Sept. 24, 1957 K. D. SMITH 2,807,712

ELECTRONIC SYSTEMS

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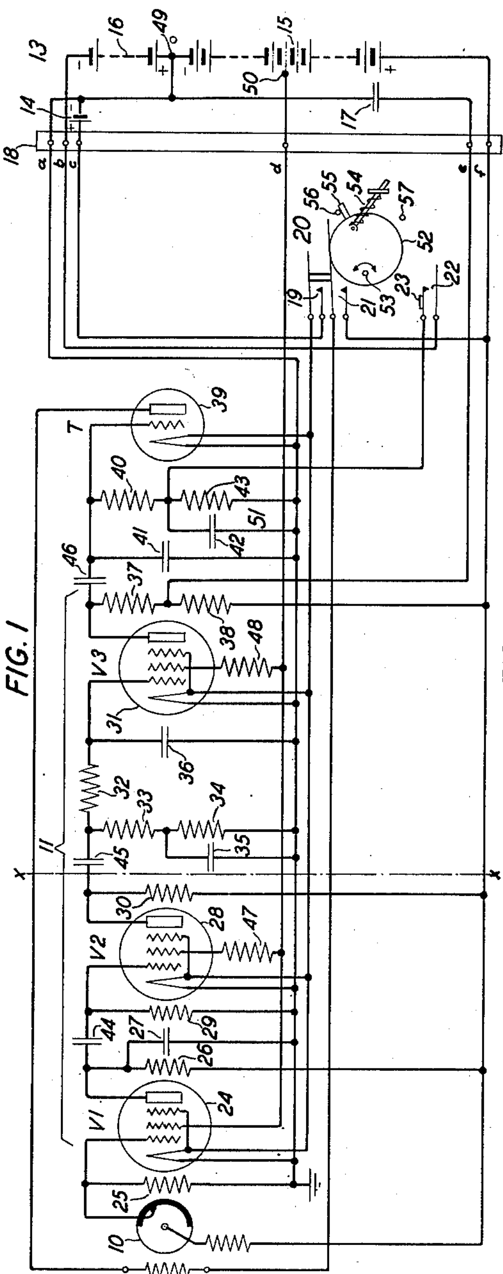

FIG. 1

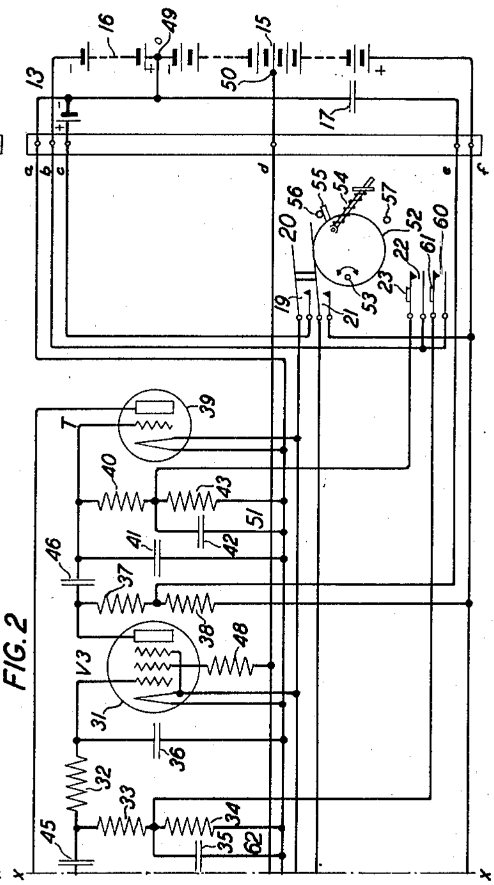

FIG. 2

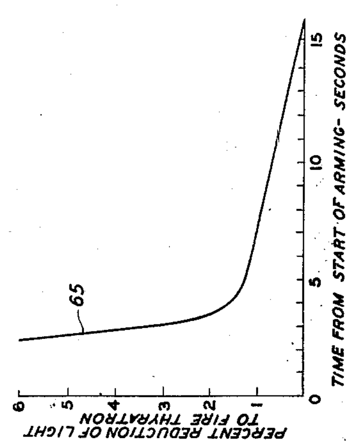

FIG. 3

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ELECTRONIC SYSTEMS

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This invention relates to electronic systems and more particularly to such a system adapted to be controlled by radiant energy.

An object of the invention is to provide an improved radiant energy controlled electronic system.

Another object of the invention is to provide a radiant energy controlled system having a space discharge device which is operated by suitable changes in the received radiant energy and having means to make said device responsive to progressively smaller changes in the radiant energy during a given time interval.

In an example of practice of the invention an electronic system comprising a photoelectric cell, a vacuum tube amplifier and a thyratron is arranged to detonate an explosive projectile. The function of the system is to detect the presence of an object, such as an airplane, in proximity to the path of travel of the projectile to which it is attached, due to an impulsive reduction in the amount of light incident on the cell and to cause the explosion of the explosive charge. If no object is encountered the explosive charge is exploded independently of the photoelectric cell before the projectile approaches near enough to the earth to cause damage by its explosion. Precautions must be taken to prevent premature detonation before the projectile has moved far enough away from its handlers to prevent damage. These functions are accomplished by applying automatically a negative blocking voltage to the grid of the thyratron and reducing this voltage at a predetermined rate until the thyratron fires independently of the photoelectric cell. The blocking voltage is applied through switch contacts which are closed by forces of acceleration during the initial stages of the projection of the projectile. At the same time a condenser connected in a circuit between the grid and cathode of the thyratron is charged to the same voltage. When the acceleration of the projectile falls below a predetermined value, as when the projectile approaches the target zone, the contacts open and the condenser begins to discharge through a large shunting resistance, thereby reducing the negative biasing voltage on the grid of the thyratron. This negative biasing voltage approaches zero on an exponential curve. Until the projectile is projected toward the target zone this system is inoperative to effect detonation because power is not supplied to the cathodes of the amplifier tubes and the anode of the thyratron. By this arrangement the projectile is unarmed during handling and for all practical purposes is unarmed during the early stages of its travel toward the target zone. During the time interval when it is travelling through the target zone it becomes sensitive to progressively smaller changes of light on the photoelectric cell. Finally, soon after it leaves the target zone the negative bias has been so much reduced that the thyratron fires and detonates the projectile independently of the photoelectric cell. For destructive purposes there is an advantage in requiring the projectile to approach closer to a target to effect detonation as it enters the target zone, than after it has travelled a considerable

distance through the target zone. Such advantage is obtained by applicant's arrangement.

In a modified arrangement a blocking voltage is also applied to the grid circuit of one of the amplifier stages, which biasing voltage is reduced more rapidly than that on the thyratron. By this arrangement the rate at which the projectile is armed and the time of self-destruction as well as the effectiveness of the disarming may better be controlled. Furthermore, a smaller negative voltage may be used to effect disarming.

This invention is useful for other purposes than the detonation of explosive projectiles. It is useful wherever indications of timed events are desired, which events are to occur within a predetermined time interval.

The invention will now be described more in detail having reference to the accompanying drawings.

Fig. 1 is a schematic circuit arrangement of one embodiment of the invention.

Fig. 2 is a schematic circuit arrangement of a modified embodiment of the invention.

Fig. 3 is a graph showing the reduction in light required to effect firing of the thyratron versus time after start of arming in the arrangement of Fig. 2.

The same reference characters are used to designate identical elements in the several figures of the drawing.

Referring now to Fig. 1, a circuit arrangement suitable for being housed within a container which is attached to an explosive projectile comprises a photoelectric cell **10**, a three-stage vacuum tube amplifier **11** and a thyratron stage T. The output circuit of thyratron stage T is coupled to a heater resistor **12** which may be used to ignite the detonating squib of the projectile. Energizing current is furnished by a battery unit **13**. The battery unit **13** comprises a filament heating battery **14**, a plate battery **15**, a negative biasing battery **16** and a by-pass condenser **17**. The battery **13** is connected to the rest of the circuit by means of a multiple contact connector **18**. The filament heating circuit is controlled at contacts **19** of acceleration switch **20**. The output circuit of thyratron stage T, including the load resistor **12**, is controlled at contacts **21** of switch **20**. The application of negative blocking voltage for the grid-filament circuit of thyratron stage T is controlled by contacts **22** of switch **20** which contacts may be closed by forces of acceleration operating on a mass **23** mounted on the relatively movable contact spring of contacts **22**.

The input stage V1 of amplifier **11** comprises vacuum tube **24**, input resistance **25**, plate resistance **26**, and by-pass condenser **27**. The intermediate stage V2 of amplifier **11** comprises vacuum tube **28**, input resistance **29** and plate resistance **30**. The third or output stage V3 of amplifier **11** comprises vacuum tube **31**, series input resistance **32**, shunt input resistances **33** and **34**, shunt condenser **35**, input condenser **36** and output resistances **37** and **38**. The thyratron stage T comprises thyratron tube **39**, input biasing resistance **40**, input condenser **41**, biasing control condenser **42** and discharge resistance **43**. The amplifier stages V1 and V2 are coupled by condenser **44**, stages V2 and V3 by condenser **45** and stages V3 and T by condenser **46**. The screen grids of vacuum tubes **28** and **31** are energized through resistances **47** and **48**, respectively, from a portion of battery **15** extending from the grounded negative terminal **49** to the intermediate connection **50**. The screen grid of vacuum tube **24** is connected directly to the intermediate connection **50**. The network **51** comprising condenser **42**, shunting resistance **43**, negative biasing battery **16** and contacts **22** of switch **20**, functions according to this invention to disarm the projectile during the initial stages of its travel toward the target zone, to arm the projectile and make it operative on progressively smaller changes of light as it travels through the target zone, and, finally, to cause the self-destruction of the projectile soon after it leaves the target zone if it has not previously been detonated by passing in proximity to a target.

The operation of the circuit of Fig. 1 when used to detonate an explosive projectile is briefly as follows.

When the projectile with which the circuit is used is in storage or normal transportation prior to use, switch **20** is in the condition illustrated in Fig. 1 with the contacts **19**, **21** and **22** open. A cam **52** supported on a pivot **53** is held against movement in a clockwise direction by the spring stop **54**. It is prevented from moving in a counter-clockwise direction by projection **55** being stopped against stop pin **56**. The circuit is deenergized since the filament heating circuit is open at contacts **19** of switch **20** an the output circuit of thyratron stage T is open between the load resistor **12** and the positive terminal of battery **15** at contacts **21** of switch **20**. When the flight of the projectile begins, large forces due to acceleration are exerted on the cam **52** causing it to move in a clockwise direction around the pivot **53** until the projection **55** comes against stop **57**. The cam **52** is then held in this new position by the spring stop **54**. In this new position contacts **19** and **21** are closed. At the same time forces of acceleration acting on mass **23** cause contacts **22** to be closed. Due to the closure of contacts **22** the negative voltage of battery **16** is impressed on the grid of thyratron tube **39** through resistance **40** and at the same time condenser **42** is charged to the full voltage of battery **16**. This voltage, if high enough, effectively blocks thyratron T and prevents firing of the thyratron no matter what changes may occur in the illumination of photoelectric cell **10**. Since the thyratron T is blocked, the closure of the filament heating circuit at contacts **19** and the thyratron output circuit through load resistance **12** at contacts **21** is merely to prepare the circuit for subsequent use. When the acceleration drops below a predetermined value, as when the projectile approaches the target zone, contacts **22** are opened since the closing forces of acceleration on mass **23** are reduced. Condenser **42** begins to discharge through resistance **43** and the negative bias on the grid of thyratron **39** is reduced toward zero on an exponential curve represented by the equation

$$E_C = \frac{E_C(\text{max.})}{e^{\frac{t}{RC}}} \tag{1}$$

where Ec is the voltage across condenser **42** in volts, Ec (max.) is the voltage of battery **16** in volts, *e* the base of Naperian logarithms 2.71828, *t* the time starting with the opening of contacts **22** in seconds, R the resistance of resistor **43** in ohms and C the capacity of condenser **42** in farads. The thyratron T can be fired under control of the photoelectric cell **10** only when the negative biasing voltage of condenser **42** is overcome by the output voltage of amplifier stage V3 as it appears across condenser **41**. With the arrangement of photoelectric cell **10** and three-stage amplifier **11** of Fig. 1 an impulsive reduction of light on the cell **10** makes the grid of thyratron **39** more positive. Furthermore, the value of this positive impulse is approximately constant for any given percentage reduction in light regardless of the static intensity of the light existing at the instant the reduction takes place due to the characteristics of the input circuit of amplifier stage V1. Consequently, from the time contacts **22** are opened, progressively smaller percentages of light reduction are required to cause the firing of thyratron T until finally the thyratron fires without any reduction in the light as when the charge on condenser **42** approaches zero.

From the foregoing brief description it is seen that the single network **51** in combination with the other elements of Fig. 1 accomplishes the functions of preventing premature detonation of the projectile during ordinary transportation and handling, prevention of premature detonation during the early stages of travel toward the target zone in use, slow arming, gradual increasing of the sensitivity or reduction of the required percentage of light reduction to fire the thyratron and effecting self-destruction. This circuit is much more simple than any circuit previously known for accomplishing similar functions.

A modified form of circuit arrangement generally similar to that of Fig. 1 is illustrated in Fig. 2. The portion of the circuit to the left of the lines X—X in Fig. 2 is identical with that to the left of the lines X—X in Fig. 1. In the arrangement of Fig. 2 another set of contacts **60** is provided in switch **20**. Contacts **60** are closed by forces of acceleration acting on mass **61** mounted on the relatively movable contact spring of contacts **60**. The closure of contacts **60** impresses negative biasing voltage from battery **16** on the grid of vacuum tube **31** through resistances **32** and **33** in the input circuit of amplifier stage V3 and blocks the amplifier at this stage. Condenser **35** is simultaneously charged to the same voltage. Contacts **60** are opened when the acceleration is reduced to a predetermined value, as when the projectile approaches the target zone. When the contacts **60** are opened condenser **35** begins to discharge through resistance **34** and in a relatively short time removes completely the negative biasing voltage from the grid of vacuum tube **31**, thereby bringing the amplifier **11** to full sensitivity.

The network **62** comprising condenser **35**, shunting resistance **34**, negative biasing battery **16** and the contacts **60** of switch **20** functions to block amplifier stage V3 during the initial stages of the travel of the projectile toward the target zone and to relatively slowly arm the system by gradually restoring the amplifier to full sensitivity. For a given value of negative biasing voltage from battery **16** more effective blocking may be obtained at the grid of amplifier stage V3 than at thyratron stage T. However, if thyratron stage T is to be fired independently of the photoelectric cell **10** the negative biasing voltage on the grid of thyratron T must be reduced. By properly choosing the values of capacitance of condensers **42** and **35** and the resistance of resistances **43** and **34**, the rate of arming, the rate of increasing the sensitivity and the time of self-destruction for any given voltage from battery **16** may be varied to suit the actual conditions of use. The networks **51** and **62** of the arrangement of Fig. 2 cooperate to make this possible.

The characteristics of an arrangement according to Fig. 2 are given by the graph **65** of Fig. 3 wherein the ordinates represent percentage reduction of light on the photoelectric cell **10** required to fire the thyratron T and the abscissas represent the time in seconds elapsed from the instant that contacts **22** and **60** are opened. With the circuit constants utilized to obtain the data for graph **65** there is required about a 37 percent reduction of light to fire the thyratron at the instant of opening contacts **22** and **60**. For all practical purposes the firing of the thyratron T by the photoelectric cell **10** is blocked when contacts **22** and **60** are closed and for a second or two after they are opened.

To facilitate the practice of this invention certain circuit constants will now be given. It is to be understood, however, that these values are merely illustrative. The characteristics of Fig. 3 were obtained with the circuit arrangement of Fig. 2 by using the following circuit constants: a thyratron **39** which fires at approximately 2.5 volts negative on the grid with a plate voltage of 90 volts, photoelectric cell **10** and amplifier **11** which gives a peak impulse across condenser **41** of approximately 6 volts for a one per cent reduction in light on the cell **10**, battery **16** of 9 volts, condenser **35** of 0.25 microfarad, condenser **42** of 0.25 microfarad, resistance **34** of 4 megohms and resistance **43** of 50 megohms.

Use of this invention is not confined to the detonation of explosive projectiles. It may be used in other fields where the time elements involved are widely different, requiring widely different circuit constants than those given hereinbefore for purposes of illustration. The scope of the invention is defined by the accompanying claims.

What is claimed is:

1. An electronic system comprising a space discharge tube having a cathode, an anode and a control electrode, a load device connected between said cathode and anode and adapted to be operated by space current flowing in said tube greater than a predetermined amount, a radiant energy sensitive device adapted when energized by radiant energy to cause space current in said tube to operate said load device when the bias on said control electrode is within certain limits, a circuit for placing a bias independently of said radiant energy sensitive device on said control electrode including a condenser, means to charge said condenser to a potential which biases said control electrode to render said radiant energy sensitive device ineffective to cause operation of said load device and a resistance shunting said condenser, and means to incapacitate said charging means allowing said condenser to slowly discharge through said resistance and reduce the bias on said tube whereby the load device will operate at the end of a given time interval if the radiant energy sensitive device is not energized during said interval and will operate sooner if and when the radiant energy sensitive device is energized within said interval.

2. An electronic system comprising a gaseous discharge tube having a cathode, an anode and a control electrode, a load device connected between said cathode and anode and adapted to be operated by space current flowing in said tube, a radiant energy sensitive device adapted to control the flow of space current in said tube when the bias on said control electrode is within definite limits, and means comprising a condenser shunted by a resistance for placing a bias on the control electrode of said tube which bias at first prevents flow of space current in said tube regardless of the action of said radiant energy sensitive device, then is within said definite limits and finally causes flow of space current independently of said radiant energy sensitive device, said condenser being so connected in a circuit between said cathode and control electrode that its voltage is independent of the space current in said tube.

3. An electronic system comprising a gaseous discharge tube having a cathode, an anode and a control electrode, a load device connected between said cathode and anode and adapted to be operated by space current flowing in said tube, a radiant energy sensitive device adapted to control the flow of space current in said tube when the bias on said control electrode is within definite limits, means comprising a condenser shunted by a resistance for placing the said bias within said limits for a definite period of time, and means including relatively movable contacting members for charging said condenser temporarily to a potential to bias said control electrode to prevent flow of space current in said tube regardless of the action of said radiant energy sensitive device.

4. An electrical control unit for use with an element designed to be given accelerated motion in a medium capable of transmitting wave energy comprising a device sensitive to radiations transmitted through said medium, a voltage controlled space current discharge device having said radiation sensitive device in its input circuit and having space current flowing therein in the absence of blocking potential in said input circuit, and means operable to apply blocking potential to said input circuit by forces resulting from the movement of said unit in a predetermined direction at a predetermined acceleration including means to remove said blocking potential slowly whereby the flow of space current is first brought under control of said radiation sensitive device and then made independent of said device.

5. An electronic system comprising a vacuum tube having a cathode, an anode and a control electrode, a load device connected between said anode and cathode which is operated only when the voltage between said cathode and control electrode is small, a condenser shunted by a resistance connected in circuit between said cathode and control electrode, a source of direct current, connections between said condenser and said source to charge said condenser and negatively bias said control electrode with respect to said cathode, including means to open said charging circuit to permit said condenser to discharge slowly through said resistance causing said load device to operate after a fixed period when the charge on said condenser is reduced by a given amount, and a radiant energy sensitive device connected to said cathode and control electrode to quickly change the voltage on said control electrode in the same direction that the discharge of said condenser changes said voltage when energized by radiations, whereby said device will operate at the end of a given time interval if said radiant energy device is not energized and will operate sooner if and when said radiant energy device is energized.

6. An electrical control system comprising a radiant energy sensitive device, a vacuum tube amplifier having an input circuit connected to said device and an output circuit, a thyratron having an input circuit connected to the output circuit of said amplifier and an output circuit, a biasing network comprising a condenser shunted by a resistance connected across the input circuit of said thyratron, and means independent of the output circuit of said thyratron to charge said condenser to negatively bias said thyratron to effectively prevent firing thereof by said radiant energy sensitive device and to discharge said condenser through said resistance.

7. An electrical control system comprising a radiant energy sensitive device, a vacuum tube amplifier having an input circuit connected to said device and an output circuit, a thyratron having an input circuit connected to the output circuit of said amplifier and an output circuit, a biasing network comprising a condenser shunted by a resistance connected across the input circuit of said thyratron, a second biasing network comprising another condenser shunted by another resistance connected across the input circuit of one stage of said amplifier, and means to charge said condensers to negatively bias said amplifier stage and said thyratron to effectively prevent firing of said thyratron by said radiant energy sensitive device and to discharge said condensers through said resistances respectively.

8. An electrical control system comprising a radiant energy sensitive device, a vacuum tube amplifier having an input circuit connected to said device and an output circuit, a thyratron having an input circuit connected to the output circuit of said amplifier and an output circuit, a condenser connected across the input circuit of said thyratron, a biasing battery, a switch adapted when closed to connect said battery to said condenser to negatively bias said thyratron to render said radiant energy sensitive device ineffective to cause firing of said thyratron, and a resistance connected in shunt of said condenser adapted to discharge said condenser after the opening of said switch at a rate which is first rapid and then slow until the thyratron fires provided the thyratron has not previously been fired by a radiant energy impulse received by said radiant energy device.

9. An electro-optical system comprising a vacuum tube amplifier stage including a vacuum tube having a cathode, an anode, and a control electrode, a thyratron having a cathode, an anode, and a control electrode, a condenser-resistance coupling between the anode-cathode circuit of said vacuum tube and the control electrode-cathode circuit of said thyratron, a photoelectric cell coupled to the control electrode-cathode circuit of said vacuum tube for impressing electrical impulses on said circuit corresponding to light impulses on said cell, a first biasing network comprising a condenser shunted by a resistance connected between the control electrode and

cathode of said thyratron, a second biasing network also comprising a condenser shunted by a resistance connected between the control electrode and cathode of said vacuum tube, the ratio of the time constant of said first network to the time constant of said second network being of the order of ten, and means for charging the condensers of both said networks to negatively bias said control electrodes, respectively, to practically prevent firing of said thyratron by light impulses until such time as it is desired to make the circuit responsive to light impulses and then allowing said condensers to discharge through said resistances respectively.

10. An electro-optical system comprising a vacuum tube amplifier stage including a vacuum tube having a cathode, an anode and a control electrode, a thyratron having a cathode, an anode, and a control electrode, a condenser-resistance coupling between the anode-cathode circuit of said vacuum tube and the control electrode-cathode circuit of said thyratron, a photoelectric cell coupled to the control electrode-cathode circuit of said vacuum tube for impressing electrical impulses on said circuit corresponding to light impulses on said cell, a cathode energizing battery, an anode battery, a grid biasing battery, said cathode and anode batteries having their negative terminals and said grid battery having its positive terminal connected to the cathodes of said vacuum tube and thyratron, switch contacts operated by forces of acceleration for connecting the positive terminal of said cathode energizing battery to said cathodes, other switch contacts also operated by the same forces of acceleration for connecting the positive terminal of said anode battery through a load device to the anode of said thyratron, a network comprising a condenser and shunting resistance connected in circuit between the grid and cathode of said thyratron and a third set of switch contacts connecting the negative terminal of said grid biasing battery to the grid terminal of said network only so long as the acceleration exceeds a predetermined value.

11. An electro-optical system comprising a vacuum tube amplifier stage including a vacuum tube having a cathode, an anode and a control electrode, a thyratron having a cathode, an anode, and a control electrode, a condenser-resistance coupling between the anode-cathode circuit of said vacuum tube and the control electrode-

cathode circuit of said thyratron, a photoelectric cell coupled to the control electrode-cathode circuit of said vacuum tube for impressing electrical impulses on said circuit corresponding to light impulses on said cell, a cathode energizing battery, an anode battery, a grid biasing battery, said cathode and anode batteries having their negative terminals and said grid battery having its positive terminal connected to the cathodes of said vacuum tube and thyratron, switch contacts operated by forces of acceleration for connecting the positive terminal of the cathode energizing battery to said cathodes, other switch contacts also operated by the same forces of acceleration for connecting the positive terminal of said anode battery through a load device to the anode of said thyratron, a network comprising a condenser and shunting resistance connected in circuit between the grid and cathode of said thyratron and a third set of switch contacts connecting the negative terminal of said grid biasing battery to the grid terminal of said network only so long as the acceleration exceeds a predetermined value, a second network comprising another condenser and shunting resistance connected in circuit between the grid and cathode of said vacuum tube and a fourth set of switch contacts connecting the negative terminal of said grid biasing battery to the grid terminal of said second network only so long as the acceleration exceeds said predetermined value.

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