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16. Abstract

This study presents pertinent findings from on-the-scene investigations to evaluate the crashworthiness of the present fleet of agricultural applicator aircraft. A detailed presentation of 16 crashes illustrates the fact that most of these specialized aircraft structures are well designed to protect the pilot, even in severe crashes. Most injuries and deaths of aerial applicator pilots are not attributable to failure of the cockpit structure itself, but rather to factors associated with (1) pilot restraint equipment, (2) seat failures, (3) failure of the roll-over structure, and (4) a lack of head impact attenuators at the top of the instrument panel.

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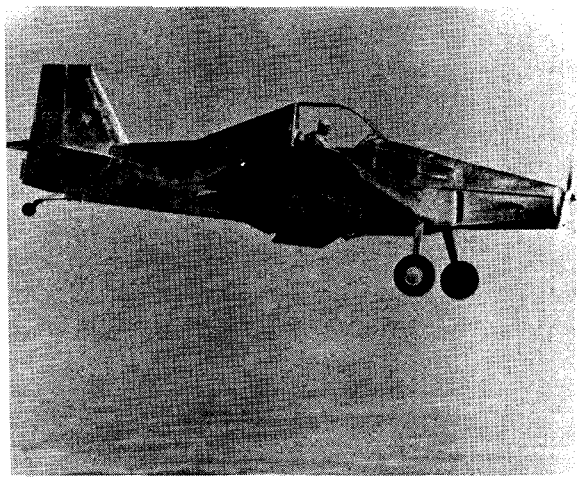
CRASH SURVIVAL ANALYSIS OF 16 AGRICULTURAL AIRCRAFT ACCIDENTS

. Introduction.

Over 20 years ago, through the joint efforts of he Departments of the Army, Navy and Air 'orce; the Civil Aeronautics Administration; the)epartment of Public Health and Preventive Medicine, Cornell University Medical College; nd the A &M College of Texas, an aircraft nown as the CAA-Texas A & M agricultural air-raft was designed and built. Designated the AG–1, this aircraft (Figure 1) embodied radi-ally new crashworthy features advocated in the



IGURE 1. Photograph of the original CAA—Texas A & M's (AG–1) agriculture airplane in flight.

ld of crash safety as early as 1943 by pioneers ke DeHaven and Hasbrook[1,2,3,4,5] and was the rerunner of most of the aerial applicator air-aft in use today. Perhaps the most important ashworthy feature of this aircraft was the sign that placed the pilot far back in the air-aft in a heavily reinforced 40–G cockpit. The G–1 provided 13 feet of crushable structure ead of the pilot for absorption of energy dur-g crash decelerations. In a head-on crash, cording to Professor Fred Weick, the designer, e initial impact would be partially absorbed by the 15–G engine mount; any remaining crash energy would then be transferred to the firewall structure just ahead of the hopper. After failure of the hopper-fuselage structure—at 25 G's—the cockpit then could collapse only if the remaining deceleration were in excess of 40 G's. In addition, the aircraft was equipped with a 40–G seat, military lap belt, and integral two-strap harness with an inertia reel. In brief, it was anticipated that the pilot of an aircraft with these design features would survive—without serious injury—a head-on collision at speeds up to 75 miles/hour.

Although only one AG–1 was built (it crashed without injuring the pilot—Figure 2), it served as a prototype for the present fleet of aerial applicator aircraft. The Piper Pawnee, Cessna

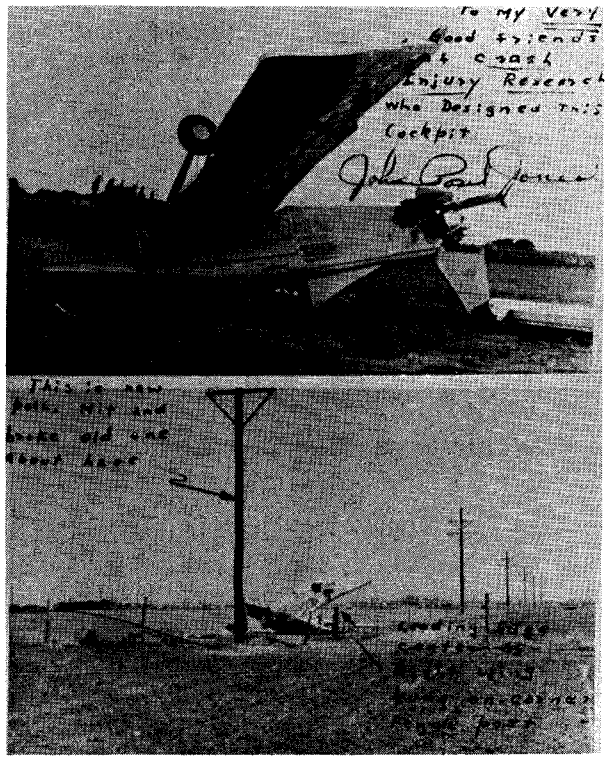


FIGURE 2. Scenes at the crash site on the AG–1.

Agwagon, Aerocommander Quail and Callair, and the Grumman Ag-Cat all incorporate many of the crash safety design features of the AG–1.

It is the purpose of this report both to evaluate the crashworthy features incorporated in these aircraft on the basis of analysis of on-the-scene crash investigations, and to point out areas where crash safety design of these specialized aircraft might be improved by only minor structural changes.

This study presents pertinent findings from nine Piper Pawnee crashes (of which three were of minor severity, one was moderately severe, four severe, and one very severe), two Cessna Agwagons (one minor and one moderately severe), and two Aerocommander Callairs (one moderately severe and one severe). Although the World War II Boeing Stearman was not designed for aerial application and does not have the specifically designed crashworthy features of the new agricultural aircraft, there still are a large number of Stearmans in use in the aerial application industry and for that reason two crashes (one moderately severe and one severe) are included in this report.

II. Method.

The 16 crashes presented are divided into four groups on a basis of accident severity and involvement of roll-over structure.

Group I: Minor—engine mounts, hopper and cockpit intact.

Group II: Same as Group I—Minor, but roll-over structure involved.

Group III: Moderately Severe—engine mounts destroyed but hopper and cockpit intact.

Group IV: Severe—engine mounts, hopper and cockpit severely damaged.

III. Results and Discussion.

GROUP I

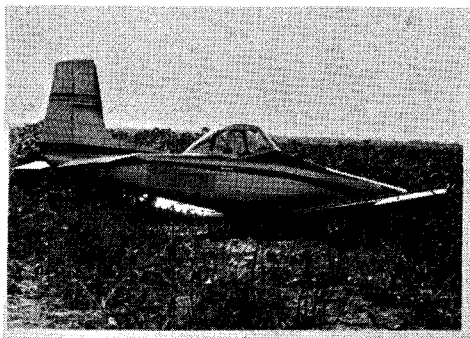
Case 1: A pilot wearing a shoulder harness, a lap belt, and a crash helmet crashed in a 1968 Piper Pawnee on level ground; the aircraft's landing gear was destroyed. While this crash is described as minor, it must be kept in mind that the term is a relative one, applying only to the discussion of these well-designed agricultural aircraft. The same crash forces in some general aviation aircraft might have produced serious injuries. The upper torso restraint, lap belt, and crash helmet protected the pilot from injury. However, the frayed shoulder straps indicated by an arrow in Case 1–b are indicative of a potential hazard. This aircraft was less than three years old and, while the frayed straps were strong enough to hold in this accident, they probably would have failed in a more severe crash. In addition, please note the metal-to-metal attachment of the shoulder harness to the lap belt buckle.

Case 2: As in Case 1, this 1968 Cessna Agwagon was involved in a minor crash, sliding 135 feet in a field of tall cotton, before coming to a stop. The pilot was also wearing shoulder straps, a lap belt, and a crash helmet and escaped without injury. Three observations are worthy of note in this accident. First, note (Case 2–c) the strong, high attachment point of the shoulder harness to the roll bar structure. Note also that the harness is attached to solid structure without an inertia reel, thereby limiting the motions of the pilot's upper torso. In many cases, pilots wear this harness loosely adjusted to provide them with better reach for control and outside vision. Second, the ends of the shoulder straps are stitched to only one face of the lap belt (Case 2–d) instead of either being wrapped around the belt and then sewn, or attached to the buckle by use of a metal-to-metal unit as in the Pawnee shown in Case 1. It is believed that this type of shoulder strap attachment (sewn on one side only) constitutes a weak link in this otherwise rugged agricultural aircraft. In fact, it can be seen in Case 2–e that the stitching began to fail even in this minor accident. Third, the light semicylinder of aluminum at the top of the instrument panel (Case 2–b) is designed to reduce head impact forces and to distribute force over large areas of the face and head. This protective device has proved to be most effective in the reduction of head injuries.

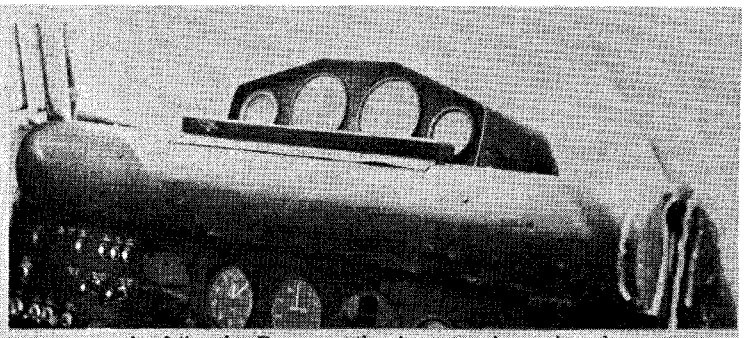
Case 3: An identical aircraft to that described in Case 2 (a 1968 Cessna Agwagon) was involved in a minor crash, sliding 175 feet in soft earth. The landing gear was torn off and, as the right wing gouged into the soft earth, the pilot was thrown to the right, his head breaking the window on that side. He was wearing the shoulder harness, a lap belt and a crash helmet and escaped without injury. One noticeable de-

ference between this aircraft and the one discussed in Case 2 is the presence of an inertia reel (Case 3–c). Again, attention is called to the aluminum semicylinder at the top of the instrument panel (Case 3–b) and to the shoulder straps stitched to one surface of the lap belt (Case 3–d). There is no sign of failure of the stitching in this case.

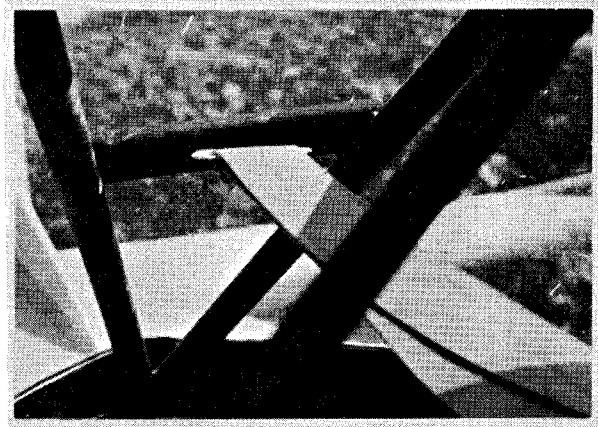
Case 4: A 1969 Callair crashed and hung in trees of moderate diameter. While the aircraft was equipped with shoulder harness and lap belt, the pilot was using only the lap belt; he wore no crash helmet. He said he escaped injury by putting his feet up on the instrument panel and bracing himself when he saw he was going to crash. This is, indeed, a poor practice and agricultural pilots should be educated to utilize upper torso restraint. In a crash of greater severity, this pilot would probably have sustained fatal head injuries from impact with the rigidly designed instrument panel (See Case 15).



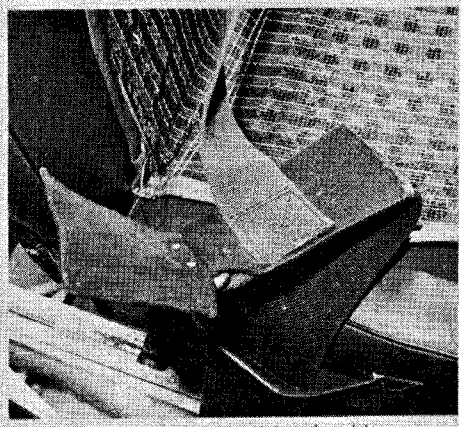
a. Side view after a minor crash of a 1968 Cessna Agwagon 188.



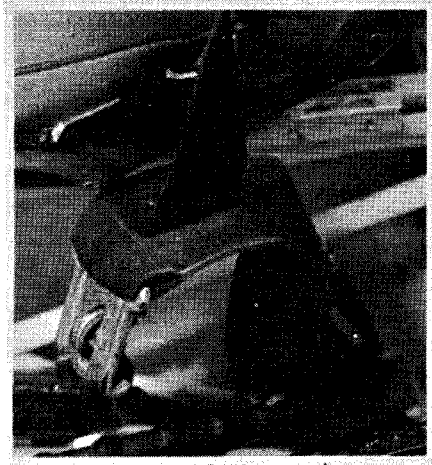
b. Like the Pawnee, the Agwagon is equipped with a light semicylinder of aluminum at the top of the instrument panel to help prevent head injury.



c. Unlike the Pawnee, the shoulder harness in the Cessna Agwagon is attached to heavy roll bar structure, high in the aircraft.



d. Stitching the ends of the shoulder straps flat to one face of the lap belts constitutes a weak point in the restraint system.

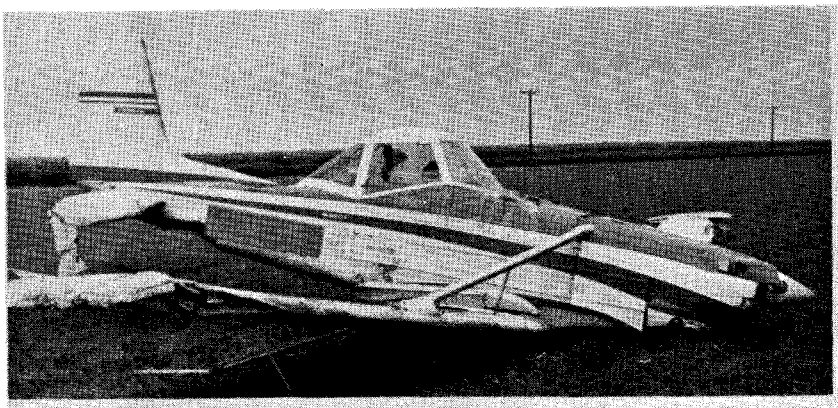


e. Even in this very minor accident the shoulder strap stitching has started to fail.

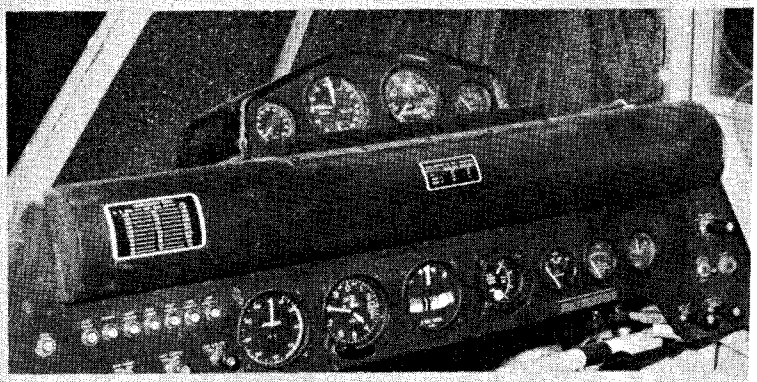
This Cessna Agwagon crashed in tall cotton and slid 130 feet before coming to rest (minor crash deceleration forces). The pilot was wearing his shoulder straps, lap belt and a crash helmet and they all remained in place. No injuries.

Accident investigated by T. Wallace.

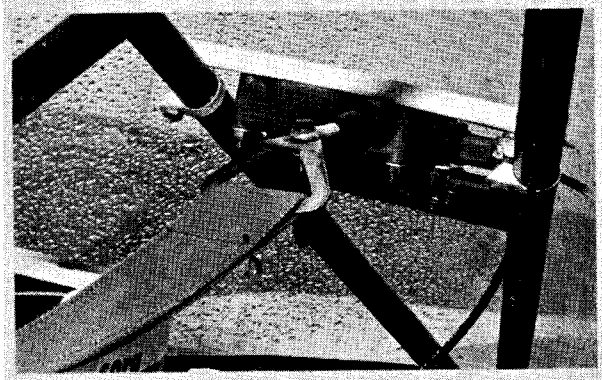
CASE 2



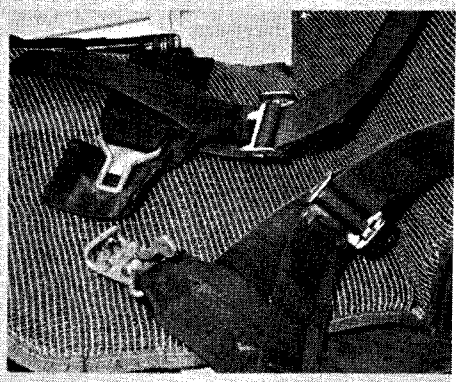
a. Minor crash landing of a 1968 Cessna Agwagon (A-188).



b. Protective aluminum roll undamaged.



c. Shoulder straps attached to inertia reel fastened to strong tubular structure high in the aircraft.



d. Shoulder straps sewed flat to one face of the lap belts.

The pilot of this aircraft was uninjured in 175-foot slide on soft earth. He was wearing shoulder straps, lap belt, and a crash helmet that broke the right side window.

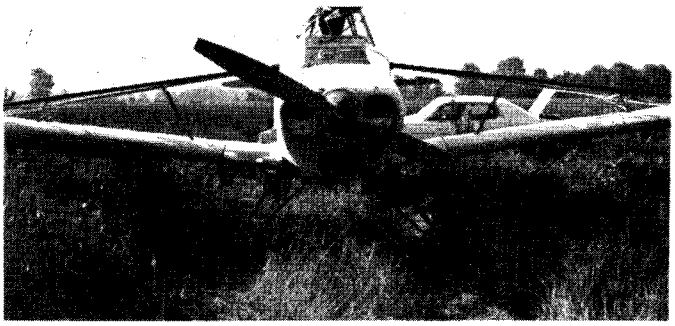
Accident investigated by T. Wallace.

CASE 3

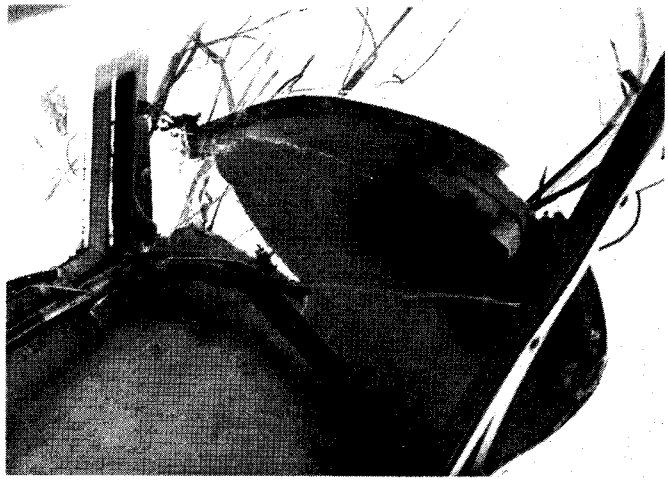
GROUP II

Case 5: This 1963 Piper Pawnee was in a minor crash landing and was flipped over onto its back. The pilot (Case 5–c) was wearing his shoulder harness, a lap belt, and a crash helmet and was uninjured. A significant hazard noted in this accident relates to incipient failure of the roll bar structure in this minor flip-over; slightly more force would probably have resulted in total failure and crushing of the pilot.

Case 6: A 1964 model Piper Pawnee descended through small trees and crashed in a river. The pilot, wearing his shoulder harness, lap belt and crash helmet, was subjected to relatively minor deceleration forces. However, the roll bar structure failed in the welded corners during impact with the trees forcing a sharp tube-end back into the cockpit (Case 6–b and c); the pilot sustained a fatal puncture wound just above his left eye (Case 6–d).



a. View of aircraft after being turned back right side up.



b. Close-up showing damage to roll bar structure--strong enough in this instance to prevent collapse on the pilot.

c. Photograph of the pilot--no injuries.

A 1963 Piper Pawnee (PA-25-235) was involved in a minor crash and rolled over into an inverted position. Pilot was wearing both lap belt and shoulder harness and there was no failure of this restraint equipment. Use of proper restraint and the integrity of the roll bar cage prevented any injuries in this accident.

Accident investigated by J. Blethrow and E. Langston.

CASE 5