive charge **30** and a charge initiator block or firing assembly **32.** The latter is fitted with connections **34** which pass through member **28**, contact **24** and body or casing **16** to a control unit **36.** It is noted that explosive charge **32** and firing assembly **34** are manufactured separately so that the two elements are brought into contact only just prior to closing and sealing of the relay. This approach both provides improved safety by reducing the possibility of an explosion occurring during handling and enables standardization of the firing assembly **34** so as to permit firing assembly **34** to be used with explosive packages of widely varying charges. An annular insulating washer **38** is positioned between member **28** and the innermost end of terminal **14.** Finally, a lead ring **40** is positioned within contact **24** between contact **24** and terminal **12** which, as set forth hereinbelow, limits the travel of the upper portion of member **28** that is sheared off.

In operation, a firing signal is transmitted from control unit **36,** through leads **34,** to firing assembly or initiator **15** to cause charge **30** to explode. The gas pressure from the explosion subjects member **28** to shear stresses in the area defined by grooves **28A** and **28B**, shearing or rupturing of the member **28** taking place as soon as these stresses exceed a particular level. At this time, the upper portion of member **28** is separated from the lower portion thereof and is driven upwardly at high speed. After traveling a preselected distance determined by the position of lead ring **40,** the separated portion of member **28** impacts against ring **40** to cause permanent deformation of the latter, this effect being enhanced by the fact the upper edge of member **28** is of triangular profile in cross section. The actuated position of the circuit breaker of FIG. **1** is shown in FIG. **3.**

A specific embodiment of the circuit-breaker described hereinabove, of cylindrical form having a diameter of 45 to 50mm. and a length of 75mm., designed for a continuous current of 600 to 800 amperes, and charged with 100mg. of pentrite, effects severance within 150 microseconds of the firing signal. The term "severance" as used here means shearing of the portion of the member **28** between grooves **28A** and **28B** and the separation and displacement of the upper movable portion of member **28** for a distance of about 5mm.

Referring to FIG. **2**, a further embodiment of the invention is illustrated which effects the severance or fracture of a calibrated strip and blade and provides subsequent translation or displacement of the sheared part. The calibrated strip can comprise a calibrated prismatic fuse. In the specific embodiment shown in FIG. **2,** a metal casing or housing, denoted **50,** houses a metallic member **52** which includes a recess **52A** which, in turn, houses a firing unit or assembly **54** of the "exploded wire" type, an explosive charge **56** and a metal anvil member **58.** Firing unit **54** is connected through a pair of leads or wires **60** to a suitable actuator (not shown), wires **60** extending through a corresponding pair of openings or holes **52B** in member **52.** As discussed hereinabove, firing unit **54** and explosive charge **56** are manufactured separately and are operatively connected together only at the final moment of assembly of the circuit-breaker. An insulating member **62** positioned above anvil member **58** includes a recess in the lower surface thereof in which the head of anvil **58** is received. Member **62** is constructed of a suitable insulating material such as "Nylon" or "Celoron" and hence serves in insulating anvil **58** from the conductor to be severed which is denoted **64** in FIG. **2.**

The conductor **64,** as mentioned above, preferably comprises a calibrated fuse which, in an exemplary embodiment, is 25mm. in width and 2.5 mm. thick. Conductor **64** includes first and second spaced perforations or points of weakness **64A** and **64B** which are spaced apart a distance equal to the width of insulating member **62** and located opposite the parallel edges or side walls of member **62.** A cover **66,** which is preferably constructed of an insulating material such as "Nylon" or "Celoron", screws onto casing **50** and includes a pair of openings **66A** and **66B** through which conductor **64** extends. Cover **66** defines a space **68** above conductor **64** as indicated in FIG. **2.**

In operation, when a firing signal is transmitted through leads **60** to firing unit **54**, the wire therein immediately melts and causes ignition of explosive charge **56**. The pressure generated by the expanding gases cause upward displacement of anvil **58** and insulating member **62** thus causing shearing of calibrated conductor **64** along perforations **64A** and **64B**, the sheared part of conductor **64**, together with anvil **58** and insulating member **62**, being driven upwardly into the space **68** defined by cover **66** as shown in FIG. **4**. Insulating member **62** is thus positioned between the ends of conductor **64** thereby limiting the danger of flashover.

It is pointed out that a specific embodiment of a circuit-breaker constructed as described above in connection with FIG. **2** and having a cylindrical form with a diameter of 55mm. and a length or height of 45mm., charged with 20mg. of lead nitride and 20mg. of pentrite, causes the severance of a calibrated fuse or conductor, having a useful width of 20mm. and a thickness of 25mm., within 155 microseconds. The term "severance" as used here means the shearing of the conductor as well as the displacement of the sheared part of the conductor over a distance of 5mm.

It is noted that, depending on the nature of insulating member **62**, the latter may be lined on its surface in contact with the conductor **64** by a metal blade (not shown) to enhance the shear effect. The severance energy required may also be reduced by subjecting the conductor or fuse to the overcurrent to which the circuit-breaker responds since the thermal energy developed in the fuse will lessen the necessary shear energy. It is also noted that the circuit breaker of FIG. **2** can be modified where desired so that the severed or sheared portion of conductor **64** comes into contact with a set of normally open terminals at the end of its travel to thereby complete a control of measuring circuit.

Devices incorporating the invention possess a number of other advantages in addition to the capability of operating with a very short time period (about 10^{-4} seconds) and the interchangeability of the devices owing to the very small differences (less than a few microseconds) in operating times from device to device. For example, such devices are suitable for utilization in any application where the switching components are inaccessible during use, e.g., undersea work at great depths, underground work and space applications. Further, the devices are capable of use in any electrical circuit requiring an ultrarapid response in the event of an overload, the practically simultaneous operation characteristics thereof enabling power to be interrupted, or connected, at a considerably higher level than would conventionally be the case.

Although the invention has been described with reference to exemplary embodiments thereof it will be appreciated by those skilled in the art that variations and modifications can be effected in these embodiments without departing from the scope and spirit of the invention.

I claim:

1. A device for severing a mechanical element comprising an electrical current conductor including a cylindrical portion and a coaxial annular portion extending outwardly from said cylindrical portion, the internal diameter of the annular portion being approximately equal to the external diameter of said cylindrical portion, said device comprising an explosive charge having an energy per unit of mass in excess of 1,000 joules/gram and a speed of propagation in excess of 3,000 ms, firing means for detonating said charge, housing means for housing and supporting the mechanical element and said explosive charge including a first electrical terminal connected to said annular portion of said mechanical element and a second electrical terminal connected to said cylindrical portion of said mechanical element, said mechanical element including means for initiating fracture comprising means defining first and second coaxial grooves located in the area joining said cylindrical portion and said annular portion, and said cylindrical portion including recess means for housing said explosive charge and said firing means such that the initial volume presented to the explosive gases, defined by the volume of said explosive charge and the housing therefor, is no greater than the volume swept by the gas during the useful displacement of the sheared portion of the mechanical element to be severed, said swept volume being equivalent to the volume of a cylinder having a diameter equal to the internal diameter of the annular portion and a height equal to the distance between the said first and second coaxial grooves.

2. A device as claimed in claim **1** wherein said explosive charge has an energy per unit mass of between approximately 2,000 and 5,000 joules/gram and a speed of propagation of 7,000 to 8,000 ms.

3. A device as claimed in claim **1** wherein said cylindrical portion and said second terminal are connected by contact means comprising an annulus formed by a plurality of sectors and spring means for holding said sectors in place.

4. A device as claimed in claim **1** further comprising a deformable annulus positioned in the path of said cylindrical portion of the element to be severed for absorbing the kinetic energy of said cylindrical portion when the latter is sheared from said annular portion.

5. A device as claimed in claim **1** wherein said housing means comprises a metal case and a cap secured to said case, one of said first and second terminals being insulatingly mounted on said case and the other of said terminals being insulatingly mounted on said cap.

6. A device for severing a mechanical element comprising a current carrying conductive strip, said device comprising an explosive charge having an energy per unit of mass in excess of 1,000 joules/gram and a speed of propagation in excess of 3,000 ms, firing means for detonating said charge, means for housing the mechanical element to be severed including a conductive case and an insulating cover secured to said case, the said current carrying conductive strip extending through said cover, said housing means further comprising a conductive member located within said case and including means for housing said explosive charge and a conductive anvil member which is displaced responsive to ignition of said charge and an insulating member located between said anvil member and said conductive strip; the initial volume presented to the explosive gases defined by the volume of said explosive charge and the housing therefor being no greater than the volume swept by the gas during the useful displacement of the sheared portion of the element to be severed, said swept volume being equivalent to the volume of the cylinder having a diameter equal to the internal diameter of the anvil housing means and a height equal to the thickness of the element to be severed.

7. A device as claimed in claim **6** wherein said explosive charge has an energy per unit mass of between approximately 2,000 and 5,000 joules/gram and a speed of propagation of 7,000 to 8,000 ms.

8. A device as claimed in claim **7** wherein said conductive strip is weakened at spaced points which are located opposite the side walls of said insulating member.

* * * * *