

Dec. 10, 1957

E. V. MARSHALL

2,815,819

FIRE AND EXPLOSION PROTECTION SYSTEM

Filed June 27, 1956

3 Sheets-Sheet 1

FIG. 2

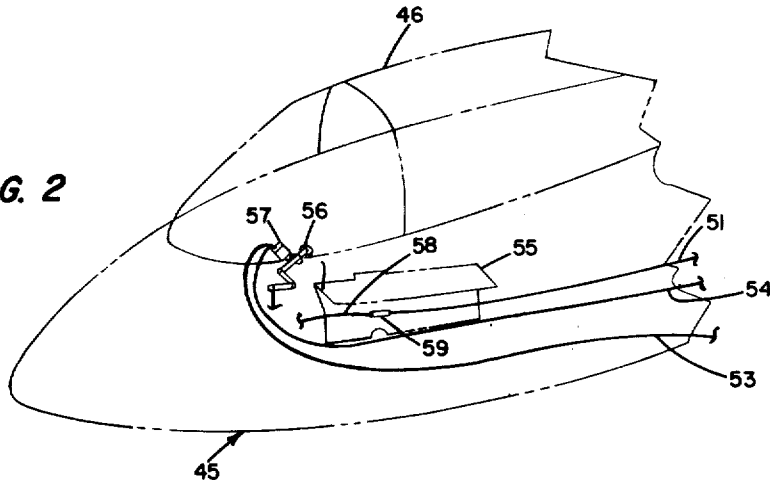
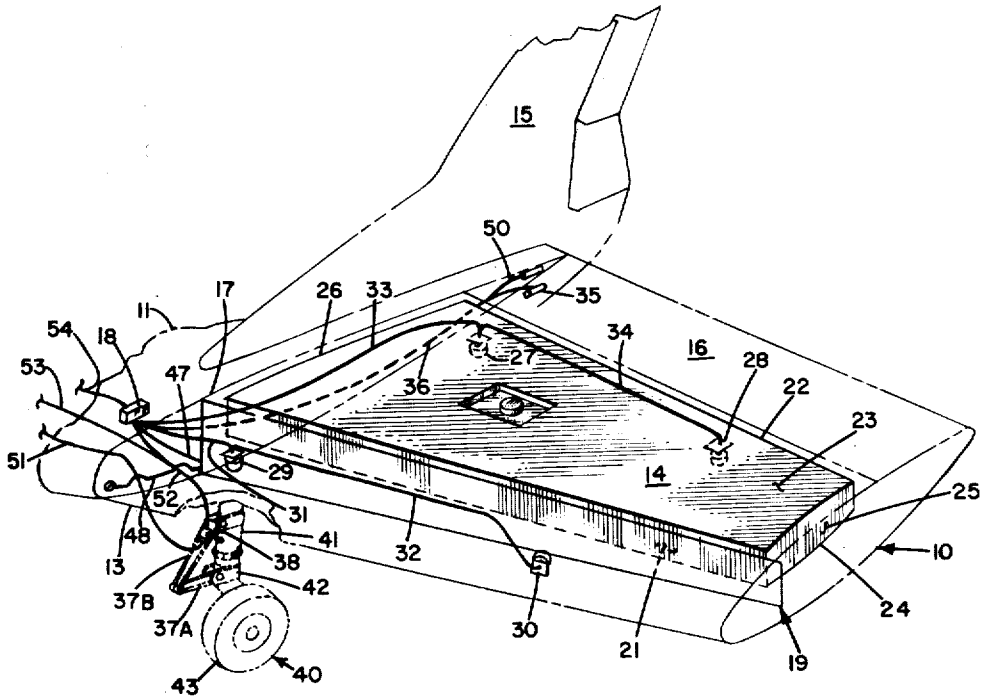


FIG. 1

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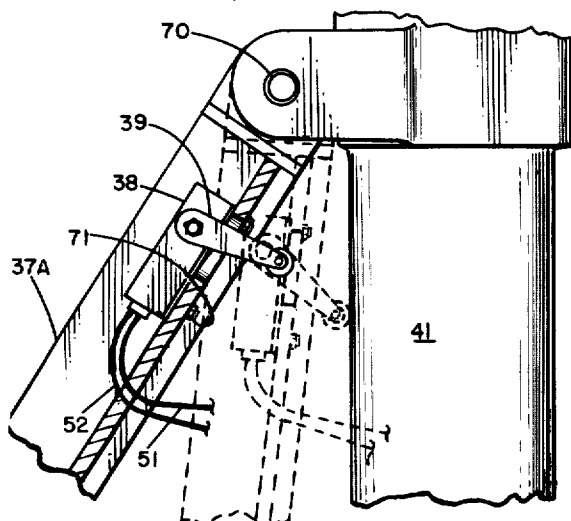


FIG. 7

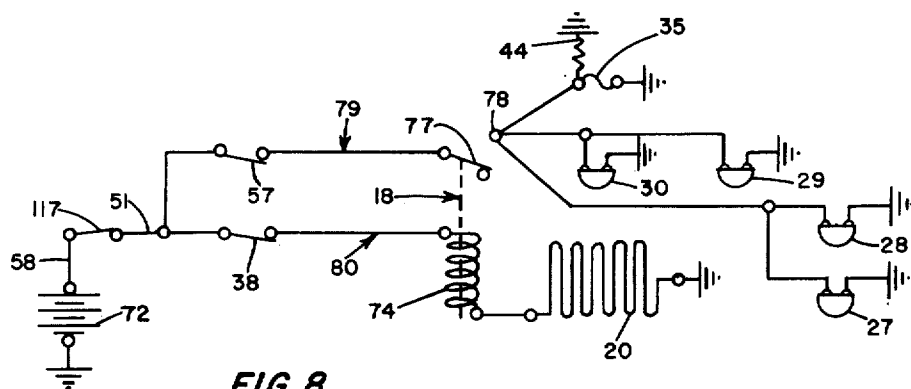


FIG. 8

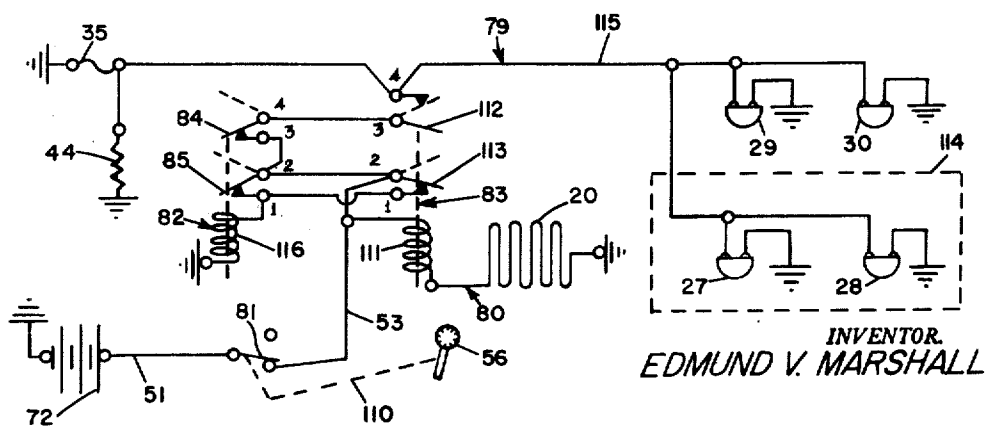


FIG. 9

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FIRE AND EXPLOSION PROTECTION SYSTEM

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17 Claims. (Cl. 169-2)

This invention relates to a fire and explosion protection system for fuel enclosures, and more particularly to a fire and explosion protection system which senses the passage of an object effecting penetration of a fuel enclosure and in response thereto disseminates a combustion-suppressing material that effectively halts or entirely precludes fire and explosion.

It has previously been proposed that fire and explosion protection systems be provided in or around enclosures containing combustible solids and fluids and mixtures thereof with air to the end that fires which might commence therein may be extinguished and explosions suppressed. To render them partially or entirely automatic in operation, many of these systems have been provided with devices intended for the detection of high temperatures of pressures, excessive rates of increase of temperature or pressure, or other physical manifestations of fires or explosions already in progress. In response to these stimuli, the fire and explosion protection systems of the above types initiate various operations directed toward the extinguishing of the fires or the suppression of the explosions in their early stages before serious damages are wrought thereby.

Considerable progress has been made in providing apparatuses which, after an explosion has already begun, sense the initial pressure rise produced by the explosion process in the affected enclosure and in response thereto emit a combustion inhibiting substance that, in the scant time remaining before a dangerous pressure level would otherwise be reached, suppresses and aborts the explosion. Where no stimulus other than the pressure rise of an incipient explosion is available for triggering the release of a combustion inhibiting substance, a pressure-rise sensitive apparatus is possibly as good as can be found, and may be of great value even though at best it cannot sense the existence of incipient explosion until a certain time interval, for instance, one or more microseconds, has passed following ignition. Regrettably, such apparatuses cannot anticipate explosions, and are not effective in dealing with or preventing, except incidentally, combustion not forming a part of or following an explosion.

Similarly, protection systems adapted for responding to an increase of temperature caused by a fire or explosion are not able to anticipate and prevent combustion, and, where a highly combustible substance such as gasoline is involved, are apt to be too slow-acting to be of great benefit.

None of the above systems are able to sense the beginning of a situation in which the danger of destructive combustion is inherent. In view of this limitation, it is desirable to provide a system able to detect the beginning of a situation in which fire or explosion are prime possibilities and to initiate prompt and effective countermeasures which will obviate fire and explosion damage. In a properly made and utilized fuel enclosure operating under normal conditions, the probability of imminent fire or explosion is virtually zero, and must remain so

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until a change occurs, that is until at least one new element or factor is added to the situation which introduces a more or less great probability that combustion will soon occur. In many military aircraft, armored cars, tanks, etc., and in other vehicles and facilities as well, fire and explosion often become actualities, or the probability of their occurrence frequently becomes great, following the rupture of a fuel enclosure by a foreign object. When an aircraft crashes, for instance, some part of the aircraft or some other object may be driven through a wall of a fuel cell or tank of the aircraft, with consequent spillage of fuel outside the tank where it may easily be ignited by a spark, etc. In combat, bullets or other missiles and projectiles may pierce the fuel tank with similar results, and if an incendiary projectile happens to hit the tank, fuel mixed with tank air may be ignited by the bullet and may proceed to explode.

In all these cases, the situation of which the tank and its fuel are a part becomes heavily explosion-prone when the tank is ruptured, and the possibility of a damaging fire or explosion can be reduced again toward zero by the quick introduction in and/or about the tank of a combustion-inhibiting substance before ignition occurs, or at least before combustion can reach serious proportions. The cue or stimulus for initiation of such action is available before or simultaneously with rupture of the tank wall, and is readily found in the kinetic energy of the rupturing object. By providing means for sensing the arrival at the tank of such an object and for making quick response thereto, the dissemination of combustion-inhibiting material may be initiated almost simultaneously with entry of the rupturing object without waiting for the start of an actual explosion inside the tank and long before combustion can start in fuel which may leak out of the tank.

Briefly described, the fire and explosion protection system of the present invention comprises sensing means responsive to the passage of a piercing object at the time of or immediately before its entry into a fuel enclosure; means for the dissemination of a combustion-inhibiting material; and programming means. The invention may also comprise indicating means and a manually or automatically operated safety switch. The sensing means includes firing circuit control means, which for example may be an electrically operated switch or relay or the like, and further includes a conductor for completing an electrical sensing circuit through the firing circuit control means and so arranged relative to the fuel enclosure that, in order to rupture the fuel enclosure, a piercing object must break the conductor and therefore the sensing circuit. In response to sensing circuit discontinuity, the firing circuit control means closes a firing circuit connecting the disseminating means to a source of electrical power through the programming means. The programming means comprises one or more switches or relays or the like for the prevention of inadvertent or untimely connection of the electrical power source to the disseminating means through the firing circuit, and is preferably automatic in operation. In one form of the invention, the programming means comprises a first switch, relay, or the like installed in the firing circuit and a second switch or relay installed in the sensing circuit, these switches or relays being arranged to operate in a sequence wherein the sensing circuit is energized to cause the firing circuit control means to open the firing circuit before firing voltage is applied to the firing circuit control means from the power source. In other forms of the invention, a programming means switch or relay may be installed in the firing circuit only and arranged to close after energization of the sensing circuit has been effected. The safety switch, where employed, manually or automatically

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disconnects the sensing and firing circuits from the electrical power source at times when energization of those circuits could compromise safety or convenience of operation of the fire and explosion protection system. The disseminating means includes one or more units advantageously employable outside as well as inside the fuel enclosure and each comprising a burstable container enclosing a quantity of a readily dispersable combustion-inhibiting material and provided with an electrically fired detonator connected to the firing circuit for connection therethrough, as dictated by the firing circuit control means and programming means, with the source of electrical power. The indicating means includes an electrically operated device sensitive to the application of electrical power to the disseminating means and providing visual or the like indication as to whether or not firing voltage has been supplied to the disseminating means for exploding the detonators, bursting the containers, and scattering the combustion-inhibiting material in and/or around the fuel enclosure. As an added safety feature, the invention may include means, such as one or more grounded resistors, for bleeding static electrical charges from the disseminating means which could conceivably make possible untimely firing of the detonator or detonators of the latter.

It is, accordingly, a major object of the invention to provide for a fuel enclosure a system which senses the presence of any object passing or about to pass through a wall of the enclosure and makes a prompt response thereto which efficiently precludes fire or explosion-damage that otherwise could follow rupture of the enclosure.

Another object is to provide a system, such as characterized above, which is fully automatic in operation in response to rupture of the fuel enclosure.

A further object is to provide a fire and explosion protection system for a fuel enclosure which utilizes an explosive force for the release of a fire-suppressant material.

A still further object is to provide a system of the sort thus far characterized which automatically begins combustion-inhibiting action before combustion has started and which comprises effective and adequate safeguards against inadvertent or spontaneous initiation of such action.

Yet another object of the invention is to provide a system meeting the above objects which provides remote indication of the accomplishment of combustion-inhibiting action by the system.

An additional object is to provide a fire protection system of the nature thus far characterized which is light in weight and comparatively simple in construction.

Other objects and advantages will be apparent from the specification and claims and from the accompanying drawings which illustrate an embodiment of the invention.

In the drawings:

Figure 1 is a fragmentary perspective view of the entire left-hand outer panel and the left-hand outboard end of the center section of the wing of a tailless aircraft embodying one form of the invention;

Figure 2 is a fragmentary, semi-diagrammatic view of the nose and the cockpit area of the aircraft showing cockpit-located items of the invention;

Figure 3 is a front elevation of part of the fuel tank sheathing showing details of construction of the same, one of the layers of the sheathing being partially removed to show the grid;

Figure 4 is an enlarged, fragmentary, cross-sectional view taken along the line IV—IV of Figure 3;

Figure 5 is an enlarged view of an indicator of the fire and explosion protection system;

Figure 6 is a schematic representation of the components of the invention shown in Figures 1 through 5 which shows the electrical connections of those components;

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Figure 7 is an enlarged view of the safety switch and adjacent parts of the related landing gear unit;

Figure 8 is a schematic representation of an alternate mode of connection of the components of the invention;

Figure 9 is a schematic representation, similar to Figures 7 and 8, of still another mode of connection of elements of the invention.

Referring now to Figure 1 of the drawings, a so-called tailless aircraft has a wing 10 whose fuselage-attached center section 11 bears at its left-hand outer end an outer panel 13 containing a fuel tank 14. A rudder-bearing vertical stabilizer or fin 15 is mounted on and faired into the wing center section 11 near the outboard end thereof, and the trailing edge of the outer panel mounts an aileron 16. The fin 15 extends somewhat below the wing center section 11 and with the latter houses a left-hand main landing gear unit 40 which from the extended position in which it is shown can be retracted by an appropriate mechanism (not shown) into the fin and center section.

The fuel tank 14 may be of any desired and appropriate construction: for instance, it may be of the self-sealing type, if desired, or it may even be integral with the outer panel 13 and formed by skins and/or internal members thereof. In the aircraft of which the wing 10 forms a part, the fuel tank or enclosure 14 may of course be housed in any desired location, and is shown as located in the wing outer panel 13 merely as a generally typical example. The tank 14 shown has forward and aft faces 21, 22, an upper face 23 and corresponding lower face 24, and inboard and outboard faces 25, 26 which, if the tank is of a non-integral sort, should ordinarily be protected from scuffing and abrasion by smooth sheathing separating the faces of the tank from the skin, structural members, etc. of the outer panel 13.

The sensing means includes one or more sensing conductors, to be described, conveniently supported and insulated from the airframe by sheathing such as 19 provided around the fuel tank 14, and further includes a firing circuit control relay 18 mounted in any convenient airframe location, as in the wing center section 11.

In the example, the sheathing 19 for the tank forward face 21 is of a special sort incorporating a sensing conductor or grid arranged therein in a manner explained in a later paragraph, and it will be understood that, although the sheathing for the other faces of the tank 14 are for clarity and simplicity of representation omitted from the drawing, all the tank sheathing should contain a detector grid throughout areas where means for detecting rupture of the tank are deemed necessary in order to implement adequate fire and explosion protection. Thus, where a projectile or other rupturing object is sufficiently likely to pierce any and all faces of the tank 14, all the tank faces should be provided with a grid-containing sheathing member such as the forward-face sheathing 19. On the other hand, ordinary sheathing may be used over tank areas where the intended mode of flight operation of the aircraft, the construction of the outer panel 13, etc. make the likelihood of tank rupture so small as to render the rupture-sensing provisions of the invention not necessary.

The disseminating means includes one or more combustion-suppressive capsules located as explained below. One such capsule 27 is mounted by any convenient means (not shown) inside the tank 14 for rapidly disseminating a combustion-inhibiting material in the tank in the event of tank rupture by a projectile, etc. The capsule 27 should comprise a burstable or shatterable container enclosing a combustion-inhibiting substance and provided with a detonator of the electrically-fired type. Reference is made to U. S. Patent No. 2,693,240 issued November 2, 1954 to W. G. Glendinning et al. on "Method and Apparatus for Preventing Explosions and Extinguishing Fires" for a full description of such a capsule, the construction of which will not be further explained other than to state that the combustion-inhibiting material should

preferably be a substance, such as chlorobromomethane, which will not have a greatly adverse effect on aircraft engine performance when and if the capsule is exploded and the fire-suppressant material released into the fuel tank 14. The fire-suppressant material is generally much more effective when released into the air and/or fuel vapors above the liquid or solid fuel in the tank; consequently, the capsule 27 is preferably mounted in the top of the tank 14. Where the tank is so large that the one capsule is inadequate for its needs, another capsule 28 of the same sort may be added, and still other capsules may be added as needed.

If the tank 14 is ruptured, fuel may pour therefrom into the interior of the outer panel 13 and may in some way become ignited, thus producing combustion initiated outside the tank. To protect the aircraft from such fires, other disseminating means capsules of the same sort as the tank capsule 27 may be provided externally of the tank 14 in any area or areas into which the spilled fuel or a dangerous concentration of the fumes thereof might pass. In the example, the tank-enclosing structure, namely, the outer panel 13, is separated from the rest of the airframe by a bulkhead 17 which prevents the passage of liquid fuel or fumes thereof from the outer panel into the wing center section 11. Two capsules 29, 30 are mounted by any appropriate means in the outer panel leading edge forward of the tank 14, and still other capsules may be mounted in the outer panel rearwardly, above, below, or at the ends of the tank as deemed advisable. The capsules 27—30 are connected to the relay 18 by electrical cables or leads 31, 32, 33, 34.

The indicating means will now be considered. It is conceivable that the detonators of the disseminating means might accidentally be fired because of a wrong connection or other error made during testing or repair operations made on the electrical circuits of the fire protection system or on other circuits of the aircraft, and it is obviously desirable to make sure that the detonators of the capsules are unfired at the time of preflight and other inspections made on the aircraft. Located inside and outside the fuel tank in the wing outer panel, the capsules are of course not immediately accessible for inspection; consequently, it is desirable that remote indicating means be provided to show whether or not firing voltage has been delivered to their detonators. Where the operator of the aircraft should be notified immediately of rupture of the fuel tank, the indicator is preferably placed in the cockpit, and may comprise a horn, a dial-type instrument, an indicator light, or the like indicating unit. Where the operator need not immediately be advised of fuel tank rupture, the indicator may be placed in any area conveniently accessible to inspecting personnel. A readily available and efficient indicating means comprises a fuse 35 mounted, for example, in the compartment provided for the landing gear 40 in the center section 11 and vertical fin 15. The indicator fuse 35 is connected by a lead 36 to the relay 18.

A safety switch 38 is mounted on the left-hand main landing gear unit 40 in such manner that the switch is closed by a lengthening motion of the landing gear unit which normally occurs when the aircraft leaves the ground. Conversely, compression of the unit 40, which occurs when the aircraft lands and is generally maintained so long as the aircraft is on the ground, serves to open the switch 38. The landing gear unit 40 of the example follows a well-known construction wherein a shock strut has an upper, airframe-mounted cylinder 41 which mounts a lower member 42 that is reciprocal within the cylinder and that bears a supporting wheel 43 on its lower end, the cylinder and lower member being connected by a pair of scissors members or torque arms 37A, 37B. The safety switch 38 is mounted on, for instance, the upper torque arm 37A, and its button, toggle, shaft, or other actuated element is adapted to be moved for opening and closing the switch in response to relative

motion between the cylinder 41 and lower member 42, as will be more fully described.

One lead 47 connects the sensing grid in the tank forward face sheathing 19 to the relay 18, and another lead 48, attached to the airframe by a screw or other suitable fastening means, connects the grid to ground. Another lead 50 connects the indicator fuse lead 36 to a suitable means, such as a grounded resistor 44, for bleeding static electrical charges from the leads extending to the capsules 27—30 and to the indicator fuse 35. A lead 51, shown as broken away in the drawing, extends from a fuselage location specified below through the wing 10 and down the left-hand main landing gear unit 40 to the safety switch 38, which in turn is connected by a lead 52 to the relay 18 and by a lead 53 to a fuselage-located item to be identified. A lead 54 extends from the fuselage to the relay 18.

The nose section of the airframe of which the outer panel 13 and center section 11 are a part is represented in Figure 2, to which figure reference is now made. The nose section 45 is provided with a cockpit 46 in which are housed a pilot's console 55 above which is mounted, as by usual and well-known means, a lever by suitable positioning of whose handle 56 a pilot of the aircraft is enabled to cause actuating mechanisms to extend or retract the landing gear as desired.

Mounted near the handle 56 is a programming switch 57 which is directly contacted by the handle 56 in one of its operating positions, or is linked thereto in such manner that when the handle is in its position for retraction of the landing gear, the switch is closed, and when the handle is placed in its position for extending the landing gear, the switch is opened.

Electrical power for the fire and explosion protection system is supplied by a battery or other suitable power source connected by a lead 58 to a fuse or other protective means 59 which may be used as desired in the system and which may be mounted in the console 55. A lead 51 extends rearwardly through the fuselage from the fuse 59 and, as shown in Figure 1, terminates at the safety switch 38 on the landing gear unit. The leads 53 and 54 respectively extending into the fuselage from the safety switch 38 and relay 18 terminate, as may be seen in Figure 2, at the programming switch 57.

With reference now to Figure 3, the forward face sheathing 19 is a thin sheet-like structure made of materials of adequate strength and otherwise characterized by physical properties rendering it suitable as a fuel tank sheathing. The sheathing 19 is made of two layers 60A, 60B bonded together and containing between them a conductor 20, such as a wire or tape, arranged therein in a to-and-fro manner to form a grid-like pattern. Adjoining runs of the conductor 20 within the sheathing 19 should be so close to each other that no projectile at all likely to be able to pierce the fuel tank can pass through the sheathing 19 without breaking the conductor 20. The two ends of the conductor 20, shown broken away at 61 and 62, are connected as described to the relay (Figure 1) and to ground. With continued reference to Figure 3, it is desired that breaking of the conductor 20 at any point between its two ends will result in an open circuit; consequently, the conductor should not cross itself within the sheathing 19 unless well insulated from itself at the crossing-points. A convenient mode of construction utilizes a bare conductor 20, non-conductive sheathing layers 60A, 60B and a non-conductive bonding agent for bonding the layers 60A, 60B together with the conductor, which is not at any point allowed to cross itself, between them.

With reference to Figure 4, one smooth face 63 may be easily provided on the sheathing 19 even though a wire 20 of comparatively large diameter is employed for the conductor. This is accomplished when the layers 60A, 60B are bonded together by pressing one layer 60B down around and between successive runs such as

65A, 65B of the wire 20 and into good contact with the other layer 60A which, as by keeping it on a flat surface during the pressing operation, is kept flat and smooth. the pressed layer 60B of course assuming a corrugated contour. When installed, the smooth layer 60A is preferably placed next to the fuel tank to minimize rubbing and chafing between the tank and sheathing. The sheathing 19 may be mounted adjacent the fuel tank by any convenient, efficient means, care being taken during the mounting process that the conductor 20 within the sheathing 19 is not broken by the drilling of mounting holes or contacted by any conductive mounting fasteners used.

Referring to Figure 5, the indicator fuse 35 is mounted in the fin 15 by means of a fuse block 66 provided with mounting clips 67A, 67B. One end of the fuse 35 is connected to the relay 18 (Figure 1) by the lead 36, and a ground lead 68 connects the other end of the fuse to the fin 15. As long as the fusible element of the fuse 35 is entire, firing voltage has obviously not been supplied to the detonators; if the fuse 35 is blown, inspecting personnel are advised thereby that the detonators have been fired. Although an ordinary fuse is adequate for the purpose, a visual-indicating type fuse (such as manufactured, for instance, by the Bussman Manufacturing Company of St. Louis, Missouri) is preferred. This type of fuse has an indicator pin which is retracted as shown at 69A when the fuse element is entire, and which extends as shown at 69B when the fuse 35 is blown.

Referring to Figure 7, the torque linkage upper arm 37A is pivoted by a pin 70 on the shock strut upper portion or cylinder 41. The safety switch 38, which in the particular example shown should be of the normally closed type, is mounted as by fastening means 71 on the upper arm 37A and has an actuator arm 39 extending from the switch toward the shock strut cylinder 41. When the weight of the aircraft is not on its landing gear, the landing gear unit comprising the cylinder 41 and torque arm 37A is fully extended, the torque arm 37A lies in its position shown in solid lines, the actuator arm 39 does not contact the cylinder 41, and the switch 38 is closed. When the aircraft is supported by its landing gear, compression of the landing gear unit on which the switch 38 is mounted moves the torque linkage arm 37A and switch 38 to their positions shown in dotted lines. Before this motion is completed, the actuator arm is thereby brought into contact with the cylinder 41, and the balance of the torque arm motion effects a change in position of the actuator arm 39 relative to the switch 38 which opens the switch. The leads 51 and 52 respectively connect the safety switch to the circuit protection device 59 in the cockpit (Figure 2) and relay 18 (Figure 1).

Reference is now made to Figure 6, wherein a typical circuit for the fire and explosion protection system is illustrated. The system is supplied with electrical power by a battery or the like power source 72 grounded at 73 and connected through the lead 51 to one side of the safety switch 38. The other side of the safety switch 38 is connected through the lead 53 to a terminal of the programming switch 57 and through the lead 52, the winding 74 of the firing circuit control relay 18, and the sensing conductor or grid 20 with ground, the lead 52, winding 74, and grid 20 constituting the sensing or control circuit 80. It will frequently be found desirable to employ detector grids in the sheathings for some or all the other faces (Figure 1) of the fuel tank 14 in addition to the grid described as located in the forward-face sheathing. If employed, all such grids should be connected in series; and the grid 20 shown in Figure 6 symbolizes all such grids, connected in series, as may be employed. The grid or grids 20 should of course have a total electrical resistance which ensures a current flow through the sensing circuit 80 whose value is such as to secure proper operation of the relay 18. The program-

ming switch 57 is connected by the lead 54 to one side of the relay movable contact 77, a fixed contact 78 of the relay having connection through the leads 31—34 with the detonators of the disseminating means capsules 27—30 and through the lead 36 with the indicator fuse 35. The resistor 44 provided for bleeding static electrical charges is connected at one of its ends to ground and is at its other end connected at any convenient point to the firing circuit by a lead 50 which, in the example, connects the resistor 44 to the ungrounded end of the indicator fuse 35. The lead 53, programming switch 57, lead 54, relay contacts 77, 78, leads 31—34, and the capsules 27—30 and their ground connections may be said to constitute the firing circuit 79.

While the aircraft is on the ground, compression of the landing gear holds the safety switch 38 in its open position, thus shutting off electrical power to the balance of the firing and sensing circuits 79, 80. The landing gear control handle 56 (Figure 2) is assumed to be constrained at this time to its "down" position in which the programming switch 57 is held open. The relay 18 (Figure 6) is held by force provided by a spring, etc. in its closed position; but, since the safety and programming switches 38, 57 are open, no electrical energy flows from the battery 72 to the detonators of the capsules 27—30.

When the aircraft leaves the ground, its weight is taken off the landing gear and the safety switch 38 closes automatically, thus completing the control circuit 80 through the relay winding 74 and the grid 20. Thus energized, the winding 74 causes the relay contacts 77, 78 to open. With the aircraft off the ground, the landing gear control handle 56 is placed in its "up" or equivalent position for retraction of the landing gear and for causing closing, as previously described, of the programming switch 57, thus connecting the relay movable contact 77 with the battery 72. The winding 74 already having been energized by closing of the safety switch 38, the relay contacts 77, 78 are open when the programming switch 57 closes; consequently, no electrical power is delivered through the firing circuit 79 to the detonators of the capsules 27—30, nor to the indicator fuse 35, whose fusible element remains intact and whose indicator pin of the fuse remains in its retracted position 69A (Figure 5).

Under certain conditions, there may conceivably be present the possibility that static charges may build up on the detonator leads 31—34 to the extent that one or more of the detonators of the capsules 27—30 may be fired thereby. To prevent such an occurrence, the resistor 44 is connected as already described between the firing circuit 79 and ground for bleeding off any static charges which may occur. The resistor 44 should be of high enough value to prevent its acting as a short or ground of the firing circuit 79 when the firing circuit is connected to the battery 72, as will now be described.

If an object ruptures the fuel tank 14 (Figure 1), it must first pass through the continuous, grid-like conductor 20 (Figure 3), thus breaking the sensing circuit 80 (Figure 6) and immediately deenergizing the relay winding 74, thus placing the fire and explosion protection system in action before any combustion has started. As a consequence, the relay contacts 77, 78 close and complete the firing circuit 79, which delivers electrical power to and fires the detonators of the capsules 27—30, at the same time blowing the indicator fuse 35. Burst by the exploding detonators, the combustion-inhibiting contents of the capsules 27—30 are rapidly dispersed throughout the fuel tank and within the outer panel in which the tank is mounted, and fire or explosion damages which otherwise could be sustained are obviated. When the fuse 35 is blown, its indicator pin moves to the position 69B (Figure 5), thus showing that firing voltage has been delivered to the detonators.

If no rupture of the tank and breaking of the conduc-

for 20 (Figure 6) by a projectile, etc. occurs during the flight of the aircraft, the landing gear handle 56 (Figure 2) is of course placed in its "down" or equivalent position for extending the landing gear before the aircraft is returned to the ground. In so doing, the programming switch 57 (Figure 6) is opened. Landing impact and/or the weight of the aircraft compresses the landing gear unit on which the safety switch 38 is installed, and the safety switch 38 is thereby opened, deenergizing the fire and explosion protection system and allowing the relay contacts 77, 78 to close, the latter already being deenergized by the programming switch 57.

While the aircraft remains supported by its landing gear, the programming switch 57 is open, the relay contacts 77, 78 are closed, and the safety switch 38 remains open for complete deenergization of the firing and control circuits 79, 80, thus obviating inadvertent firing of the capsules of the detonators which otherwise could occur in connection with disconnection and reconnection of the protection system from its electrical power source or from various repair and maintenance operations which might be performed on the firing and control circuits 79, 80 and on adjacent or otherwise related components of the aircraft.

Referring now to Figure 8, a modification of the invention is shown wherein a master switch 117 controls parallel connection of a firing circuit 79 and sensing circuit 80 to the power source 72 through the lead 58. With the master switch 117 closed, the firing circuit 79 draws electrical power directly from the power source 72 rather than through the safety switch 38. With this exception, the components and connections of the fire and explosion protection system are the same as described above in connection with Figure 6, and their operation is the same except that the battery side of the programming switch 57 is continuously energized, and opening and closing of the safety switch 38 does not control energization of the programming switch 57.

Figure 9 shows in schematic fashion a further modification of the invention wherein a safety switch 81 is actuated by the landing gear control handle 56 and a programming relay 82 having normally closed movable contact elements 84, 85 is employed in the firing circuit.

The safety switch 81 is mounted in any convenient manner in the aircraft and is mechanically connected to the landing gear control handle 56 by a linkage 110 in such fashion that when the handle is placed in its "up" or equivalent position for effecting retraction of the landing gear, the safety switch is closed as shown in the drawing. Similarly, placing the handle 56 in its "down" position for extending the landing gear brings about opening of the safety switch 81, one side of which is connected by a lead 51 to a suitable source of electrical power 72, the other side of the switch 81 having connection through a lead 79 with one end of the winding 111 and with a terminal 2 of a firing circuit control relay 83. The other end of the winding 111 has electrical continuity with ground through a sensing conductor or grid 20 whose construction is similar or identical with the grid already described and which is similarly disposed relative to a fuel enclosure. The lead 79, winding 111, and grid 20 may be designated a control or sensing circuit 80 which, while intact and while energized by the battery 72 through the safety switch 81, causes the movable contacts 112, 113 of control relay 83 to be positioned as shown in solid lines. The relay 83 is biased to return the contacts 112, 113, when the winding 111 is not energized, to their positions shown in dotted lines wherein one contact 112 is closed and one contact 113 is open.

A fuel enclosure 114 of the aircraft contains one or more interiorly mounted combustion suppressive capsules such as 27, 28, and one or more additional capsules such as 29, 30 may be mounted in a compartment enclosing the tank as described previously in connection with Figure 1. All the capsules 27—30 are of the detonator-

activated sort described in an earlier paragraph, and all are connected in parallel by means of appropriate leads to a lead 115 connected in turn to a terminal 4 of the control relay 83.

The indicating means for showing whether or not firing voltage has been delivered to the detonators of the capsules 27—30 may comprise a fuse 35 such as described above in connection with Figure 6. One end of the fuse 35 is connected to ground, and the other is connected to the terminal 4 of the control relay 83.

As also previously described relative to Figure 6, a resistor 44 of relatively high value is connected between the detonators of the capsules 27—30 and ground. The resistor 44 is conveniently connected to the ungrounded end of the fuse 35.

The programming relay 82, which prevents energization of the terminal 4 of the control relay 83 while the grid 20 is unbroken, is interconnected with the control relay 83. The respective terminals 1 of the two relays 82, 83 are interconnected, as are the terminals 2 of their movable contacts 85, 113, and terminal 4 of the programming relay 82 is connected to terminal 3 of the control relay 83. Terminals 2 and 3 of the programming relay 82 are interconnected, and the winding 116 is connected at one of its ends to ground and at its other end to the programming relay terminal 1.

The control or sensing circuit 80 of the fire and explosion protection system of Figure 9 comprises the lead 53, control relay winding 111, and grid 20. The firing circuit comprises the lead 53, the two relays 82, 83 and interconnecting leads, and the leads connecting the detonators of the capsules 27—30 to the control relay terminal 4. The firing and sensing circuits 79, 80 are both supplied with electrical power by the power source 72 through the safety switch 81.

When the landing gear control handle 56 is placed in its position effecting extension of the landing gear, the mechanical linkage 110 opens the safety switch 81, thus deenergizing the firing and sensing circuits 79, 80. The contact elements 84, 85, 112, 113 of the two relays 82, 83 occupy their positions shown in dotted lines in the drawing. When, as after takeoff, the handle is placed in its position implementing retraction of the landing gear, the safety switch 81 is placed in its closed position by the linkage 110.

With the safety switch 81 thus closed, a number of events follow in series. First, the sensing circuit 80 is completed, and an electrical current flows through the control relay winding 111 through the grid 20 to ground. At the same time, the terminals 2 of both relays 82, 83 and the terminal 3 of the programming relay 82 are energized. The movable contacts 84, 85, 112, 113 of the two relays 82, 83, at the time of closing of the safety switch 81, are in their positions shown in dotted lines, and because of the inertia of the relay moving parts, etc., the movable contacts 112, 113 of the control relay 83 remain in their dotted-line position during a brief interval after completion of the sensing circuit 80; thus, the movable contact element 112 of the control relay 83 is closed during this interval against the associated terminal 4, the latter being electrically connected to the detonators. No firing voltage is delivered to the detonators, however, because the firing circuit is open at the programming relay contact element 84.

Next, the energized winding 111 effects movement of the control relay movable contacts 112, 113 to their respective positions shown in solid lines, thus energizing contact 1 of the programming relay 82 and the winding 116 connected thereto and opening the firing circuit 79 at the control relay contact 112.

Finally, the programming relay movable contacts 84, 85 are moved to their positions shown in solid lines by forces exerted by the energized winding 116, thus connecting the already energized programming relay terminal 3 with the control relay terminal 3. At the same

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time, the programming relay winding 116 is connected through the movable contact element 85 with the previously energized programming relay contact 2. As long as the safety switch 81 in closed and the grid 20 is not broken, the relays remain in their last described positions.

If an object pierces the fuel enclosure 114 in the area covered by the grid 20, the grid 20 is broken thereby. Continuity of the sensing circuit 80 being lost, the winding 111 of the control relay 83 is deenergized and the associated movable contacts 112, 113 move to their respective dotted-line positions. Receiving electric power for its winding 116 through its closed movable contact 85, the programming relay 82 is not positionally affected by opening of the control relay movable contact 113, and hence continues to transmit voltage from the control relay terminal 2 to the control relay terminal 4. The firing circuit 79 is consequently complete, and electrical power is supplied to the detonators of the capsules 27—30 and to the indicator fuse 35, with results such as described in connection with the indicator fuse and capsules of Figure 6.

If no rupture of the fuel enclosure 114 breaks the grid 20, moving the landing gear handle 56 to its position effecting extension of the landing gear moves the linkage 110, opens the safety switch 81, and deenergizes the fire protection system as previously explained.

While only one embodiment of the invention, together with several modifications thereof, have been shown in the accompanying drawings, it will be evident that various other modifications are possible in the arrangement and construction of the fire and explosion protection system components without departing from the scope of the invention.

I claim:

1. In association with an enclosure having a wall and intended for containing a combustible substance, a fire and explosion protection system comprising: a source of electrical power; disseminating means operative in response to an electrical signal for disseminating a combustion-inhibiting material in a space in which ignition of said combustible material might occur subsequent to rupture of said enclosure; sensing means connected to said source of electrical power and to said disseminating means and responsive to the passage through an element thereof of an enclosure-rupturing object for delivering to said disseminating means an electrical signal effecting operation of the latter and programming means for preventing the delivery of spurious signals to said disseminating means which could effect inadvertent operation of the latter, said programming means being connected between said disseminating means and said source of electrical power.

2. A fire and explosion protection system such as claimed in claim 1, said sensing means comprising a conductor disposed adjacent a surface of a wall of said enclosure, said signal being delivered to said disseminating means by said sensing means in response to severance of said conductor by an enclosure-rupturing object.

3. A system such as claimed in claim 2, said conductor being normally continuous and being disposed in discrete, relatively closely spaced runs throughout an area coextensive with at least a substantial area of a wall of said enclosure.

4. In association with an enclosure having a wall and intended for containing a combustible substance, a fire and explosion protection system comprising: a source of electrical power; disseminating means comprising a burstable container normally enclosing a quantity of combustion-inhibiting material, and explosive means associated with said container and operative, upon receipt of an electrical signal, for bursting said container and disseminating said combustion-inhibiting material in a space in which ignition of said combustible material might occur

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subsequent to rupture of said enclosure; sensing means having electrical connection to said explosive means and to said source of electrical power and comprising a continuous conductor disposed in electrically discrete, relatively closely spaced runs throughout an area coextensive with at least a substantial area of a wall of said enclosure, said sensing means being responsive to severance of said conductor by an enclosure-rupturing object for delivering to said explosive means an electrical signal effecting operation of the latter; and programming means for preventing the delivery of spurious signals to said explosive means, said programming means being connected between said explosive means and said source of electrical power.

5. A system such as claimed in claim 4, said system further including means connected to said explosive means and operative for indicating delivery from said sensing means to said explosive means of an electrical signal.

6. In association with an enclosure having a wall and intended for containing a combustible substance, a fire and explosion protection system comprising: disseminating means comprising a burstable container normally enclosing a quantity of combustion-inhibiting material and further comprising explosive means electrically fireable for bursting said container and spreading said combustion-inhibiting material within an area likely to experience combustion of said combustible material following rupture of said enclosure; a firing circuit electrically connected to said explosive means; a control device comprising relatively movable contacts in said firing circuit and electrically energizable means having an electrically conductive element, said electrically energizable means being operative in response to electrical current flow through said conductive element for moving at least one of said contacts for introducing a discontinuity at said contacts in said firing circuit, continuity being established thereat when current flow through said conductive element is interrupted; a sensing circuit comprising said conductive element of said control device and further comprising a normally continuous electrical conductor disposed in electrically discrete runs relatively densely spaced throughout an area coextensive with a substantial area of a wall of said enclosure, continuity of said sensing circuit being broken and current flow through said conductive element being interrupted in the event of severance of said conductor by an enclosure-rupturing object; connecting means operable for connecting said firing and sensing circuits to a source of electrical power; and programming means in said firing circuit for ensuring the presence of a discontinuity in said firing circuit from a time including the time of connection of said firing and sensing circuits to said source of electrical power to a time when current flow through said sensing circuit shall have effected opening of said contacts of said control means.

7. A fire and explosion protection system of the sort claimed in claim 6, said programming means comprising a switch in said firing circuit and further comprising a mechanically actuated linkage connecting said switch to an article routinely altered in position in a manner causing said linkage to open said switch during times when the event of connection of said firing and sensing circuits to said power source is likely.

8. A system such as claimed in claim 7, said connecting means comprising a switching device connected between said source of electrical power and said firing and sensing circuits and further comprising a mechanically actuated linkage connecting said switching device to an article routinely altered in position in a manner causing said linkage to open said switching device during times when deactivation of said fire and explosion protection system is desirable.

9. A system such as claimed in claim 6, said programming means including an electrical relay interconnected with said electrically energizable means and with at least one of said relatively movable contacts of said

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control device, said relay being normally operative for preventing connection of said at least one of said relatively movable contacts to said electrical power source before introduction of a discontinuity in said firing circuit by movement of said contacts by said electrically energizable means.

10. A system such as claimed in claim 9, said connecting means comprising a switching device connected between said power source and said sensing and firing circuits and further comprising a mechanically actuated linkage connected to said switching device and to an article routinely altered in position in a manner actuating said linkage for opening said switching device during times when deactivation of said fire and explosion protection system is desirable.

11. In association with an enclosure having a wall and intended for containing a combustible substance, a fire and explosion protection system comprising: means operative in response to an electrical signal for disseminating a combustion-inhibiting material in a space in which combustion of said combustible material might occur following rupture of said enclosure; and sensing means having a grid and responsive to the passage through said grid of an enclosure-rupturing object for delivering to said disseminating means an electrical signal effecting operation of the latter, said grid lying adjacent and being in area coextensive with a substantial surface portion of said wall of said enclosure, said grid comprising a sheet and a conductor, said sheet having plies adhesively bonded together, and said conductor being disposed between said plies in relatively close, electrically discrete runs throughout the greater part of said sheet.

12. For an aircraft provided with a fuel enclosure having a wall, retractable landing gear, a control unit for governing actuation of said landing gear, and an electrical power source, a fire and explosion protection system comprising: an electrical relay mounted in said aircraft, said relay having a coil and first and second relatively movable, normally closed contacts; disseminating means comprising a burstable container normally enclosing a quantity of combustion-inhibiting material and further comprising explosive means electrically connected to said second contact of said relay and operable in response to an electrical signal for bursting said container and spreading said combustion-inhibiting material within a space in said aircraft likely to experience combustion of said combustible material in the event of rupture of said enclosure; a normally continuous electrical conductor disposed in electrically discrete runs relatively densely spaced throughout an area coextensive with a substantial area of a wall of said enclosure, said conductor being connected to said coil of said relay for completing an electrical circuit therethrough, said circuit being broken in the event of severance of said conductor by an enclosure-rupturing object; a first switch connected to said first contact of said relay; a second switch for connecting said relay coil and first switch to said power source; a first mechanical linkage between said first switch and said control unit for governing actuation of said landing gear, said first linkage being operative for opening said first switch when said control unit is positioned for extension of said landing gear and for closing the same upon positioning of said control unit for retraction of said landing gear; and a second mechanical linkage between said second switch and a component of said retractable landing gear, said second linkage being operative for opening said second switch when said aircraft

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is supported by said landing gear and for closing said second switch when said aircraft is airborne.

13. A fire and explosion protection system such as claimed in claim 12, said system further including indicating means electrically connected to said explosive means for indicating delivery of an electrical signal to the latter.

14. A system such as claimed in claim 13, said system further including means electrically connected to said explosive means and operative for bleeding static electrical charges therefrom.

15. For an aircraft provided with a fuel enclosure having a wall, retractable landing gear, a control unit for governing actuation of said landing gear, and an electrical power source, a fire and explosion protection system comprising: a first electrical relay mounted in said aircraft, said relay having a coil and first and second relatively movable, normally closed contacts, energization of said coil causing opening of said contacts; disseminating means comprising a burstable container normally enclosing a quantity of combustion-inhibiting material and further comprising explosive means electrically connected to said second contact of said first relay and operable in response to an electrical signal for bursting said container and spreading said combustion-inhibiting material within a space in said aircraft likely to experience combustion of said combustible material in the event of rupture of said enclosure; a normally continuous electrical conductor disposed in electrically discrete runs relatively densely spaced throughout an area coextensive with a substantial area of a wall of said enclosure, said conductor being connected to said coil of said first relay for completing an electrical circuit there-through, said circuit being broken in the event of severance of said conductor by an enclosure-rupturing object; a first switch connected to said first contact of said relay; a second switch for connecting said relay coil and first switch to said power source; a first mechanical linkage between said first switch and said control unit for governing actuation of said landing gear, said first linkage being operative for opening said first switch when said control unit is positioned for extension of said landing gear and for closing the same upon positioning of said control unit for retraction of said landing gear; a second mechanical linkage between said safety switch and a component of said retractable landing gear, said second linkage being operative for opening said second switch when said aircraft is supported by said landing gear and for closing said second switch when said aircraft is airborne; and a second electrical relay interconnected with at least said first contact of said first relay and normally operative for preventing energization of said first contact by said power source before energization of said coil of said first relay shall have effected opening of said first and second contacts.

16. A system such as claimed in claim 15, said system further including visual indicating means connected to said explosive means and operative for registering delivery of an electrical signal to the latter.

17. A system such as claimed in claim 15, said system further including means electrically connected to said explosive means and operative for bleeding static electrical charges therefrom.

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