June 18, 1968 F. T. PISANO ET AL 3,388,879

ELECTRONICALLY TIME DELAYED CUTTER

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Fig. 1

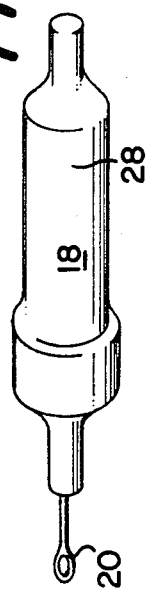
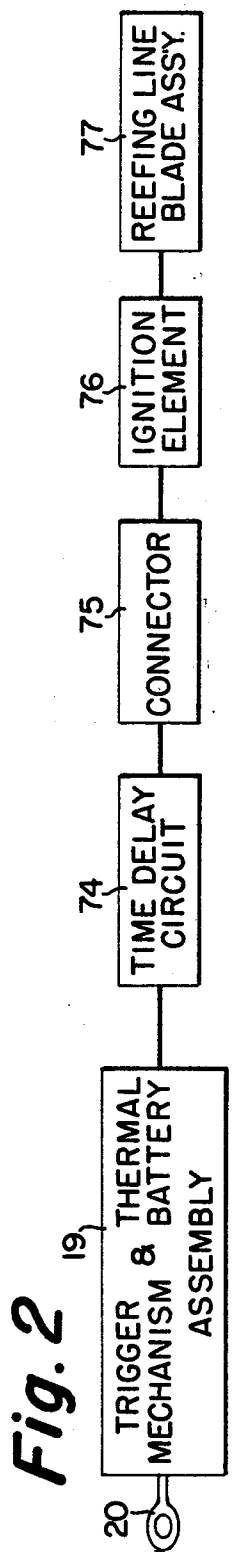


Fig. 2



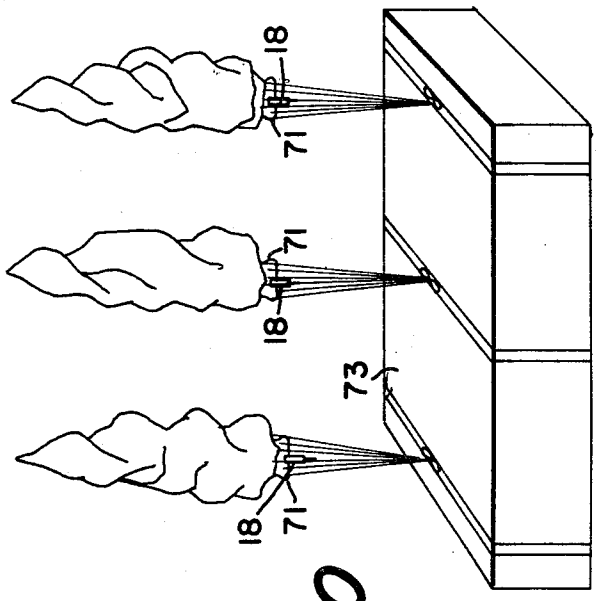


Fig. 10

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ELECTRONICALLY TIME DELAYED CUTTER

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Fig. 3

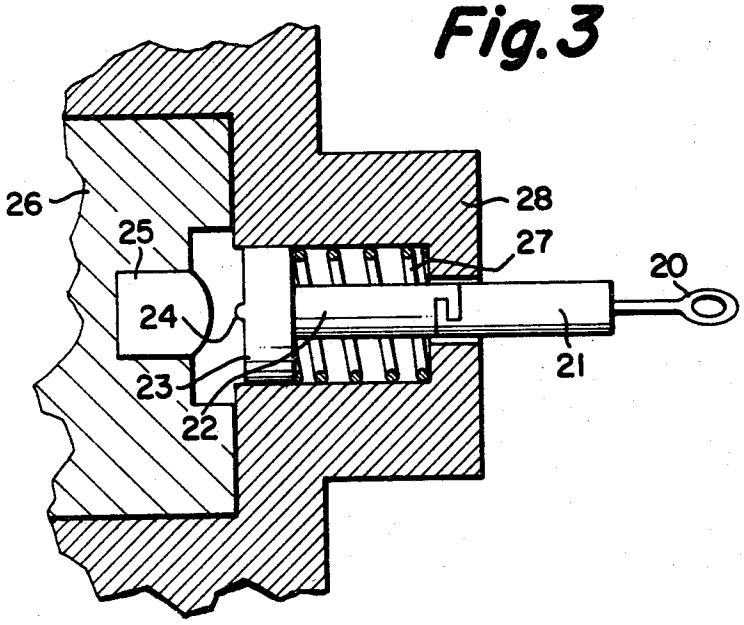
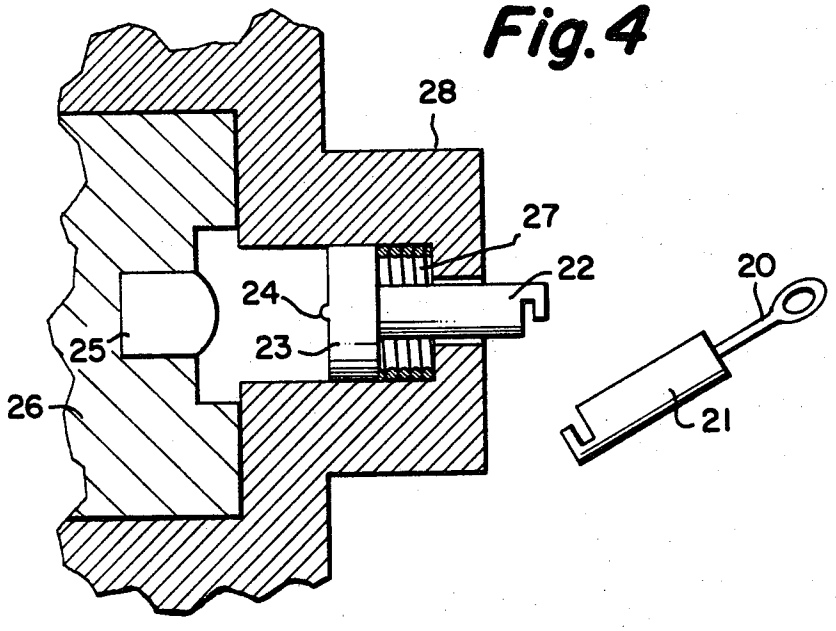


Fig. 4



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ELECTRONICALLY TIME DELAYED CUTTER

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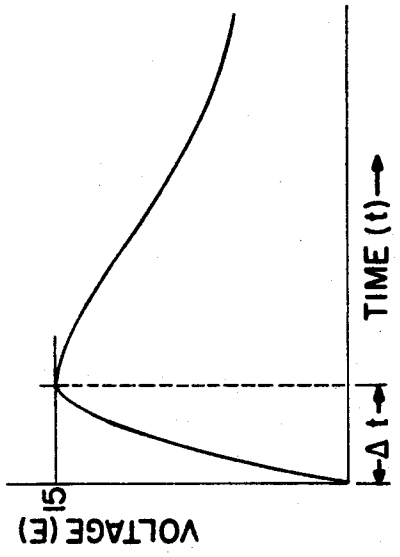


Fig. 6

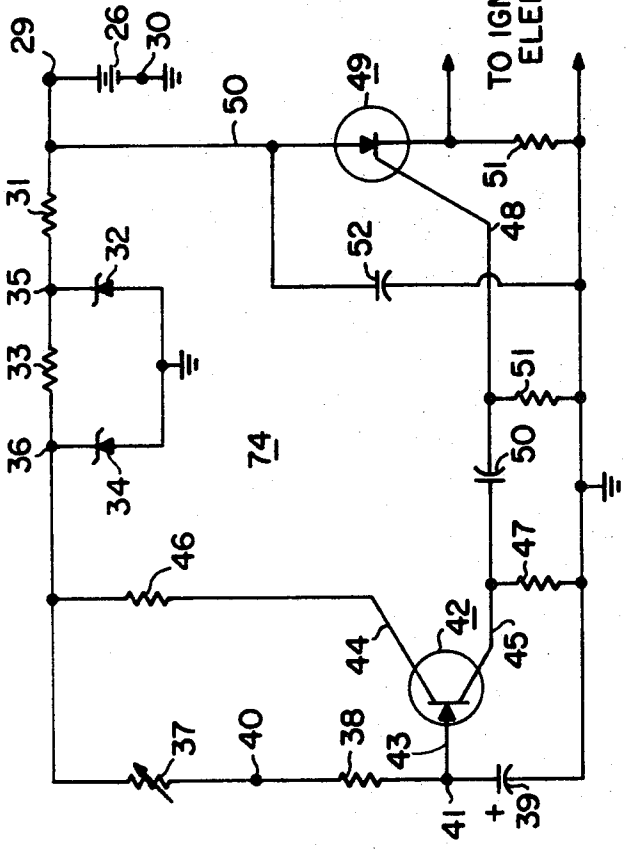


Fig. 5

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Fig. 9

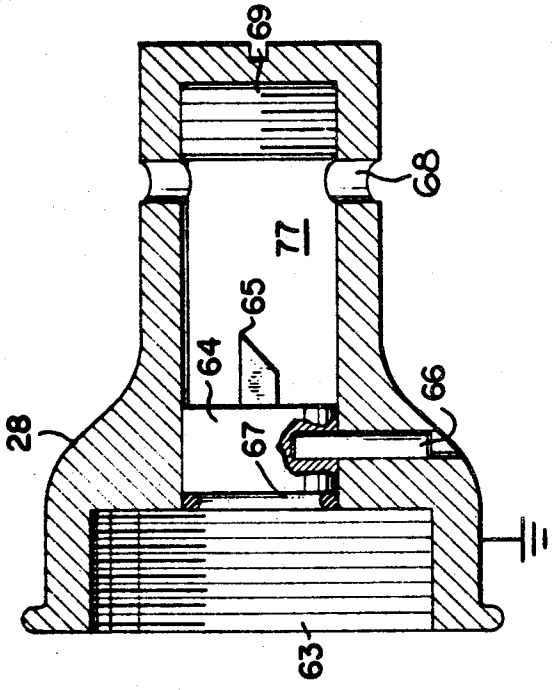


Fig. 8

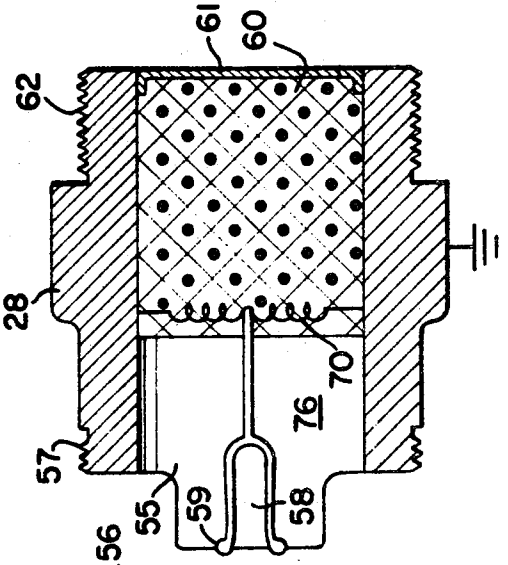
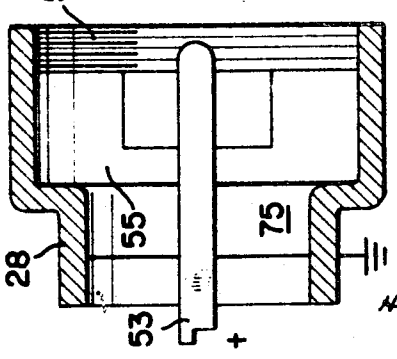


Fig. 7



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ELECTRONICALLY TIME DELAYED CUTTER

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Filed July 31, 1967, Ser. No. 657,732
11 Claims. (Cl. 244—152)

ABSTRACT OF THE DISCLOSURE

A delay type cutting device is provided to sever the reefing line of a load-dropping parachute after a limited time for free fall, thereby to insure opening of said parachute. A current source, such as a thermal battery, is manually triggered at the time of the load release, and generates an electric current which, after being electrically delayed for the predetermined delay time required, is passed through a bridgewire seated in an explosive charge, thereby initiating an explosion. The explosion of the charge ruptures a diaphragm or seal and drives a cutting blade forward toward and through the reefing line, thereby severing it. The electrically time delayed cutter comprising the invention is adapted for multiple use with a plurality of parachutes in dropping large and massive loads. Thus a plurality of such cutters in a multichute single-drop system may be used when the load or cargo is too massive to be supported by a single parachute. The electrical time delay is designed to be temperature stable from —100° F. to +250° F., thereby eliminating the problems of either premature or excessively delayed parachute blossoming presently attendant with multichute systems.

The invention described herein may be manufactured, used, and licensed by or for the Government for governmental purposes without the payment to use of any royalty thereon.

The present invention relates to a line or cord cutting apparatus wherein a knife or like blade is driven forward by the explosive force of an electro-explosive or propellant actuated device after the expiration of a predetermined time interval. More particularly, the invention relates to a line cutter adapted to cut the reefing line of a parachute or the like at a predetermined time after the parachute has been dropped from an airplane or similar flying craft, thereby permitting the parachute to blossom. Moreover, in accordance with the invention, a plurality of such cutters may be used for a multichute single-drop operation wherein the load or cargo is too massive to be supported by a single parachute.

There is a great need for a multichute single-drop system as, in many instances, cargo is too heavy to be supported by a single parachute. In such a system moreover, it is paramount that all chutes open simultaneously since staggered openings result in severe damage to the cargo or load. For example, if one parachute should blossom far in advance of the others, the canopy thereof might readily rip and be rendered useless due to the excessive loading. The remaining parachutes could not then adequately support the cargo weight and would themselves either rip and tear or, at least, drop so quickly as to injure the cargo.

There are, at present, a few propellant actuated line cutters in use. All of these, however, utilize a pyrotechnic or similar time delay. It is noted that some form of time delay is necessary as the blossoming of the parachutes must be delayed for at least a time sufficient to allow the cargo and parachutes to fall clear of the aircraft. The aforementioned delay networks, however, have an average time tolerance of ±15% over the temperature range from —65° F. to +200° F. While this time variance is acceptable for most system operations, multichute single-drop systems require time tolerances within 5% over the aforementioned temperature range and within 3% for any given temperature within that range. The present invention provides a reefing line cutter with a time delay the temperature stability of which is well within the multichute single-drop requirements.

It is therefore an object of the present invention to provide a reefing line cutter for use with a multichute single-drop parachute system.

It is a further object of the invention to provide a reefing line cutter which is propellant actuated and which servers the reefing line after a predetermined time delay.

It is yet another object of the invention to provide a reefing line cutter with an electronic time delay circuit which is temperature stable from —65° F. to +250° F.

Still other aspects, objects, and advantages of the present invention will become apparent from the following description of an illustrative embodiment thereof and with reference to the accompanying drawings, the scope of the invention being recited in the appended claims.

FIG. 1 is a top view, in perspective, of an assembled reefing line cutter device embodying the invention,

FIG. 2 is a block diagram of the cutter device of FIG. 1 showing the various components thereof in accordance with the invention,

FIGS. 3 and 4 are enlarged, fragmentary cross-sectional views of the device of FIG. 1 showing further details of certain of its components in FIG. 2, as provided in accordance with the invention for two different operating conditions,

FIG. 5 is a schematic circuit diagram of an electronic time delay component of the cutter device as shown in FIG. 2,

FIG. 6 is a graphical representation of certain operating characteristics of a thermal battery adapted for use with the device of the present invention,

FIGS. 7–9 are cross-sectional views, in elevation, showing further details, in accordance with the invention of certain components as included in the block diagram of FIG. 2, and

FIG. 10 is a view, in perspective, representing a multiparachute system supporting a massive load in free fall and provided with reefing line cutters and the respective reefing lines therefor in accordance with the invention.

Referring to the drawings, wherein like reference numerals and characters are used to designate like elements throughout the various figures and referring particularly to FIGS. 2 and 4, a trigger mechanism and thermal battery assembly **19** is provided with a lanyard **20** affixed to the first pair of releasably jawed connectors **21** and **22**. The connector jaw **22** has affixed at one end thereof a hammer **23** having a firing pin **24** positioned approximately at the center thereof. Also shown in FIGS. 3–4 is a battery primer **25**, thermal battery **26**, and com-

pressible spring **27**. The entire assembly is contained within the suitably constructed housing **28**.

To initiate operation of the system, lanyard **20** is pulled back against the action of the spring **27**, thereby compressing the spring **27** and drawing the hammer **23** and firing pin **24** along the inner surface of the housing **28** to the position shown in FIG. 4. When the spring **27** has been compressed to the point where connector jaws **21** and **22** are no longer seated within the housing **28**, the jaws **21** and **22** separate (as in FIG. 4) and hammer **23** and firing pin **24** are driven forward toward and beyond their original position shown in FIG. 3 by the spring **27** with a force sufficient for the pin **24** to impact with the primer **25**. This impact, or force impulse, initiates the mingling of the pressure sensitive chemicals within the thermal battery **26**, thereby initiating the generation of electrical energy. As can be seen in FIG. 6, the voltage generated by thermal battery **26** increases rapidly to a maximum value of approx. 12–15 volts and then begins to decay. The rise time Δt is on the order of a few milliseconds. It is noted that the characteristic curve of the thermal battery is similar to that of a capacitor. In fact, in some of the tests of the system that were conducted, a capacitor was employed in place of the thermal battery. The battery, however, was found to be more efficient.

This generated 12–15 v. voltage is applied to the input terminals **29** and **30** of the electronic time delay circuit **74** as can be seen in FIG. 5. The circuit is connected in cascade with the thermal battery **26** and operates as follows.

Two voltage regulation networks are in parallel circuit connection with thermal battery **26**. The first regulator network is comprised of a resistor **31** and a Zener diode **32**. The resistor **31** is connected between the positive terminal **29** of battery **26** and the node **35**. Zener **32** is connected as shown between node **35** and ground. In the present circuit, the 12–15 volt input is converted to approx. 10 volts by this first regulator network. The second regulator network, comprising a resistor **33** and a Zener diode **34** and connected, respectively, between the nodes **35** and **36** and the node **36** and ground, converts the 10 volts signal to approximately 4 volts. It is noted that the resultant 4 volt signal is smoother and more steady than the original input signal.

This 4 v. signal then enters the time delay portion of the circuit composed of a variable resistor **37**, a resistor **38** and a capacitor **39**. Also utilized as part of the time delay is a silicon controlled switch **42** which may be a unijunction transistor having an emitter **43** and upper and lower bases **44** and **45**. The resistor **46** is used to set the operating level of controlled switch **42**. It is noted that when a certain positive voltage, called the firing or command voltage, is applied to the emitter **43** of unijunction transistor **42**, the normally high resistance between emitter **43** and base **45** drops considerably, thereby permitting current flow therethrough. This feature of the unijunction transistor **42** is utilized in conjunction with achieving the desired time delay as follows. The current attendant with the 4 volt signal appearing across the Zener **34** begins charging capacitor **39** toward 4 volts through the resistors **37** and **38**. However, when the unijunction transistor firing voltage is reached (approximately 0.5 v. for the 2N2840 unijunction transistor here employed), the capacitor **39** discharges through the now conductive path from emitter **43** to base **45**, thereby causing a positive voltage pulse to appear across the resistor **47** in the output or lower base **45** circuit of unijunction transistor **42**. The time required to reach the firing voltage of transistor **42** is controlled and delayed by properly setting variable resistor **37** as will be hereinafter explained.

The aforementioned positive pulse is coupled to the gate **48** of a silicon epitaxial planar PNPN controlled switch **49** or the like by the coupling and filtering network composed of a capacitor **50** and a resistor **51**. When the aforementioned positive pulse is applied to the gate **48**, switch **49** is rendered conductive and current from battery **26** flows through conductive lead **50**, the switch **49**, and the resistor **51** to ground, consequentially firing the ignition element of FIG. 8 as will be hereinafter explained. The capacitor **52** is used as a bypass to prevent random firing of controlled switch **49**.

The amount of time delay available with the present circuit is given by the formula:

$$Td = -RC\ 1n\ N(1-N)$$

where:

Td=time delay,
R=the series sum of the resistance of resistors **37** and **38**,
C=capacitance of capacitor **39** and,
N=the intrinsic standoff ratio of the unijunction transistor.

For the 2N2840 unijunction transistor, N has a minimum value of 0.62 and a maximum value of 0.75.

By substituting these values into the above equation and ignoring the minus (—) sign, it is seen that the time delay has a maximum of 1.39 RC and a minimum of 0.97 RC, or more succinctly, $Td = 1.18\ RC \pm 0.21\ RC$. Note also that since resistor **37** is variable, the time delay may be varied and preset exactly, prior to use, by a proper choice of both "R" and "C."

The temperature coefficients of the various delaying elements are preselected to achieve a constant time delay over the temperature range from —100° F. to +250° F. with a unique accuracy of ±3% over the temperature range.

Below is a table showing the results of a test run on the time delay circuit. The temperatures of interest are room temperature, +250° F., and —100° F. The delay was set for 6.0 seconds and the circuit was tested 25 times.

TIME DELAY (SEC.) OF CIRCUIT OVER THE TEMPERATURE RANGE

	Room Temperature	250° F.	—100° F.
Test Run No.:			
1	6.01	5.91	5.89
2	6.01	5.90	5.90
3	6.00	5.89	5.91
4	6.00	5.90	5.91
5	6.00	5.91	5.90
6	6.01	5.91	5.90
7	6.01	5.89	5.91
8	5.99	5.90	5.90
9	5.99	5.89	5.91
10	6.00	5.89	5.91
11	6.01	5.89	5.91
12	6.01	5.90	5.90
13	6.00	5.90	5.90
14	5.99	5.90	5.90
15	5.99	5.90	5.91
16	6.01	5.89	5.88
17	6.01	5.90	5.90
18	6.00	5.91	5.91
19	5.99	5.90	5.91
20	5.99	5.90	5.94
21	6.01	5.91	5.90
22	5.99	5.91	5.90
23	6.00	5.90	5.91
24	6.01	5.91	5.89
25	6.01	5.91	5.89
Average	6.00	5.90	5.90
Maximum	6.01	5.91	5.94
Minimum	5.99	5.89	5.88

Referring now to FIGS. 7–9 the operation of the remainder of the system will be explained.

The connector **75** of FIG. 7 attaches to the ignition element **76** of FIG. 8 which in turn attaches to the blade assembly **77** of FIG. 9 via, respectively, threaded portions **56** and **57** and threaded portions **62** and **63**. These threads are cut directly into the housing **28** and all three units comprise one assembly in actual operation.

When the units of FIGS. 7–9 are threaded together, the pin **53** fits snugly into the provided socket **58** of the receptacle **59**. Both the pin **53** and the receptacle **59** are electrically conductive and are therefore surrounded by an insulating material **55**.

The electrical output of the time delay (appearing across the resistor **51** in the cathode circuit of controlled

switch 49, FIG. 5) is conducted by the pin 53 and the receptacle 59 to the bridgewires 70 which are seated in the charge 60 and attached to the housing 28, which is grounded. This output current heats the wires 70 causing them to glow and thus ignite the charge 60, thereby causing an explosion. The attendant expanding gas derived from the explosion ruptures the diaphragm or seal 61 and drives the blade holder 64 and the blade 65 in a straight path toward the anvil 69 thereby severing the reefing line which has previously been seated in the provided apertures 68. It is noted that the holder 64 of the blade 65 is held in place prior to the explosion, by means of a shear pin 66 which is broken by the force of the expanding gases of the explosion. The cutting blade 65, itself, is secured to the holder 64 by any suitable manner. The "seal-O-rings" 67 are provided to minimize gas leakage after the explosion.

It should now be apparent that a reefing line cutter has been provided to sever the reefing line of a parachute a predetermined time after the chute and cargo are in free fall. Moreover, since the provided time delay is precise and stable over so wide a temperature range, it is to be appreciated that a plurality of such cutters may well be utilized as shown in FIG. 10 with a like plurality of parachutes to support a single massive cargo. The line cutters 18 may be depended upon to sever the reefing lines 71 virtually simultaneously, thereby assuring simultaneous blossoming of all parachutes 72 and substantially contributing to the safe and undamaged landing of the massive load 73.

We claim:

1. A cutting device suitably housed in a single unit and adapted to sever the reefing line of a parachute in free fall the combination comprising,

trigger means for imparting a mechanical impulse to an electric energy generating means, said energy generating means being adapted to generate an electric current upon the receipt of said mechanical impulse,

electrical delay means in cascade connection with said energy generating means adapted to delay the passage of said electric current for a predetermined time interval,

electrically conductive means in circuit connection with said electrical time delay means, said means adapted to initiate an explosive upon the recipt thereto of said electric current and,

blade means operatively connected with said last-named means and adapted to be driven forward in a straight path toward and through said reefing line by the expanding gases attendant with said explosion.

2. The invention as defined in claim 1 wherein said trigger means comprises,

first and second releasably jawed connectors seated within a suitably constructed housing which permits forward and backward lateral movement therethrough wherein one of said connectors is provided with a hammer and firing pin means to impart said impulse to said electrical energy generating means upon the disconnection of the jaws of said connectors and the expansion of previously compressed spring means.

3. The invention as defined in claim 1 wherein said electrical energy generating means comprises a thermal battery adapted to generate maximum voltage a few milliseconds after being impacted.

4. The invention as defined in claim 1 wherein said electrical time delay means comprises,

first and second voltage regulator networks connected in parallel circuit configuration with said electrical energy generating means and adapted to receive said electrical energy and to provide a voltage of lower and more steady magnitude than received,

first and second electronic switch means connected in parallel circuit configuration both with each other and with said regulators and said electrical energy generating means, said second switch means being responsive to a voltage pulse produced by said first switch means and adapted to permit the passage of electrical energy from said energy generating means upon the recept thereto of said voltage pulse from said first switch means,

said first switch means adapted to produce said voltage pulse upon the receipt thereto of an electrically delayed command signal derived from said steady regulator voltage.

5. The invention as defined in claim 4 wherein said first electronic switch means comprises a unijunction transistor having upper and lower bases and an emitter, said emitter adapted to receive and transmit an electrical discharge from a suitably connected electrical charge and discharge means, the rate of charge of said last-named means being controlled by fixed and variable resistance means in circuit connection between said emitter and said electrical energy generating means.

6. The invention as defined in claim 5, wherein said electrical charge and discharge means comprises a capacitor and second electronic switch means comprises a silicon epitaxial planar PNPN controlled switch.

7. The invention as defined in claim 1, wherein said electrically conductive means comprises a pin means and receptacle therefor connected, respectively, to the output of said electrical circuit delay means and to a plurality of bridgewire means and adapted to receive and transmit said electrical energy from said circuit delay means to said bridgewire means,

explosive charge means surrounding said bridgewire means and adapted to explode upon the receipt by said last-named means of said electrical energy and,

blade cutting means positioned in juxtaposition with blade holding means and adapted to be driven forward toward an anvil by said explosion upon the rupture of a diaphragm means positioned between said explosive charge and said blade holding means and the breaking of a shear pin means partially positioned within said blade holding means and said housing.

8. In a multiparachute single-drop system wherein a plurality of parachutes are affixed to a massive load too heavy to be supported by a single parachute and further wherein each of said parachutes is provided with a cutting device adapted to sever the separate reefing lines thereof, the combination comprising,

blade means responsive to the force of an explosive charge positioned behind it and adapted to sever said reefing lines upon the initiation of said charge,

bridgewire means seated in said charge and adapted to glow and initiate said explosion upon the receipt thereto of electrical energy from an electrical energy supply means,

electrical time delay means positioned between said bridgewire means and said electrical energy supply means and adapted to delay the transmittance of said electrical energy from said supply means to said bridgewire means for a predetermined time interval, said time interval being substantially constant over the temperature range from —100° F. to +250° F.

9. The invention as defined in claim 8, wherein said electrical time delay means comprises,

first and second voltage regulator networks connected in parallel circuit configuration with said electrical energy generating means and adapted to receive said electrical energy and to provide a voltage of lower and more steady magnitude than received,

first and second electronic switch means connected in parallel circuit configuration both with each other and with said regulators and said electrical energy generating means, said second switch means being responsive to a voltage pulse produced by said first switch means and adapted to permit the passage of electrical energy from said energy generating means

upon the receipt thereto of said voltage pulse from said first switch means,

said first switch means adapted to produce said voltage pulse upon the receipt thereto of an electrically delayed command signal derived from said steady regulator voltage.

10. The invention as defined in claim **9**, wherein said first electronic switch means comprises a unijunction transistor having upper and lower bases and an emitter, said emitter adapted to receive and transmit an electrical discharge from a suitably connected electrical charge and discharge means, the rate of charge of said last-named means being controlled by fixed and variable resistance means in circuit connection between said emitter and said electrical energy generating means.

11. The invention as defined in claim **10**, wherein said electrical charge and discharge means comprises a capacitor and said second electronic switch means comprises a silicon epitaxial planar PNPN controlled switch.

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