TECHNICAL REPORT STANDARD TITLE PAGE

| | | |
|---|---|---|
| 1. Report No.<br>FAA-AM-72-15 | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle<br>CRASH SURVIVAL ANALYSIS OF 16 AGRICULTURAL AIRCRAFT ACCIDENTS | | 5. Report Date<br>April 1972<br>6. Performing Organization Code |
| 7. Author(s)<br>J. J. Swearingen, D.Av.T.; T. F. Wallace; J. G. Blethrow; and D. E. Rowlan | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address<br>FAA Civil Aeromedical Institute<br>P. O. Box 25082<br>Oklahoma City, Oklahoma 73125 | | 10. Work Unit No.<br>11. Contract or Grant No.<br>13. Type of Report and Period Covered |
| 12. Sponsoring Agency Name and Address<br>Office of Aviation Medicine<br>Federal Aviation Administration<br>800 Independence Avenue, S.W.<br>Washington, D.C. 20591 | | 14. Sponsoring Agency Code |

15. Supplementary Notes

Research leading to preparation of this report was performed under Projects AM-A-72-PRS-37 and AM-A-71-PRS-37.

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.

| | |
|---|---|
| 17. Key Words<br>Crash injury, structural parts, aviation accidents, aircraft design, aircraft seats, restraint installation, agricultural aircraft, head impact. | 18. Distribution Statement<br>Availability is unlimited. Document may be released to the National Technical Information Service, Springfield, Virginia 22151, for sale to the public. |

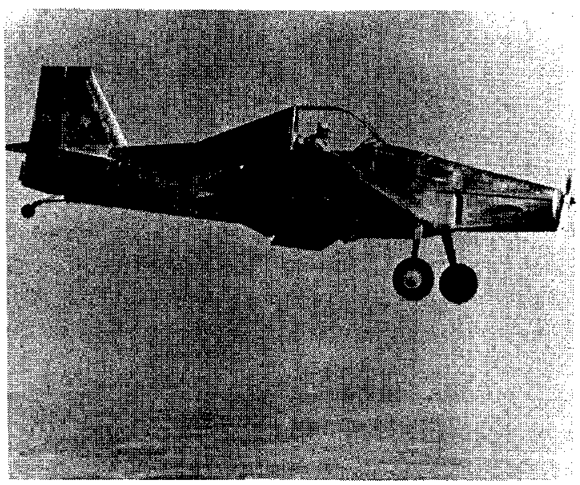
| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 24 | $3.00 |

Form DOT F 1700.7 (8-69)

# 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 Aedicine, Cornell University Medical College; nd the A &M College of Texas, an aircraft nown as the CAA-Texas A & M agricultural airraft was designed and built. Designated the G–1, this aircraft (Figure 1) embodied radially 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 airaft in use today. Perhaps the most important ashworthy feature of this aircraft was the sign that placed the pilot far back in the airaft in a heavily reinforced 40–G cockpit. The G–1 provided 13 feet of crushable structure ead of the pilot for absorption of energy durg 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

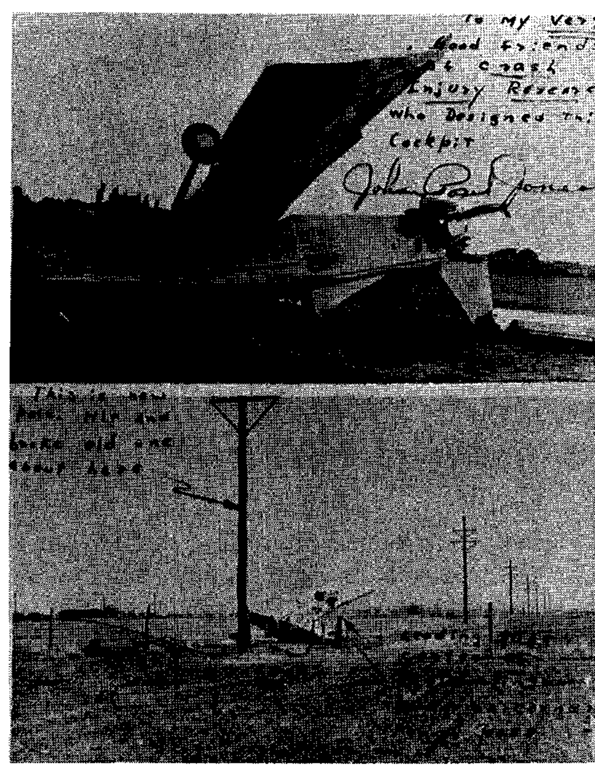


FIGURE 2. Scenes at the crash site on the AG–1.

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.

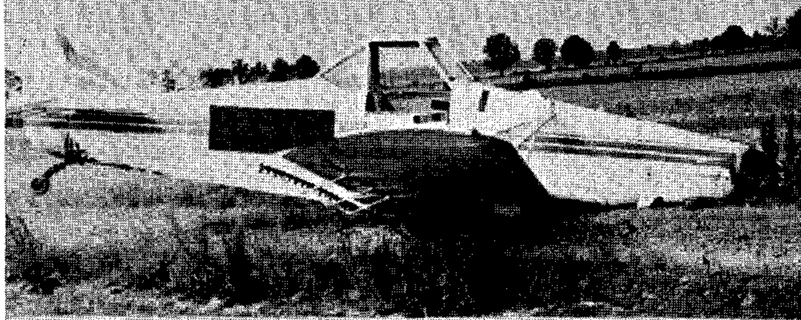
### GROUP I

**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 bel buckle.

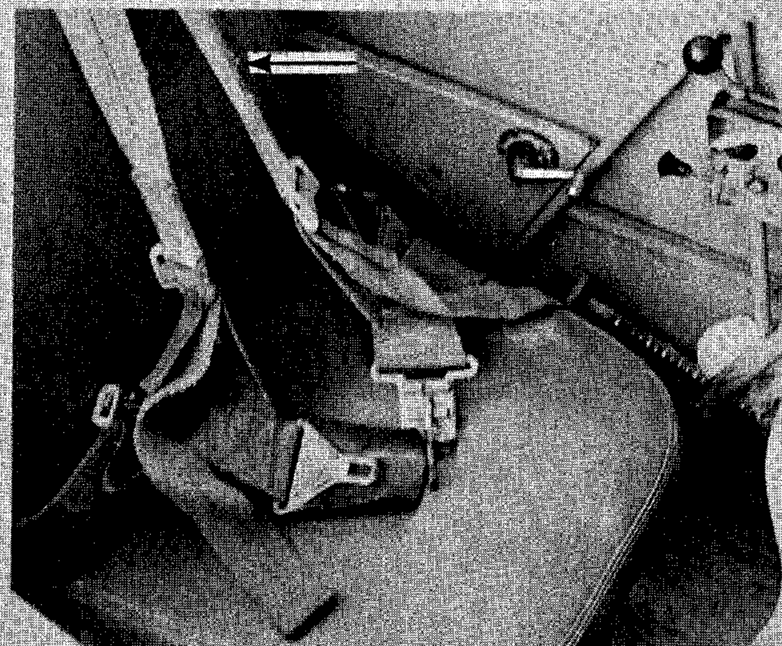
**Case 2:** As in Case 1, this 1968 Cessn Agwagon was involved in a minor crash, slidin 135 feet in a field of tall cotton, before coming t a stop. The pilot was also wearing shoulde straps, a lap belt, and a crash helmet and escape without injury. Three observations are worth of note in this accident. First, note (Case 2–c the strong, high attachment point of the shoulde harness to the roll bar structure. Note also tha the harness is attached to solid structure withou an inertia reel, thereby limiting the motions c the pilot's upper torso. In many cases, pilo wear this harness loosely adjusted to provic them with better reach for control and outsic vision. Second, the ends of the shoulder stra are stitched to only one face of the lap be (Case 2–d) instead of either being wrappe around the belt and then sewn, or attached to tl buckle by use of a metal-to-metal unit as in tl Pawnee shown in Case 1. It is believed that th type of shoulder strap attachment (sewn on o side only) constitutes a weak link in this othe wise rugged agricultural aircraft. In fact, it ca be seen in Case 2–e that the stitching began fail even in this minor accident. Third, the lig semicylinder of aluminum at the top of the i strument panel (Case 2–b) is designed to redu head impact forces and to distribute force ov large areas of the face and head. This protecti device has proved to be most effective in the r duction of head injuries.

**Case 3:** An identical aircraft to that describ in Case 2 (a 1968 Cessna Agwagon) was involv in a minor crash, sliding 175 feet in soft ear The landing gear was torn off and, as the rig wing gouged into the soft earth, the pilot w thrown to the right, his head breaking t window on that side. He was wearing shoulder harness, a lap belt and a crash heln and escaped without injury. One noticeable d 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 of aircraft showing minor damage mostly to landing gear and propeller.



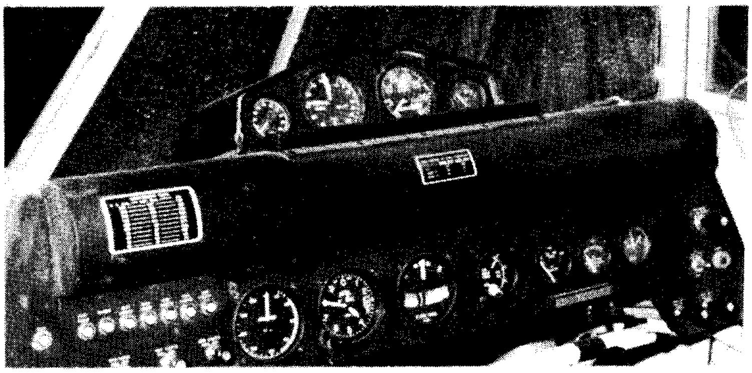
b. Shoulder straps and lap belt held in this minor accident but it should be noted that the shoulder straps are becoming frayed (see arrow) and would be sure to fail in an accident of greater crash severity.

Minor accident of a 1968 Piper Pawnee (PA-25-235) presented to show the use of frayed shoulder straps. No injuries were inflicted in this accident.

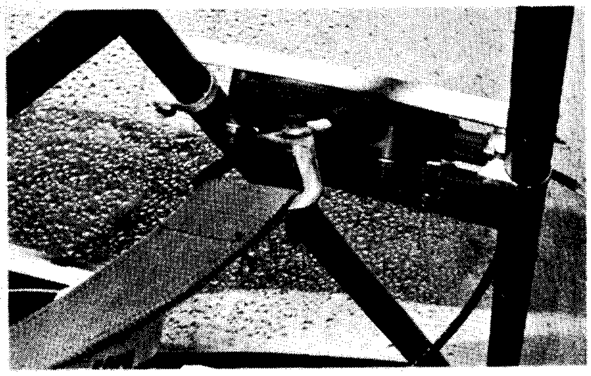
Accident investigated by D. Rowlan.

**CASE 1**

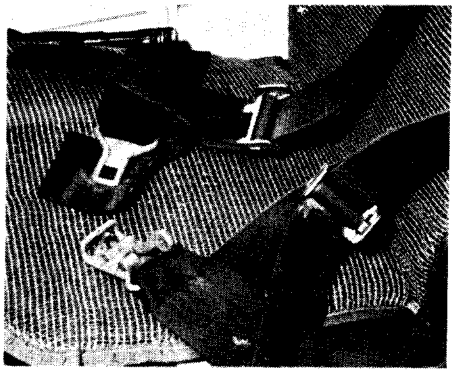
a. Minor crash landing of a 1968 Cessna Agwagon (A-188).



b. Protective aluminum roll undamaged.



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



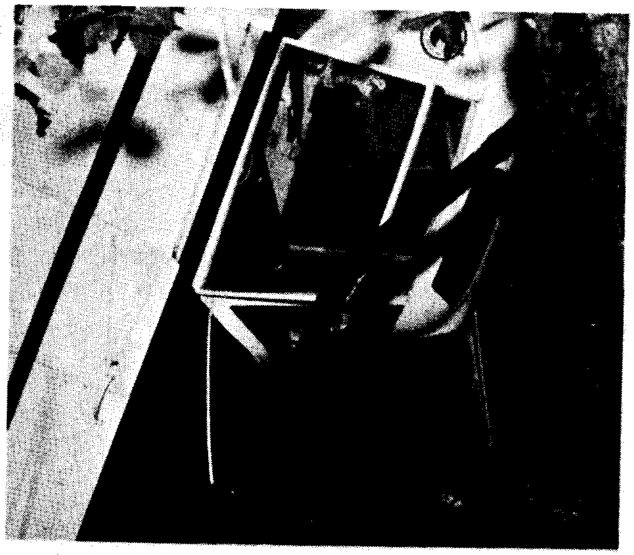
d. Shoulder straps sewed flat to one face of the lap belts.

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.

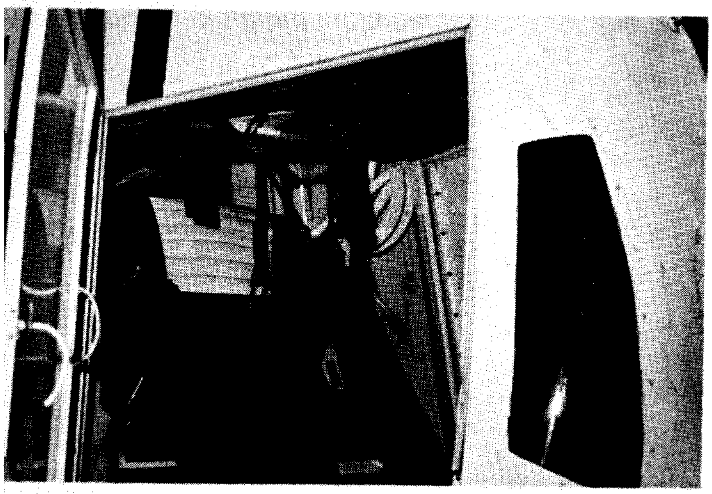
Accident investigated by T. Wallace.

# CASE 3

a. A 1969 Aerocommander Callair A-9B involved in a moderately severe crash in trees.



b. Close-up showing cockpit area with only minor damage.



c. Aircraft was equipped with shoulder harnesses, but the pilot was not wearing them.

d. Pilot uninjured.

This Callair probably experienced some rather high G forces as it broke off some trees 6 to 8 inches in diameter. The pilot stated that he avoided head injury by bracing his feet up on the instrument panel when he saw he was going to crash.

Accident investigated by T. Wallace.

# CASE 4

## 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.

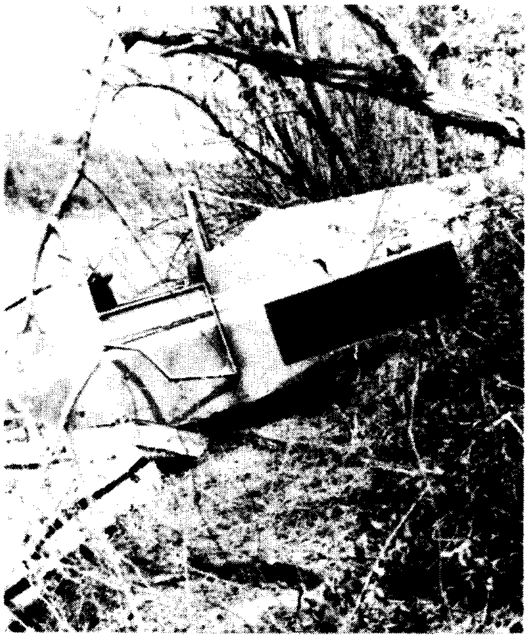
b. Close-up showing damage to roll bar structure--strong enough in this instance to prevent collapse on the pilot.

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.

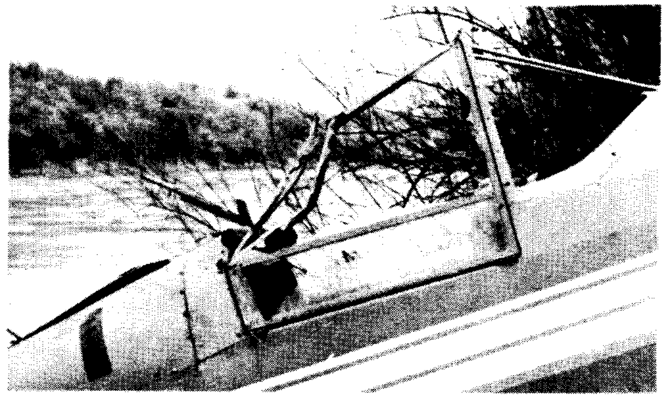
Accident investigated by J. Blethrow and E. Langston.

c. Photograph of the pilot--no injuries.

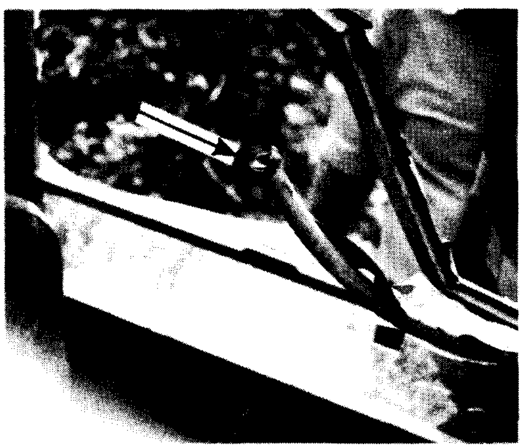
# CASE 5



a. Side view of aircraft after being pulled out of the water.



b. Close-up showing failure of roll bar structure.



c. Broken weld joint of vertical bar formed sharp cutting edge (see arrow)

d. Puncture wound (fatal) just below edge of helmet inflicted as broken roll bar was forced down and to the rear into the cockpit.

Minor crash of a 1964 Piper Pawnee (PA-25-235). The pilot, wearing shoulder harness, lap belt and crash helmet, flew through some trees and crashed in a river. Impact force with the tree limbs caused roll bar failure resulting in the fatal puncture wound (the only facial injury) shown in figure d above.

Accident investigated by J. Blethrow.

# CASE 6

## GROUP III

**Case 7:** Although most lap belts and shoulder harness straps are not marked with a manufacturing date, it is believed the pilot of this 1964 Piper Pawnee was wearing restraint equipment probably manufactured during World War II. If this is true, the webbing was 25–30 years old. Since the 25–G hopper (and cockpit) were undamaged, it may be assumed the cockpit deceleration was less than 25 G's—yet both shoulder straps failed about six inches ahead of the cable attachment point (The lap belt held).

Unfortunately, cotton webbing materials deteriorate with age, and with exposure to the elements and insecticides, and become frayed with long usage. Since the cockpits of most agricultural aircraft are designed to withstand 40–G crashes, it is imperative that the pilot's restraint equipment be changed periodically if he is to survive such decelerations without serious injury. In this instance, the pilot was jackknifed over his lap belt and his face was buried in the light aluminum semicylinder (Case 7–c) designed to yield and distribute crash force over a large area of the head. Because of the excellent yield characteristics of this structure, the pilot received only a slight concussion and a small laceration of his chin from contact with the altimeter reset knob (Case 7–d).

**Case 8:** The crash force and structural damage involved in the 1969 Pawnee case shown here appear to be similar to those related to the 1964 model described in Case 7. However, this aircraft (manufactured five years later) may have been equipped with a newer shoulder harness. It is also noteworthy that while the lower ends of the shoulder straps are sewn to the lap belt, they are also wrapped around the belt and sewn all the way through (Case 8–c), as compared to Cases 2, 3, and 9, in which the shoulder straps are stitched to only one face of the belt. Surprisingly, although the pilot was wearing both shoulder straps and lap belt and there was no failure of the webbing or cables, a head impact depression was found in the aluminum semicylinder at the top of the instrument panel (Case –d). In this aircraft the inertia reel and lap belt cables are attached to a cross tube in the lower fuselage, back of the seat. In this crash, the lower tube was buckled up (Case 8–b) allowing 10 inches of slack in the shoulder harness and right half of the lap belt. This permitted the pilot to move forward, striking the top of his head on the broken windshield. The aluminum semicylinder undoubtedly prevented serious facial injuries.

**Case 9:** This 1970 Cessna Agwagon was involved in a moderately severe crash and the pilot, wearing his shoulder harness, lap belt and crash helmet, escaped with only bruises. As mentioned before, the shoulder harness is attached to solid structure in the roll bar framework in this aircraft and has no inertia reel (Case 9–c). As in Case 2, because of the lack of an inertia reel, the pilot usually wears his shoulder straps loosely adjusted to provide good vision and maneuverability in the cockpit. In this accident, the slack in the shoulder straps allowed the pilot's head to strike the aluminum semicylinder (Case 9–b). The use of an inertia reel in this aircraft would probably have prevented this head strike despite failure of the seat-lock pin which allowed the seat to slide forward and detach itself from the tracks.

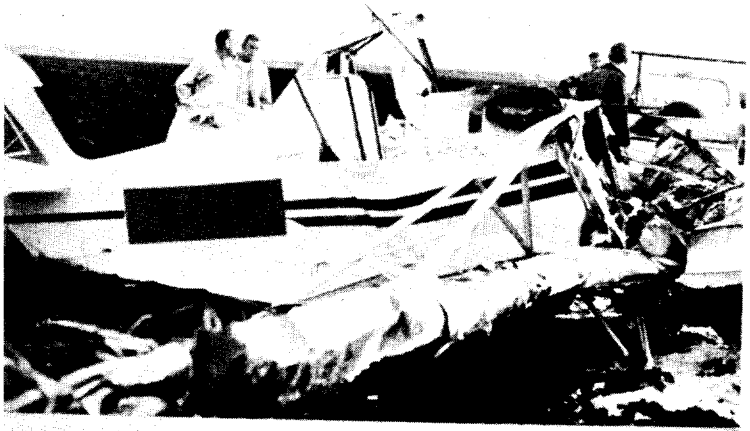
In a 40–G cockpit, the pilot should be given the protection of a 40–G seat tie-down. Rather than a lightweight single lock-pin, heavy duty lock-pins in both tracks seem to be indicated.

**Case 10:** In this accident involving a 1969 Aerocommander Callair, the pilot, who was wearing a crash helmet and had adjusted his shoulder harness and lap belt snugly, sustained only bruises from the shoulder straps. This appears to be an excellent installation of body restraint equipment, including a metal-to-metal attachment of the shoulder straps to the lap belt (Case 10–e). The shoulder straps pass over the pilot's shoulders, through an opening behind the pilot, and down to a strong tubular frame structure behind the seat. However, caution should be observed in the maintenance of this restraint system because of webbing contact with the rough edges of the opening behind the seat. The less than two-year-old shoulder straps in this aircraft already showed signs of fraying (Case 10–d). Such fraying seriously reduces the webbing strength. Also, the restraint system should include an inertia reel. The snugly adjusted belt and harness prevented the pilot's head from striking the instrument panel. Without any energy attenuating device (padding or aluminum roll) for head impact protection, any head strike would probably have proved disastrous (See Case 15).

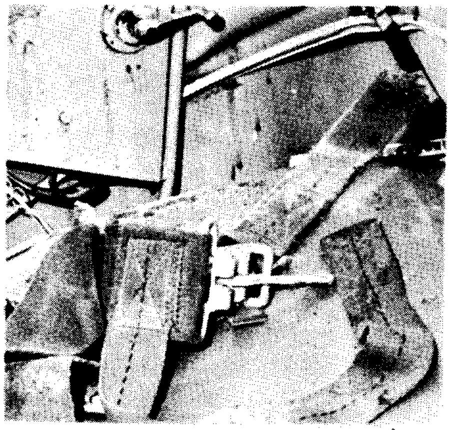
**Case 11:** The Boeing-Stearman was designed prior to America's entry into World War II and was used as a military primary trainer. As such, it was designed as a rugged aircraft, able to withstand moderately severe crashes without being totally destroyed. Many of these aircraft, purchased as "surplus" planes, were converted and used for agricultural aircraft purposes.

Since a large number of these aircraft are still being used in aerial application work, two accidents are included in this report.

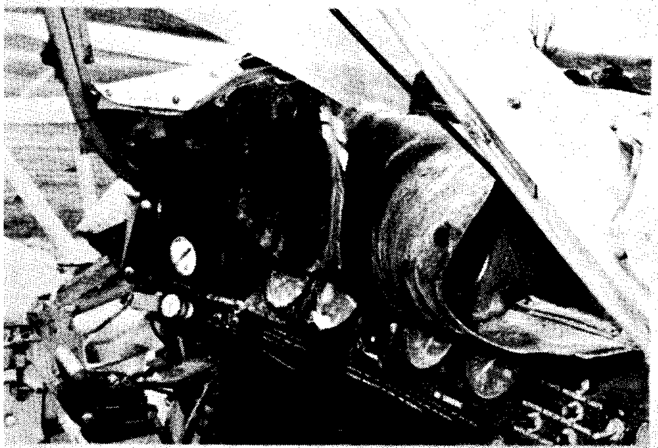
This Stearman flipped over after initial impact. Despite the fact that the aircraft was not equipped with shoulder harness, the pilot escaped without injury. However, the crash force was sufficient to throw the pilot forward over his lap belt and his head struck the roll of padding at the top of the instrument panel (Case 11–c). Also, the pilot was protected from being crushed under the inverted aircraft by the top wing which acted as a roll-over structure.



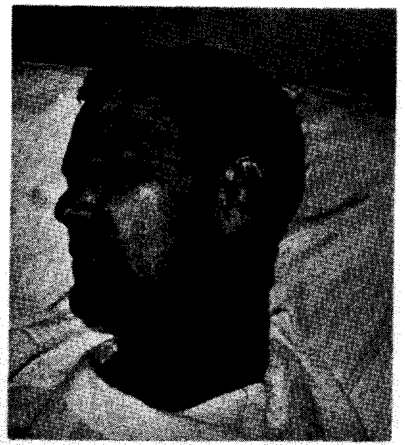
a. Side view of an aircraft involved in a severe crash.



b. Both shoulder straps broken, lap belt held.



c. Dent in aluminum roll from head impact.



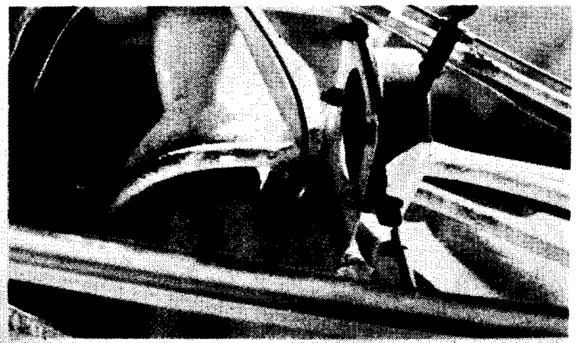
d. Photograph showing cut on pilot's chin from contact with altimeter reset knob.

Injuries in this 1964 Piper Pawnee (PA-25-235) accident were minor: slight concussion, lacerations of chin and left hand.

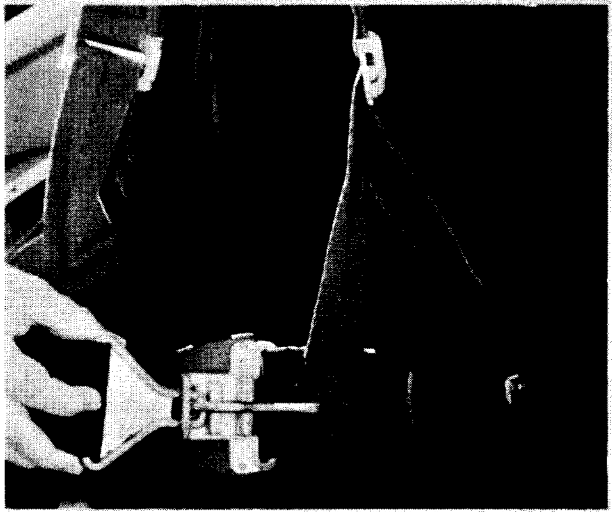
Accident investigated by G. Braden.

# CASE 7

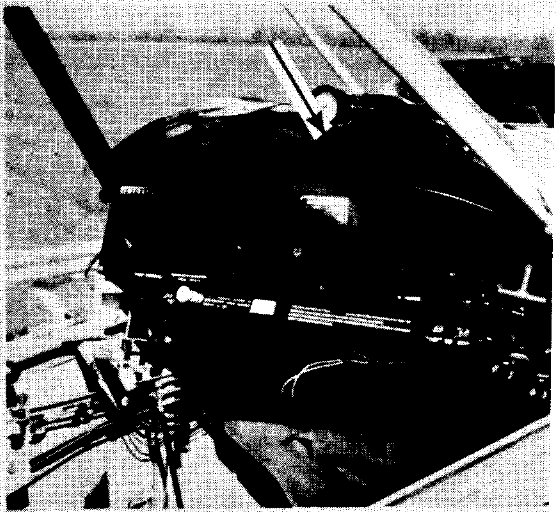
a. Side view of aircraft showing considerable damage to right wing, motor mount, and lower fuselage tubing to the rear of the cockpit.



b. Upward bending of lower fuselage tubing at the attachment point of the inertia reel and right lap belt cable allowed 10 inches of slack and forward motion of the pilot.



c. Photograph showing that restraint equipment remained intact.



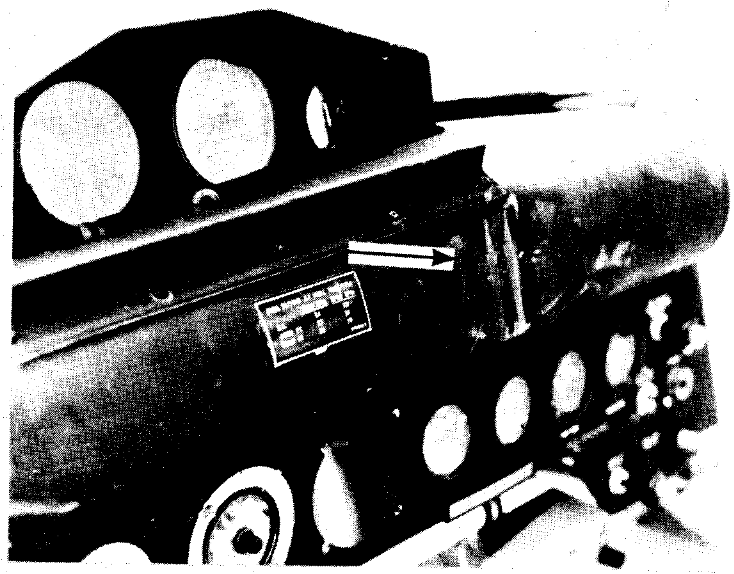
d. As the restrained pilot moved forward and to the right in the cockpit, his head impacted the light aluminum roll at the top of the instrument panel (see arrow indicating dent) and his right knee contacted the lower instrument panel to the right of the RPM gage.

The pilot of this 1969 Piper Pawnee (PA-25-235) received lacerations on the top of his head from the broken windshield (no crash helmet), facial bruises from contact with the aluminum semicylinder (designed for head impact protection), and a slight knee laceration. All forward motion of the pilot resulted from the upward failure of the inertia reel and right seat belt attachment point.

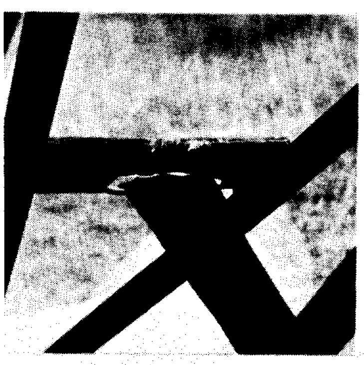
Accident investigated by T. Wallace.

# CASE 8

a. View of a moderately severe crash of a 1970 Cessna Agwagon (188B)

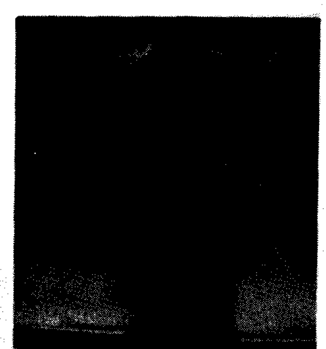


**b. Pilot was wearing his shoulder straps loosely, allowing his head to strike the aluminum roll (see arrow).**



**Strong shoulder harness attachment.**

**d. Restraint system was in use and held.**



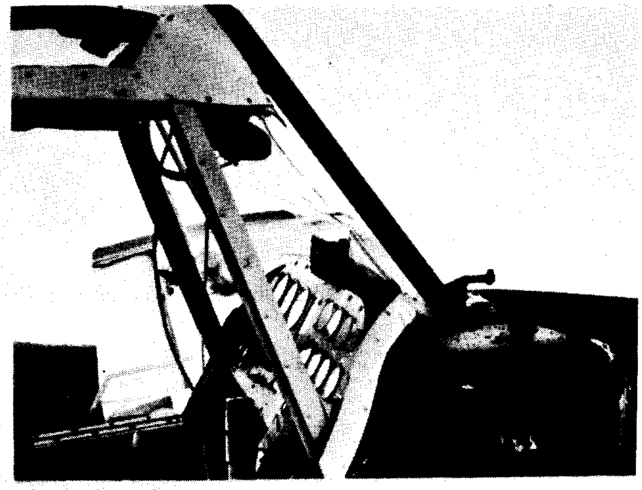
**e. As in previous cases, shoulder straps stitched to belt surface, but did not fail.**

Pilot of this aircraft received only minor bruises. Severe to fatal injuries could have occurred had his head struck instrument panel not equipped with the light aluminum roll. However, since the cabin & restraint systems remained completely intact, he would not have experienced a head impact had he been wearing his restraint equipment snugly. On the other hand, note that in fig. c above, this aircraft was not equipped with an inertia reel & the pilot probably wore his shoulder straps loosely for maneuverability. All shoulder straps should be attached to inertia reels to avoid this situation

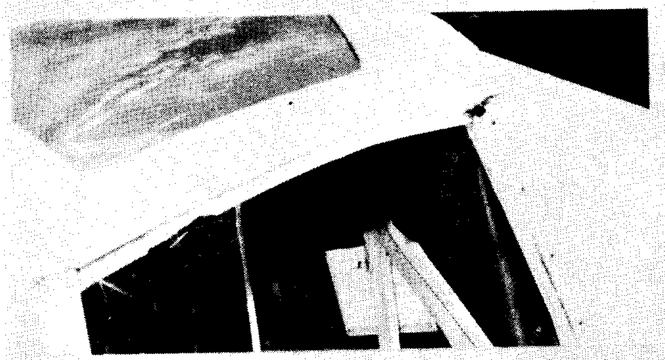
Accident investigated by T. Wallace.

# CASE 9

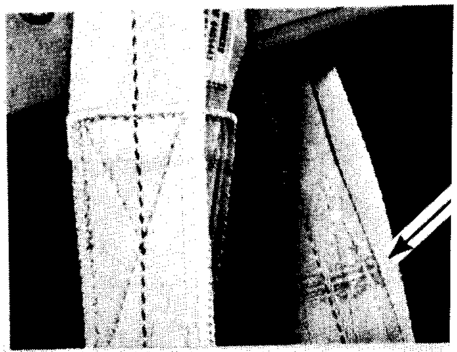
a. A moderately severe crash of a 1969 Aerocommander Callair A-9B and the uninjured pilot.



b. Rigid instrument panel without head impact protection.



c. High strong attachment of shoulder harness.



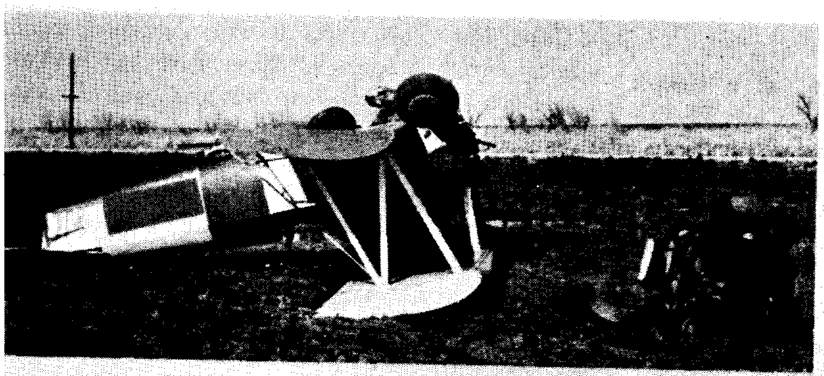
d. Shoulder strap webbing is becoming frayed and should be replaced.

e. Metal-to-metal attachment of shoulder straps to lap belt forms a more reliable restraint system than sewing shoulder straps to one surface of the belt.

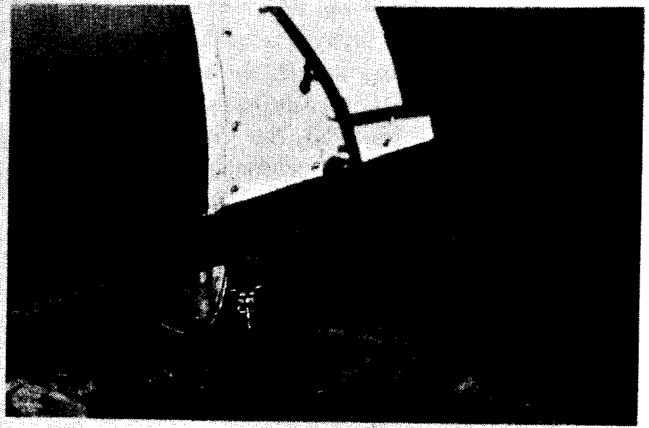
This young pilot survived with only shoulder strap bruises a moderately severe crash since he was wearing strong, reliable restraint equipment and a crash helmet.

Accident investigated by T. Wallace.

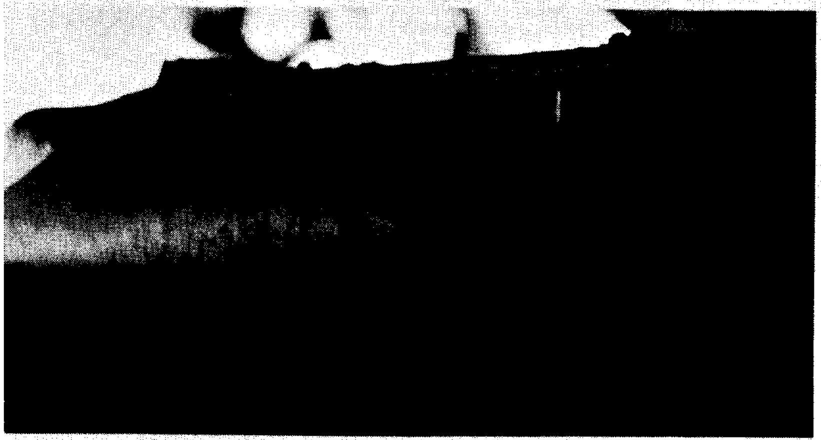
# CASE 10



a. Moderately severe crash of a 1940 Boeing Stearman (B-75) that gouged into hard ground and flipped over.



b. Open cockpit without roll bars was held off of pilot by high wing structure. Note padding on edges and front of cockpit.



c. Large padded roll at the top of panel in front of the pilot. Also note that there are no instruments in this panel.

Since this aircraft is not equipped with shoulder harness and the pilot was wearing his seat belt, one would expect severe head injuries in a crash of this severity. The fact that the pilot escaped without injury must be explained by the fact that he hit his head on the large padded roll shown in c above.

Accident investigated by L. Lowrey.

## CASE 11

## GROUP IV

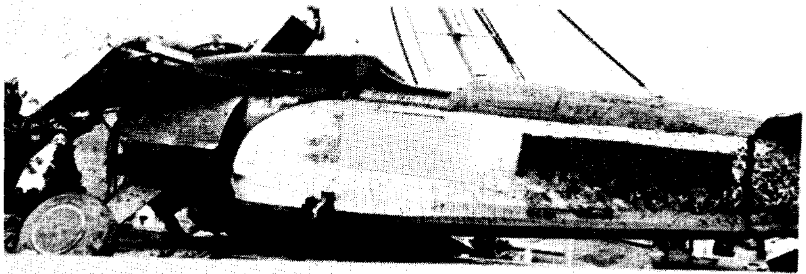
**Case 12:** This Stearman crashed at a steep angle. The top wing struts failed (Case 12–a) in a forward direction due to forward momentum. Although a shoulder harness was available, the pilot was only wearing his lap belt (loosely adjusted) and a cloth helmet. The front of the instrument panel was padded with foam rubber, but since the pilot was wearing a loosely-adjusted belt, his head was thrown above the padding and his neck impacted the top (unpadded) portion of the panel (see arrow, Case 12–c) with sufficient force to fracture the larnyx, displace cervical vertebra, and completely severe the spinal cord. Since the cockpit did not collapse and the aircraft did not become inverted, the pilot probably would have survived this accident with minor injuries *had he been wearing his shoulder harness and a tight lap belt.*

**Case 13:** This 1965 Piper Pawnee was involved in a severe accident which resulted in structural failure of the engine mounts, hopper, and part of the cockpit. The pilot was wearing his shoulder harness, the lap belt and a crash helmet. He sustained injuries of a survivable nature because of a combination of failures of his restraint system. The left cable to the lap belt broke (Case 13–c) and the attachment point of the inertia reel and right lap belt cable (lower fuselage tubing) buckled upward (as in Case 8) allowing considerable slack in the restraint system (Case 13–b). As a result of these restraint system failures, the pilot was thrown into the right front portion of the cockpit. Forceful contact of his pelvis against the heavy radio (Case 13–e) resulted in a fracture of the upper right femur and right iliac crest. He also suffered fractures of both legs below the knees and fractures of the right wrist and right elbow. Stronger lap belt cables and relocation of the attachment point of the inertia reel are indicated.

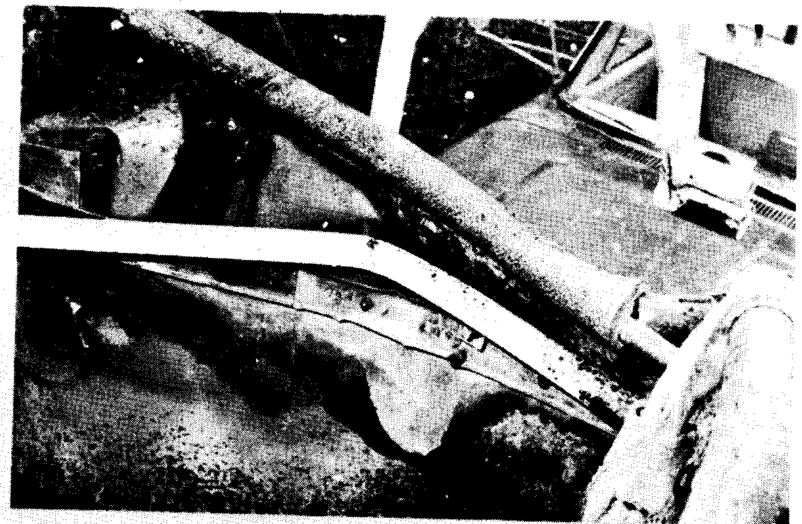
**Case 14:** This 1960 Pawnee crashed unde similar circumstances as those described in Case 13. Both halves of the lap belt and both shoulde straps broke (Case 14–b) allowing the pilot to b thrown forward, burying his knees in the fiber glass hopper and his face in the aluminum semi cylinder at the top of the instrument panel (Cas 14–c). The yield characteristics of the fiberglas and the light aluminum roll were such as to pro duce only minor injuries. The condition of th lap belt and shoulder harness indicated th webbing was old and probably under-strengt again emphasizing the need for periodic inspec tion and replacement of the restraint system.

**Case 15:** This 1968 Aerocommander Callai was involved in a crash similar to the tw Pawnees described in the two previous cases an as in Case 14, the age of the webbing caused th lap belt to break in two places (Case 15–d). A the lap belt broke, the single shoulder strap (tie to the belt with nylon rope) offered no resistan to the forward motion of the pilot; his face in pacted the instrument panel (Case 15–c). Th need for light aluminum semicylinders at the to of the instrument panel is clearly evident whe the minor head injuries of the pilot in Case 14 a compared to the fatal crushing injuries of t face and cranium of the pilot in this crash (Ca 15–f). The forward motion of the pilot al caused fractures of both arms and both legs. U of newer webbing and the installation of an in pact attenuation device at the top of the instr ment panel would probably have permitted th pilot to survive with minor injuries.

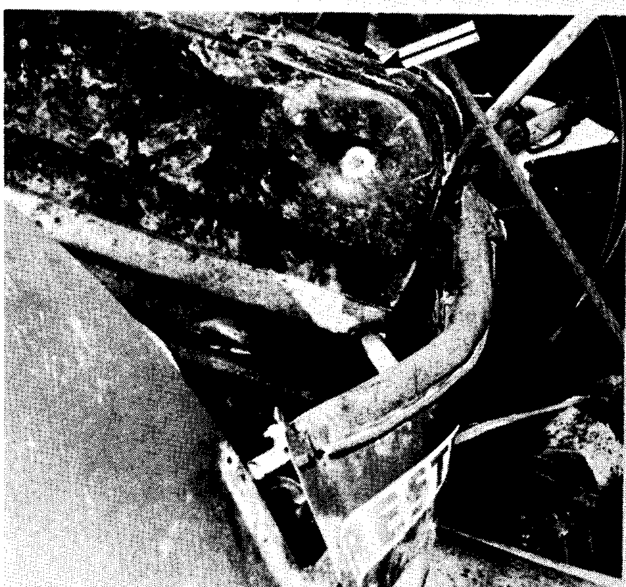
**Case 16:** This 1964 Piper Pawnee crashed i verted at a steep angle. Forces were of su magnitude as to cause almost complete destru tion of the aircraft and the accident should classed as nonsurvivable. The pilot died fr multiple fractures and a ruptured heart.



a. A 1943 Boeing Stearman A-75 crashed at a steep angle with sufficient force to drive the top wing forward but did not flip over.



b. Right side of open cockpit.

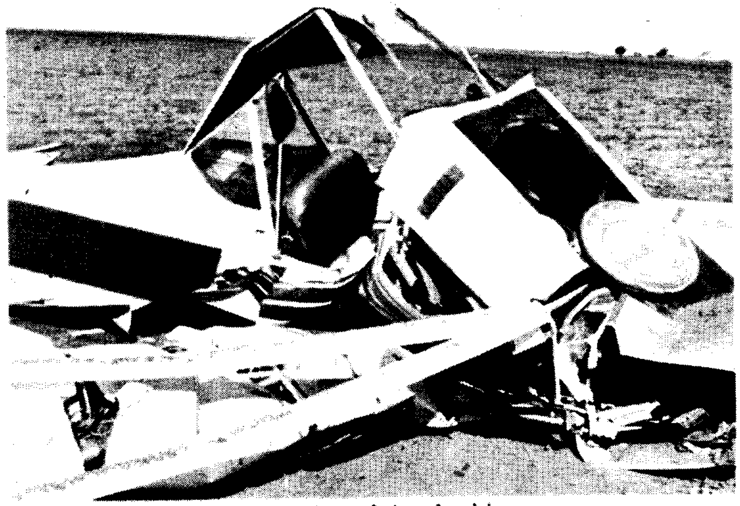


c. Pilot was thrown forward, hitting his neck on the top of the instrument panel (note arrow).

This aircraft was equipped with both shoulder harness and seat belt, but the pilot was wearing only the lap belt (loosely) and a cloth helmet. The neck impact with the top of the instrument panel fractured the pilot's larnyx and drove the neck vertebra back to such an extent as to completely sever the spinal cord. He should have survived without injury if he had been wearing properly his shoulder harness and seat belt.

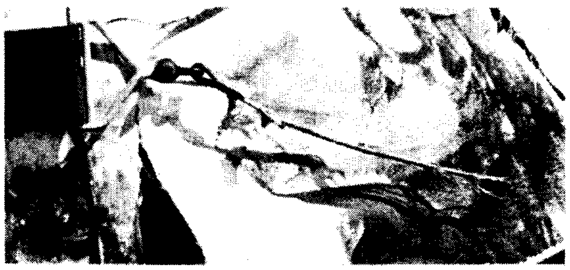
Accident investigated by T. Wallace

# CASE 12

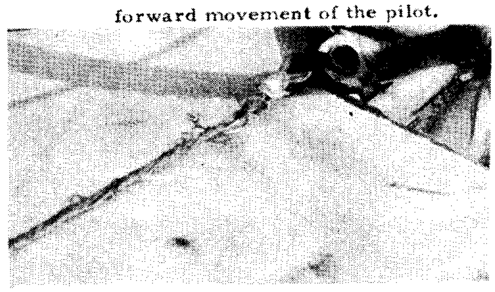


a. Side view of an aircraft involved in a severe crash. Severity of crash is indicated by failure of motor and its mounts, collapse of the hopper and partial collapse of cabin.

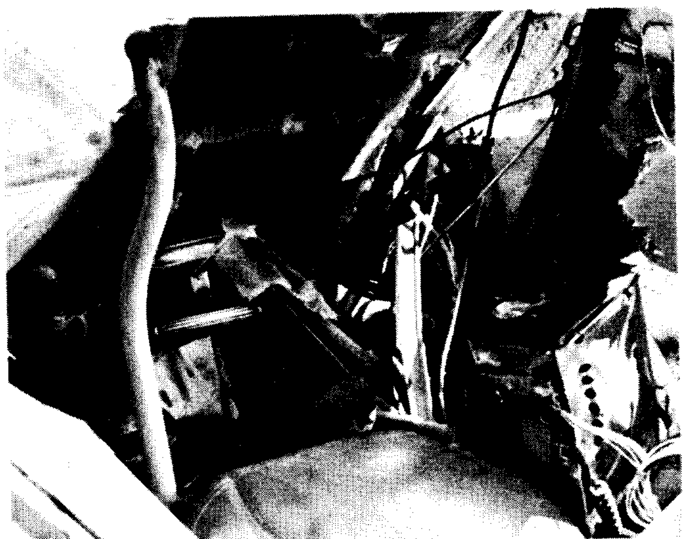
b. Upward bending of inertia reel attachment on lower fuselage tubing to rear of cockpit allowed slack in shoulder harness & forward movement of the pilot.



c. Left seat belt cable broken from crash forces.



d. Right seat belt cable badly frayed but did not break.

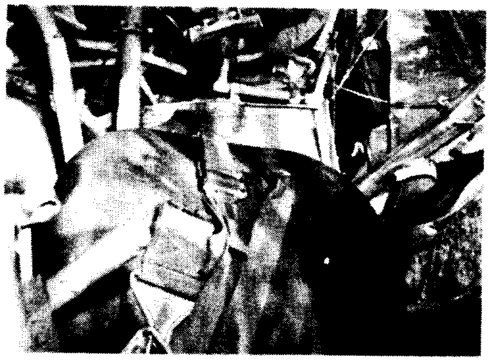


e. As shoulder harness became slack and the left seat belt cable broke, pilot was thrown into right forward corner of cockpit (note heavy radio).

The pilot of this 1965 Piper Pawnee (PA-25-235) received severe but non-fatal injuries after failure of his restraint equipment (see captions above). His most severe injuries, including extensive fractures of his right hip, iliac crest, wrist and elbow, resulted from body contact with the heavy radio (Fig. e). In addition he suffered fractures of both legs below the knees from floor structure failure. Head injuries consisting of a small laceration on the right side of his face and slight concussion were major since his head was thrown over the right side of the cockpit.
Accident investigated by D. Rowlan.

# CASE 13

a. Side view of an aircraft involved in a very severe steep angle impact with hard ground.



b. Force of impact was sufficient to break both shoulder straps and the 3-in. lap belt in two places.

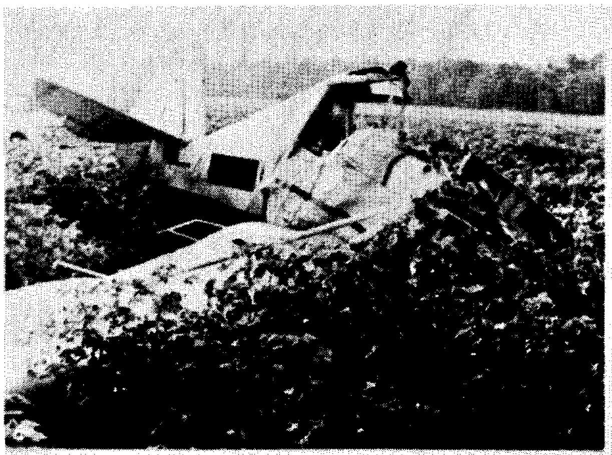
c. Dent in light semicylinder of aluminum from head impact of pilot.

d. Photograph of pilot four days after the crash.

Considering the severity of the crash impact of this 1960 Piper Pawnee (PA-25), it is worth note that the pilot escaped with relatively minor injuries; namely, a fracture of the right frontal sinus, moderate concussion, fracture of left ankle, and minor cuts.

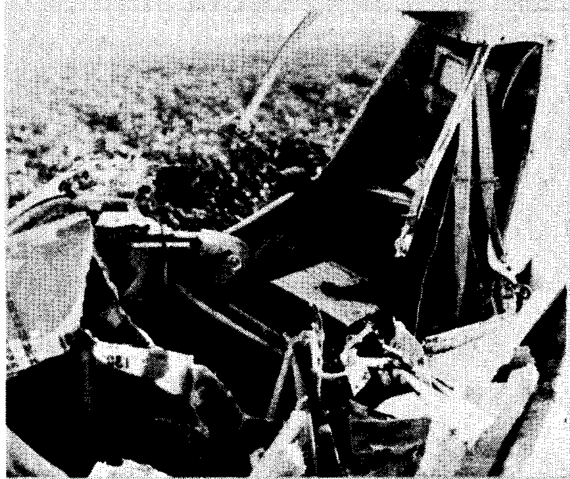
Accident investigated by J. Simpson and J. Blethrow.

## CASE 14

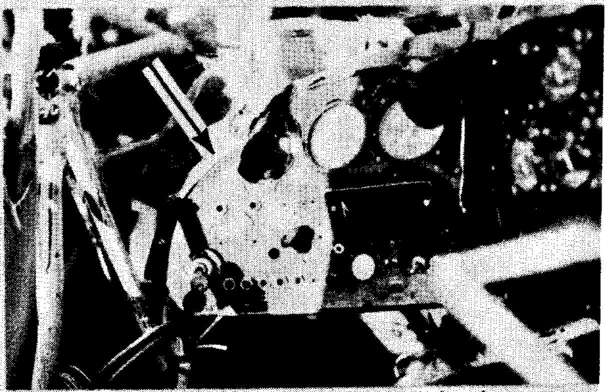


a. Overall view of a 1968 Aerocommander Callair A-9B involved in a severe crash.

b. Severity of crash forces are indicated by the fact that the hopper has disintegrated and there is a partial failure of the cockpit.

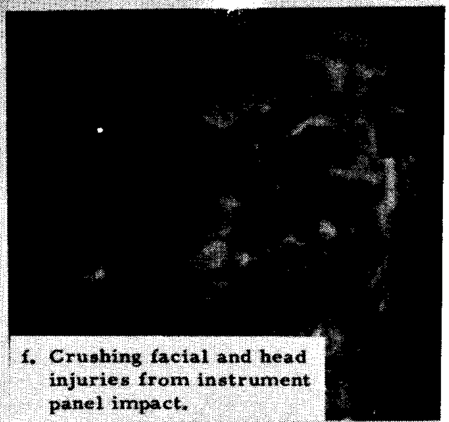


c. View into cockpit showing seat belt & shoulder straps. Pilot was utilizing only one shoulder strap tied to lap belt.



e. View of left instrument panel showing facial impact area. Note the absence of the protective aluminum semicylinder pointed out on the Pawnees & Callairs.

d. Single shoulder strap tied to lap belt. Note the 3-in. belt broke on both sides of buckle at approx. contact points of iliac crests of pelvis.



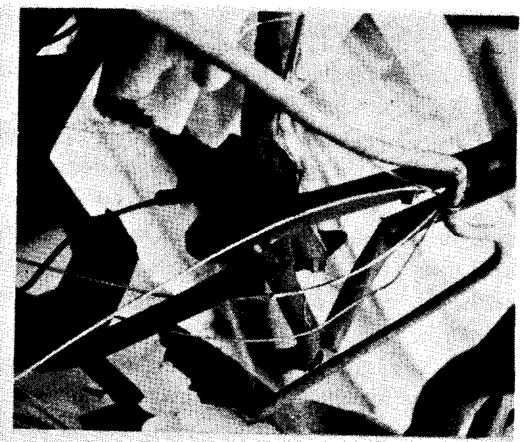
f. Crushing facial and head injuries from instrument panel impact.

This was a severe crash but would probably have been survivable if both shoulder straps had been in use, if the belt had not been weakened by age, and/or if the instrument panel had been equipped with the Pawnee type aluminum roll. Pilot also suffered fractures of both arms and both legs--all from forward body motion after restraint failure.

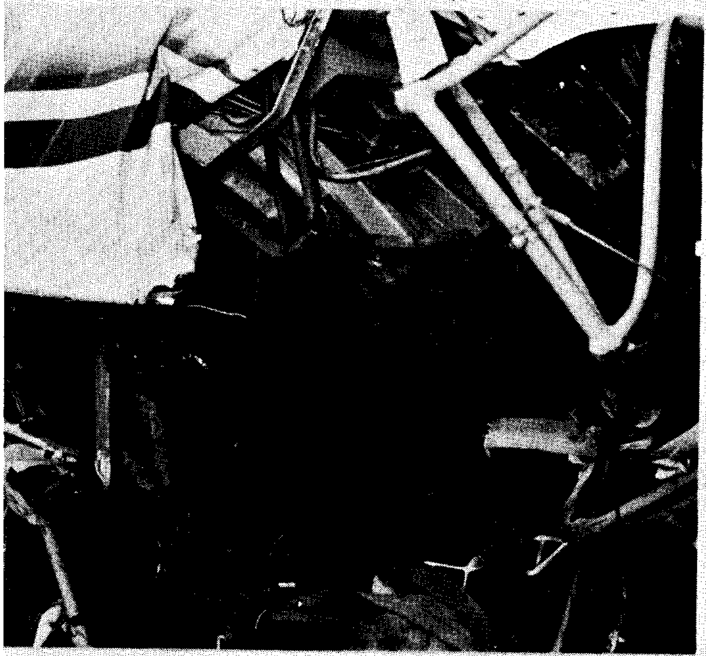
Accident investigated by J. Blethrow.

# CASE 15

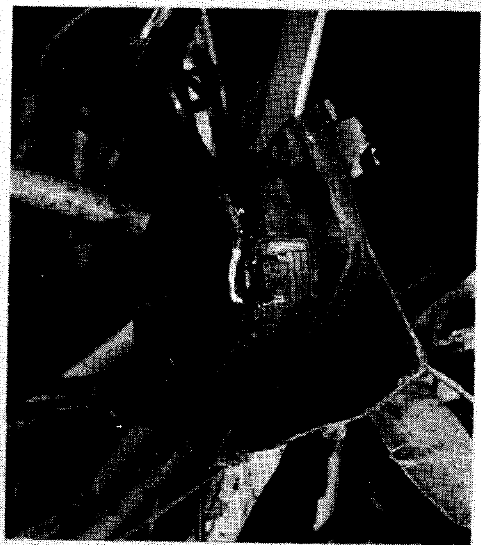
a. Side view of a very severe crash.



b. Upward bending of inertia reel and lap belt attachment points to lower fuselage tubing behind the cockpit.



c. Almost complete failure of cockpit cabin integrity. Note that the lap belt did not fail.



d. Inertia reel torn loose by crash forces.

This 1964 Piper Pawnee (PA-25-235) aircraft was involved in a crash of such severity that it would probably have to be classified as non-survivable. Injuries fatal to the pilot consisted of severe facial lacerations, severe fractures of both legs, fractures of all ribs on the left side, and a ruptured heart.

Accident investigated by T. Wallace.

# CASE 16

## IV. Conclusions.

The modern fleet of aerial applicator aircraft that have incorporated the crashworthy design features of the AG–1 are, indeed, a rugged breed of aircraft. Some pilots are undoubtedly surviving crashes equalling 30 to 40 G's or more with minor or no injuries. On the other hand, fatalities and serious injuries are occurring in crashes of much lower deceleration. The analysis of crash injuries presented in this study has shown that most injuries and deaths in aerial applicator crashes are not attributable to failure of cockpit structure itself, but rather to factors associated with pilot restraint and/or seat failures, failure of the roll-over structure, and lack of head impact attenuators at the top of the instrument panel.

Based upon our observation, it is concluded that increased survival and reduced injuries would accrue if the following modifications were made:

1. Equip all aircraft with inertia reels;

2. Attach all inertia reels to structure that i least likely to deform or fail during a survivabl crash;

3. Strengthen lap belt and shoulder harnes cables;

4. Design the restraint system so that the pilc must wear the shoulder harness when he weai the lap belt;

5. Replace lap belts and shoulder harnesse every five years, or sooner if signs of fraying c deterioration become evident;

6. Use a more positive seat tie-down wit double lock pins;

7. Incorporate light aluminum semicylinders ( similar structures at the top of the instrumei panels of all aerial applicator aircraft to hel prevent head injuries.

Moreover, a stronger roll-over structure shoul be designed.

## REFERENCES


1. National Research Council, Committee on Aviation Medicine, Report #230, 17 Nov. 1943.
2. National Research Council, Committee on Aviation Medicine, Report #440, 9 July 1945.
3. DeHaven, Hugh: Crash Research From the Point of View of Cabin Design. *Aeronautical Engineering Review*, Vol. 5 #6. Jan. 1946.
4. DeHaven, Hugh: Development of Crash-Survi Design in Personal, Executive and Agricultural A craft. Crash Injury Research, Cornell Univers Medical College, N.Y., N.Y., May 1953.
5. Hasbrook, A. Howard: What a Spray Plane Sho Have. *Aviation Week*, 13 Feb. 1950, pp. 25–31.