A lightweight, add-on structure which employs linear shaped pyrotechnic charges 40 to smoothly cut an airframe's skin 20 along an egress area periphery 30 and compromises reaction surfaces 62 attached to the exterior surface of the airframe's skin 20 and designed to restrict the skin deflection and jettison that portion of the airframe within the egress area periphery 30 and retention surfaces 72 and sealing walls 78 attached to the interior surface of the airframe's skin 20 and designed to shield the interior of the aircraft during detonation of the pyrotechnic charges 40.
FIG. 1
EXPLOSIVELY ACTIVATED EGRESS AREA

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435, USC 2457).

BACKGROUND OF THE INVENTION

This invention relates to rapid egress systems that are suitable for use in light general aviation and commercial aircraft that demand egress systems that are reliable, lightweight, and do not require redesign of existing airframes. Existing rapid egress systems have been developed with aircraft of different performance parameters in mind, and do not adequately meet the unique needs of the aircraft industry in three major aspects: design, weight and cutting/jettisoning effectiveness.

Existing rapid egress system are activated by either mechanical or pyrotechnic devices; both systems detach enframed egress panels from an airframe. Supporting frames for the egress panels are incorporated into the airframes to maintain structural integrity while the egress panels are detached. Incorporating the supporting frames into existing designs is costly, and requires substantial and costly stress analysis of the resulting structures because of changes in the distribution of forces within the entire airframe.

Weight is a major concern in designing light, general aviation aircraft due to relatively small power plants, and market demands for improved performance for both general and commercial aircraft. Mechanically activated systems are undesirable because they require linkage and piston-cylinder assemblies driven by auxiliary power sources which substantially increase the airframe's weight. Supporting frames designed to be a major load carrying element in an airframe are also undesirable for similar reasons.

Since design and weight criteria restrict the use of supporting frames which protect egressing objects from roughly cut edges at the egress area periphery, it is important for the cutting means to produce a smoothly cut edge. Rough edges increase the potential of cutting an egressing object or preventing egress by snagging the object. Though flexible linear-shaped charges have been held against an airframe to cut the periphery of an egress area, there is not teaching of a structure which smoothly cuts the airframe's weight. Supporting frames designed to be a major load carrying element in an airframe are also undesirable for similar reasons.

SUMMARY OF THE INVENTION

The foregoing and other objects of the invention are achieved by holding flexible linear-shaped charges against an airframe's skin, and adjacent to structural supporting members which parallel the egress area periphery. The charges hold against the skin pass through structural supporting members which cross the periphery, while an additional charge is placed around the structural supporting member to ensure complete severance at the periphery. Reaction surfaces are attached to the exterior portion of the skin within the periphery, and extend across the periphery to limit the skin's deformation and roughness when the charges are initiated. The reaction surfaces also receive impulse forces from the charges that jettison the severed portion of the airframe while an external containment cell bounded by the reaction surfaces and skin provides adequate space for controlled deformation and cutting of the skin to occur. Retention surfaces attached to structural supporting members adjacent to, and outside the periphery, operate in conjunction with sealing walls to shield the airframe interior from explosive products on initiation of the charges while the severed portion of the airframe is jettisoned freely outward from the aircraft. The retention surfaces extend over the periphery and sealing walls before being bent toward the skin. The sealing walls extend perpendicularly from the skin within and adjacent to the periphery. An internal containment cell, bounded by the structural supporting members, retention surfaces, sealing walls and skin, contains a flexible closed-cell foam which prevents externally induced contamination and seals openings in the retention surfaces, as well as diffuses explosive forces and debris. When the charges are initiated by pulling (or pushing, according to handle layout) a handle attached to a bellcrank and lanyard-detonator assembly, that portion of the airframe within the periphery is smoothly cut from the airframe, and jettisoned from the aircraft. Plexiglass areas within the periphery are covered by fine wire mesh screens that carries the broken material with the jettisoned portion of the airframe. The resulting egress area provides smooth edges for safe egress, and is created by a lightweight, reasonable structure which does not interfere with the normal operation and design of the airframe.

Other advantages and objects, as well as a more complete understanding of the present invention will become apparent from the following explanation of an
exemplary embodiment and accompanying drawings thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of the interior of a light general aviation airframe incuding the invention with portions cut away; FIG. 2 is a sectional view of FIG. 1 along line II-—II; FIG. 3 is a sectional view of FIG. 1 along lines III—III; FIG. 4 is a sectional view of FIG. 1 along line IV—IV; FIG. 5 is a sectional view of FIG. 1 along line V—V; FIG. 6 is a cross-sectional view of a flexible linear-shaped charge; FIG. 7 is a detailed view of the bellcrank and lanyard-detonator assemblies; and FIG. 8 is a plan view of the aircraft interior showing the locations of the explosive charges along the periphery.

DETAILED DESCRIPTION OF THE INVENTION

The invention is a lightweight device for providing a rapid egress area within an existing structure by smoothly cutting the structure along an egress area periphery, and jettisoning the severed portion. Though the preferred embodiment describes a device for rapid pilot egress from an aircraft, other applications for this invention will become apparent to those skilled in the art.

FIG. 1 is an interior plan view of a light, general aviation airframe 10, and includes a preferred embodiment of the invention. The airframe is fabricated from 1.02 mm (0.04 in) 2024-T4 flat stock aluminum, and is primarily composed of a skin 20 and structural supporting members 14: ribs 16, stringers 18 and frames 28 that provide additional strength to the ribs 16 and stringers 18 at high stress points. Sectional views of FIG. 1 (FIGS. 2, 3 and 5) reveal that the ribs 16 and stringers 18 have "U"-shaped cross-sections with the base of the "U" held perpendicular to the skin 20; other aspects of these drawings which relate to the invention will be discussed below. The base of the "U" provides the ribs 16 and stringers 18 with a depth, distance between the two outer surfaces of the "U"'s legs, of 38 mm (1.5 in).

The airframe 10 also includes a 3.17 mm (0.125 in) thick plexiglass window 22 supported by a window frame 24, and having an approximate aperture of 381 X 762 mm (15 X 30 in). A fine wire mesh screen 26 protects the aircraft interior from broken pieces of the window 22 by extending across the interior side of the window area and being attached to the window frame 24. The screen 26 carries broken pieces of the window with the severed portion of the airframe as they are jettisoned safely away from the aircraft when the invention is activated.

An egress area is defined on the airframe 10 by a periphery 30 shown in FIG. 1. Though a particular shape is not required, the preferred embodiment illustrates a design for rapid pilot egress and is located adjacent to existing ribs 16 and stringers 18 to minimize the weight of retention surfaces 22 which are discussed below. Other relevant factors that determine the size, shape and location of the egress area are distance, which the severed portion of the airframe must be jettisoned, and structural integrity of the aircraft once the airframe is cut along the periphery 30.

FIG. 6 is a cross-sectional view of a (commercially available) flexible linear-shaped charge 40. The explosive material selected for this embodiment is hexanitrotolubene (organic-precipitated HNS-11) 46, enclosed in a silver sheath 48 at a concentration of 3.19 g/m (15 grams/ft). This configuration generates approximately 2.0 X 10^9 N/m^2 (3 x 10^8 psi) at a linear velocity of 7,250 m/sec (23,800 ft/sec) when initiated by an explosive pressure greater than 5.5 X 10^9 N/m^2 (800,000 psi), and resists initiation by normal gunfire, electromagnetic forces, fire or physical handling. The charges 40 are shaped in a chevron to focus and intensify forces generated by expanding gases and sheath materials during initiation. It would be apparent to those skilled in the art of pyrotechnics to vary the materials, size and shape of the charges 40 to meet different cutting requirements from those in the preferred embodiment. The charges 40 are held against the interior surfaces of the airframe 10 along the periphery 30 shown in FIGS. 1 and 8. Six lengths are used: one extending from an upper, forward manifold 110 along the upper portion of the periphery 34 to an upper, rear manifold 112, one extending from a lower, forward manifold 110 along the lower portion of the periphery 36 to a lower, rear manifold 112, and, two lengths extending between both forward manifolds 110 and rear manifolds 112. The forward manifolds 110 are located along the forward portion of the periphery 30 as oriented on the aircraft airframe 10, and the rear manifolds 112 along the rear portion of the periphery 30.

FIG. 4 reveals how charges 40 are arranged about a stringer 18 between the two manifolds 110 in such complete severance of both the stringers 18 and the skin 20. A first charge 42 lies against the skin 20 along the periphery 30 between the two manifolds, and passes through a hole 82 in the stringer 18. The hole 82 is located proximate to the skin 20, but does not significantly affect the stringer's load carrying capabilities because it is outside the bent radius of the stringer and adjacent to the skin 20. A second charge 44 is held against, and wraps around the stringer 18, along the periphery 30. When initiated, the first charge 42, cuts the skin and that portion of the stringer adjacent to the skin while the second charge 44 cuts that portion of the stringer which is not adjacent to the skin. A similar arrangement for the charges 40 is used between the two rear manifolds 112 shown in FIGS. 1 and 8.

FIGS. 2, 3 and 5 are sectional views of FIG. 1 that more clearly show those aspects of the invention which improve the charge's ability to smoothly cut the skin and frame members along the periphery, and jettison the severed portion from the aircraft.

Bolts 17 secure spring-steel retaining clips 84, reaction surfaces 62, set-off plates 64, and sealing walls 78 to that portion of the skin within the egress area periphery. The retaining clips 84 hold the charges 40 against the skin 20 with the obtuse angle of the charge facing those portions of the airframe that are to be cut.

Reaction surfaces 62 restrict the skin's deformation when the charges 40 are initiated, and transmit impulse forces received from the charges to the severed portion of the airframe. The reaction surfaces 62 on this aircraft are fabricated from 1.6 X 38.1 mm (0.063 x 1.5 in) colled-rolled steel strips which are long enough to grip the skin and that portion of the stringer adjacent to the skin (approximately 30°) toward the skin at a distance of 6.4 mm (0.25 in) from the unsecured edges which extend across the periphery 30.

An external containment cell 68, located between the reaction surfaces 62 and the skin 20, provides adequate...
space for controlled deformation and cutting of the skin when the charges are initiated. The external containment cell on this aircraft is 3.15 mm (0.125 in) thick, and is maintained by 2024-T4 aluminum set-off plates held between the reaction surfaces and the skin. Flexible closed-cell foam located within the internal containment cell is 68 mm (0.063 in) thick and is maintained by 2024-T4 aluminum set-off plates. A silicon rubber sealing compound located along edges of the reaction surface, further prevents contamination of the external containment cell and further provides a temporary seal to the explosive pressure to assist in accelerating/jettisoning of the severed portion of the aircraft.

The reaction surfaces and external containment cell operate in conjunction with each other to control the skin's deformation, and smoothness of cut, when the charges are initiated. It would be apparent to one skilled in the art to vary the geometry and materials of those aspects of the invention thus far described to meet the cutting requirements of different airframe type configurations, or to minimize aerodynamic drag induced by the reaction surfaces in a flow field.

Sealing walls, secured by bolts to that portion of the skin within the egress area periphery, are an element of the invention's structure which shield the airframe's interior from the charge's explosive forces. When the charges cut the skin along the periphery, the sealing walls also act as a supporting structure to the severed portion of the airframe. The sealing walls and the retention surfaces operate together in shielding the airframe interior from the charge's explosive forces, and will be discussed in detail below.

FIG. 2 shows bolts in lieu of rivets that secure the skin to various structural supporting members—ribs—which are adjacent to the egress area periphery. The bolts also hold reinforcement angles against the ribs to prevent the ribs from being cut when the charges are initiated. The reinforcement angles used in the preferred embodiment are fabricated from 1.27 mm (0.05 in) 6061-T6 aluminum.

"U"-shaped retention surfaces are held at their base by bolts to ribs adjacent to the egress area periphery. The bolts are held against the skin by transmitting some of the forces to the skin, the "U"-shaped retention surfaces reduce deformation of the ribs. Retention surfaces are held against the base of the reaction surfaces to further prevent deformation by the charges. The sealing walls extend perpendicularly from the skin and are held firmly against the reaction surface to prevent explosive forces and debris from entering the airframe interior when the charges are initiated.

The reinforcement plates are secured by bolts to the ribs and trans-
The portion of the airframe with the periphery weighs 6.62 Kg (14.6 lb), and is jettisoned at an initial velocity of 13.7 m/sec (45 ft/sec). Locating the center of gravity in the lower portion of the jettisoned airframe causes the lower edge to rotate outward relative to the upper edge, and increases the aerodynamic stability and the distance which the jettisoned area is thrown.

The external containment cell 68 provides necessary space for controlled deformation and cutting of the skin to occur, while the reaction surfaces 62 limit the total amount of deformation and roughness along the cut periphery. The reaction surfaces 62 also receive impulse forces from the charges 40 to jettison the severed portion of the airframe.

The retention surfaces 72 and sealing walls 78 offer no resistance to outward motion of the severed portion of the airframe while shielding the aircraft interior from the charges' explosive forces. Flexible closed-cell foam 32 contained within the internal containment cell 80 is forced by the explosive forces into any gaps or openings within the retention surfaces 72, diffuses shock waves, and absorbs debris caused by initiation of the charges 40. This structure minimizes the force of concussion waves set in motion by the charges to less than 34.5 kN/m² (5 psi) for durations of 1.0 milliseconds at a pilot's head level within the airframe; however, if the pilot is wearing a helmet, the pressure experienced by his ears will typically be less than 26.2 kN/m² (3.8 psi).

This invention is installed on existing light, general aviation airframes, and only weighs 11.17 Kg (24.6 lb). The result is a lightweight add-on structure which smoothly cuts the existing airframe along the periphery of an egress area, and jettisons the severed portion of the airframe for rapid and safe manual unassisted egress of the pilot and passengers from within the aircraft.

What is claimed is:

1. A mechanism using pyrotechnics to cut an egress area within an existing structure which separates an interior and exterior region comprising:
   a. a structure means for separating exterior and interior regions;
   b. said structure means having a periphery to an egress area and includes a skin attached to frame structural support members;
   c. explosive charge means held against said structure means for cutting said structure means along said periphery;
   d. said explosive charge means being flexible linear-shaped charges;
   e. said flexible linear-shaped charges passing through and around said structural supporting members for cutting said skin and structural supporting members along said periphery;
   f. reaction surface means attached to the exterior surface of said structure means for receiving explosive forces from said explosive charge means, and limiting deformation of said structure means; and
   g. said explosive charge means and said reaction surface means are arranged and constructed to cut smooth edges along said periphery, and jettison that portion of said structure means within said periphery when said explosive charge means are initiated.

2. A mechanism as in claim 1 wherein said reaction surface means and said structure means envelope containment cell means for improving the cutting effectiveness of said explosive charge means.

3. A mechanism as in claim 2 wherein said containment cell means contains a means for preventing con-
tamination within said containment cell means, and for
diffusing said explosive forces.
4. A mechanism as in claim 1 wherein a detonator
means initiates said explosive charge means.
5. A mechanism as in claim 1 wherein:
a retention surface means and a sealing wall means
are attached to the interior surface of said structure
means for enveloping said explosive charge means,
and shielding said interior region from said explosive
forces; and
said retention surface means and said sealing wall
means are arranged to shield said interior region
from said explosive forces and allow said structure
means within said periphery to be jettisoned freely
when said explosive charge means are initiated.
6. A mechanism as in claim 5 wherein:
said structure means includes a skin attached to struc-
tural supporting member facing said exterior re-
gion;
said structural supporting members having members
which are adjacent, approximately parallel to, and
outside said periphery;
said sealing wall means is attached to said skin, is
adjacent, approximately parallel to, and within said
periphery; and
said retention surface means extend over said explo-
sive charge means and said sealing wall means, and
is attached to said structural supporting members
which are adjacent, approximately parallel to, and
outside said periphery.
7. A mechanism as in claim 6 wherein said reaction
surface means and said skin envelope containment cell
means for improving the cutting effectiveness of said
explosive charge means.
8. A mechanism as in claim 7 wherein said contain-
ment cell means contains a flexible closed-cell foam for
preventing contamination, and diffusing said explosive
forces.
9. A mechanism as in claim 6 wherein said retention
surface means are an "L"-shaped channel with one leg
attached to said structural supporting members, and the
other leg approximately parallel and adjacent to said
sealing wall means.
10. A mechanism as in claim 6 wherein said retention
surface means are a "U"-shaped channel with its base
attached to said structural supporting members adja-
cent, approximately parallel to, and outside said periph-
ery, with its legs directed toward the skin; and
said "U"-shaped retention surface means being sym-
metric about said attached structural supporting
members for transmitting said explosive forces to
said skin, and reducing deformation of said at-
tached structural supporting members.
11. A mechanism as in claim 3 wherein said means for
preventing contamination within said containment cell
is a flexible closed-cell foam.
12. A mechanism as in claim 1 wherein a sealing
means is bonded to edges of said retention surface
means and said structure means for increasing said ex-
plosive forces upon said retention surface means.
13. A mechanism as in claim 2 wherein:
said structure means is an airframe; and
said egress area is for rapid pilot and passenger egress
from within said airframe.
14. A mechanism as in claim 1 wherein:
said skin and said structural supporting members are
part of an airframe;
said structural supporting members include ribs,
stringers, and frames;
detonator means initiate said flexible linear-shaped
charges; and,
said egress area is for rapid pilot and passenger egress
from within said airframe.
15. A mechanism as in claim 1 wherein:
said structure means is an airframe including a skin
supported by ribs, stringers, and frames;
a sealing wall means attached to said skin adjacent,
approximately parallel to, and within said periph-
ery;
a retention surface means attached to said ribs, string-
ers, and frames which are adjacent, approximately
parallel to, and outside said periphery.
said retention surface means and said sealing wall
means are arranged to shield said interior region
from said explosive forces and allow that portion of
said airframe within said periphery to be freely
jettisoned when said explosive charge means are
initiated; and,
said egress area is for rapid pilot and passenger egress
from within said airframe.
16. A mechanism as in claim 11 wherein:
said structure means is an airframe having a skin sup-
ported by ribs, stringers, and frames; and,
said egress area is for rapid pilot and passenger egress
from within said airframe.
17. A mechanism as in claim 13 wherein:
said airframe within said periphery includes a win-
dow supported by a window frame; and,
a screen means is attached to said window frame for
preventing portions of said window from entering
said airframe.