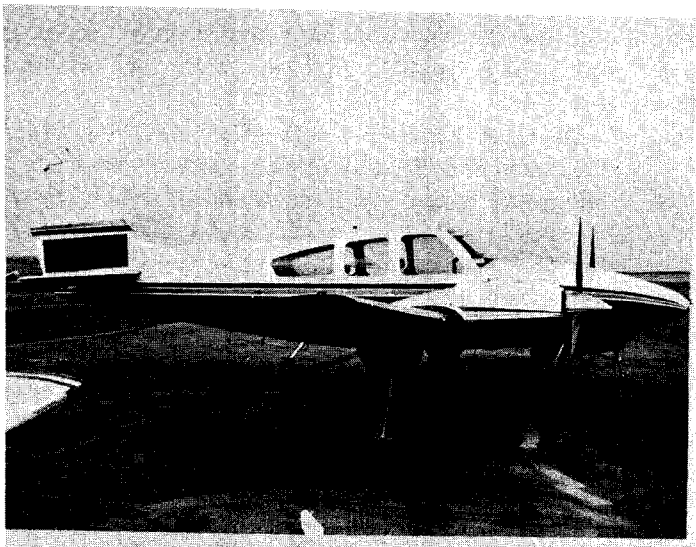
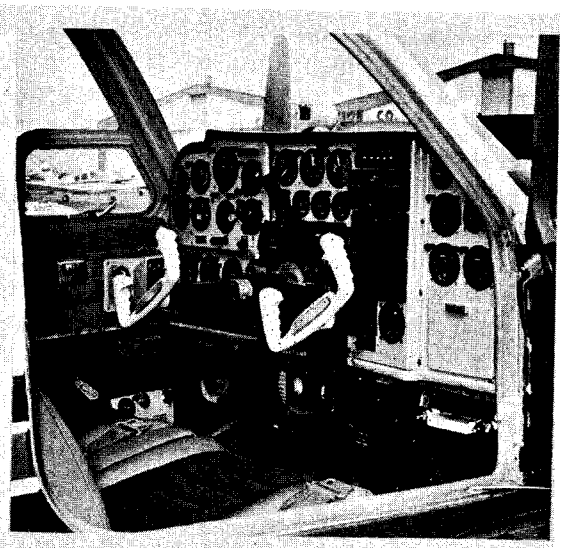




1966 BEECH BARON

BEECH BARON 95-C-55, a 1966 model aircraft with pilot and one passenger (R. F.), flew into the ground at approximately a 50° angle in a right-hand bank during bad weather. Both occupants were wearing seat belts but aircraft disintegrated, digging a hole in the ground 38 feet long, 12 feet wide, and 4 feet deep. Pilot seat belt held, but seat failed and body in the seat was found in a tree 190 feet from impact point. The passenger's seat belt buckle failed and his body was found 450 feet from impact.

ACCIDENT INVESTIGATED BY:
GALE BRADEN AND TERRY WALLACE
CAMI

CASE 1-1

A. Crater formed by aircraft impact 38' long, 12' wide, & 4' deep.

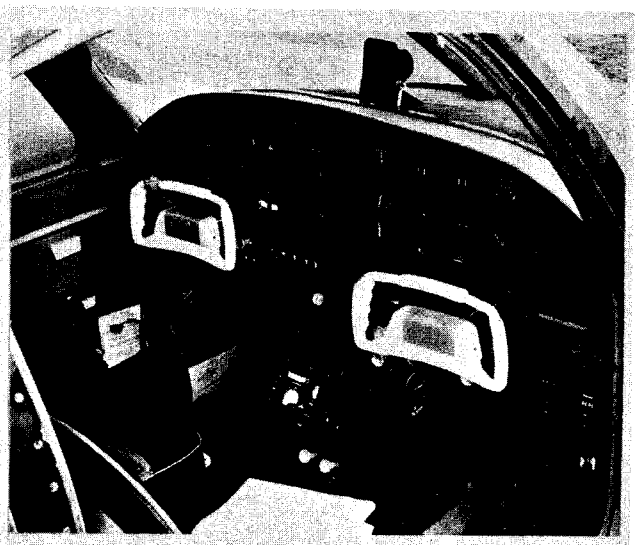
B. Broken & distorted remains of pilot control column.

C. Part of copilot's seat showing failure of tongue half of seat belt buckle.

D. Portion of instrument panel, broken, deformed & covered with tissue.

INJURIES	STRUCTURES IMPACTED
Both bodies were badly crushed (F).	Aircraft disintegration.

CASE 1-2



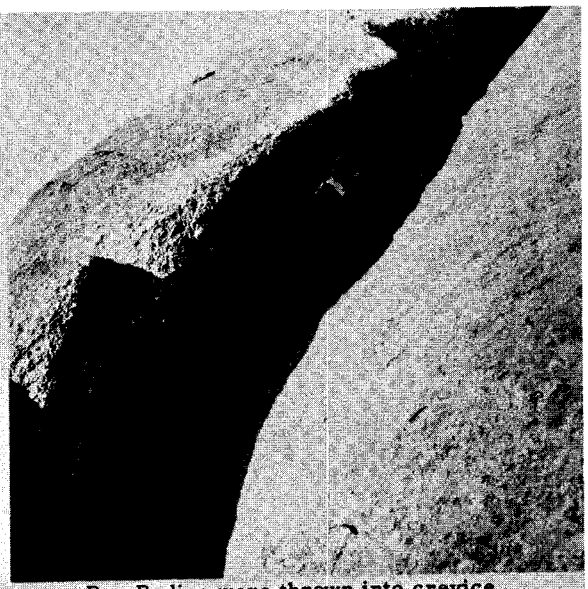
1956 CESSNA 310

CESSNA 310, a 1956 model aircraft with pilot and one passenger (R. F.), flew into the side of a solid rock mountain at full cruise velocity during a snowstorm. The aircraft disintegrated.

ACCIDENT INVESTIGATED BY:
EDDIE D. LANGSTON AND JACK BLETHROW
CAMI

CASE 2-1

A. Remains of aircraft after impact with a stone mountain. Man indicating impact point.



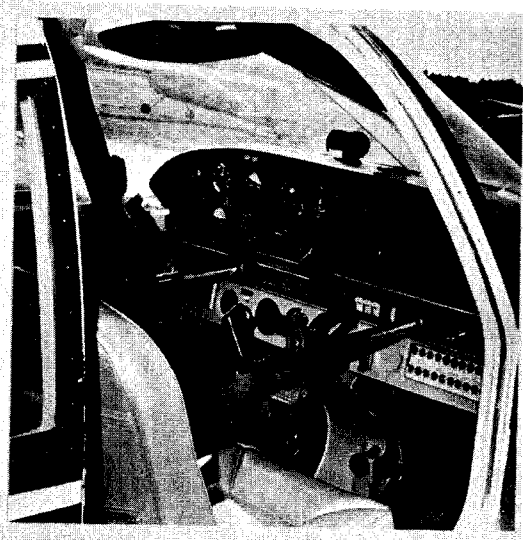
B. Bodies were thrown into crevice in the rocks.

C. Remains of passenger in right front seat.

D. Remains of pilot. Note that only his hands are not injured. They probably trailed behind the body as it was ejected from the a/c.

INJURIES	STRUCTURES IMPACTED
Both bodies were badly crushed (F).	

CASE 2-2



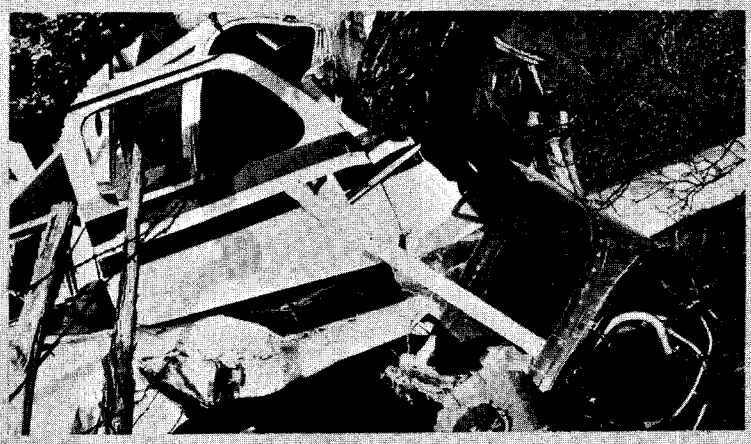
1967 PIPER CHEROKEE 180

PIPER CHEROKEE PA-28-235, a 1964 model aircraft with pilot only, flying at night, was in a very gradual descent (9^{O}). Aircraft clipped the top of some small trees and crashed into the base of a large tree two feet in diameter. The large tree trunk penetrated the aircraft at the root of the (R) wing, cut through the middle of the instrument panel and cabin, and ended up between the two front seats. The pilot was thrown forward and to the (R), impacting the tree and ending up with his legs and arms on the left side of the tree and his head and shoulders on the (R) side.

ACCIDENT INVESTIGATED BY:
GALE BRADEN AND TERRY WALLACE
CAMI

CASE 3-1

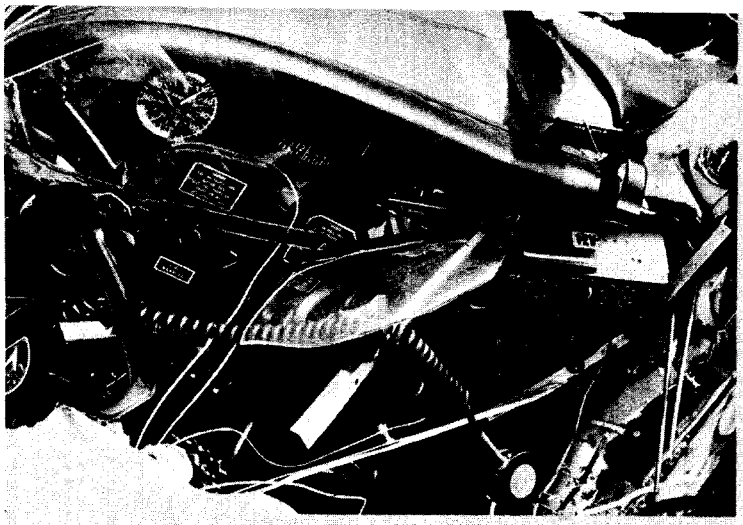
A. Overall view of aircraft impact with tree.



B. Close-up showing relative size of tree & depth of its penetration into the aircraft.

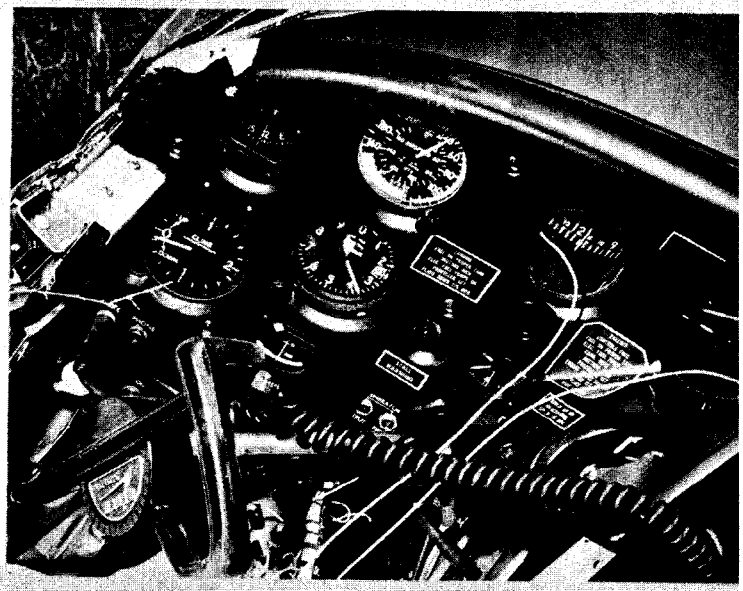
C. Inside the cabin, the tree is almost touching the front edge of the pilot's seat. An outline of a head indicates head impact area on the tree.

CASE 3-2



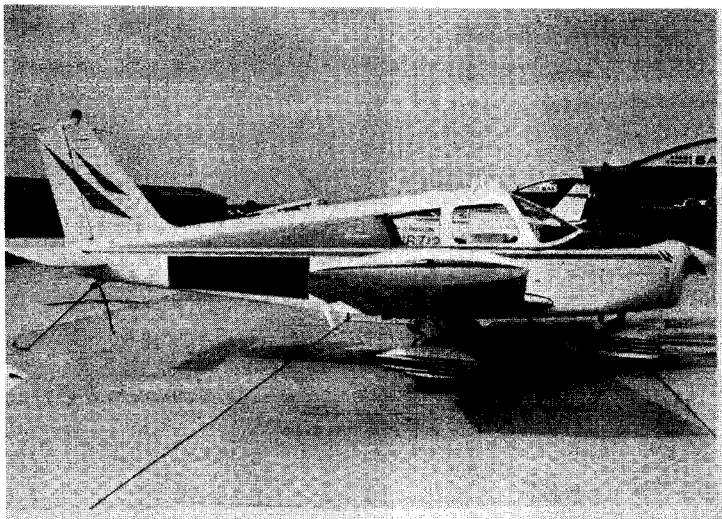
E. Right half of instrument panel sheared off by tree penetration.

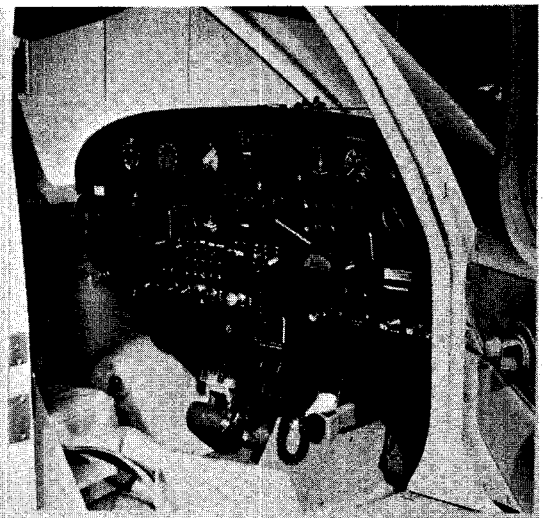
D. Left half of the instrument panel shows no signs of body impact. Note broken pieces of plastic windshield in the cockpit.



INJURIES	STRUCTURES IMPACTED
Pilot: (F) Head - Head & trunk crushed.	Tree

CASE 3-3



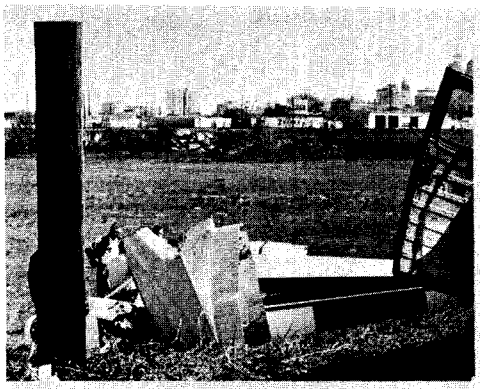


1968 PIPER CHEROKEE 140

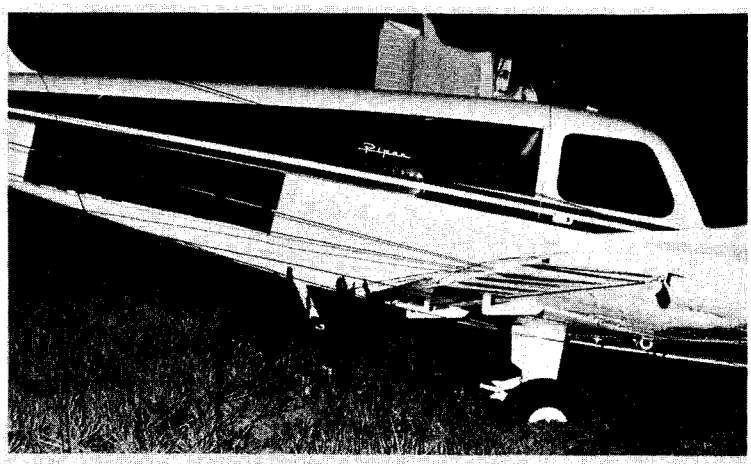
PIPER CHEROKEE PA-28-140, a 1968 model aircraft with pilot only, had taken off and climbed to 150 feet when it experienced power failure, lost altitude, and struck several strands of 1/8-inch steel telegraph wires. The aircraft traveled another 25 feet and the left wing struck a lower wooden telephone pole, turning the fuselage 90° before it reached the ground. Five strands of the steel wire were hooked around the propeller and stretched taut without breaking. These wires served as an arresting gear allowing the aircraft to decelerate with very little "g" force. Seat belt was in use and held. No shoulder harness was installed.

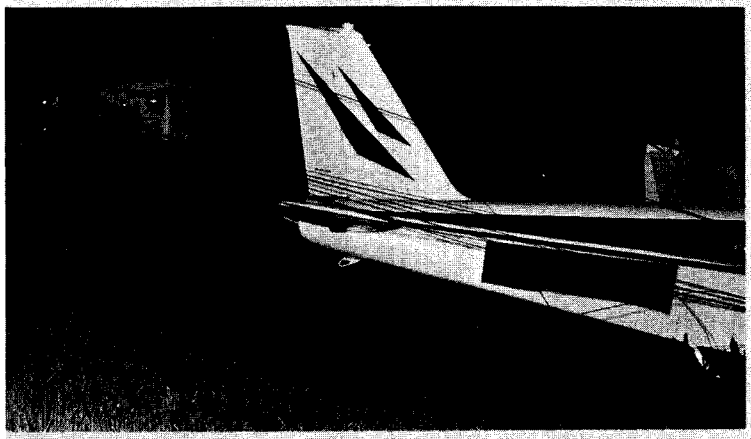
ACCIDENT INVESTIGATED BY:
TERRY WALLACE
CAMI

CASE 4-1

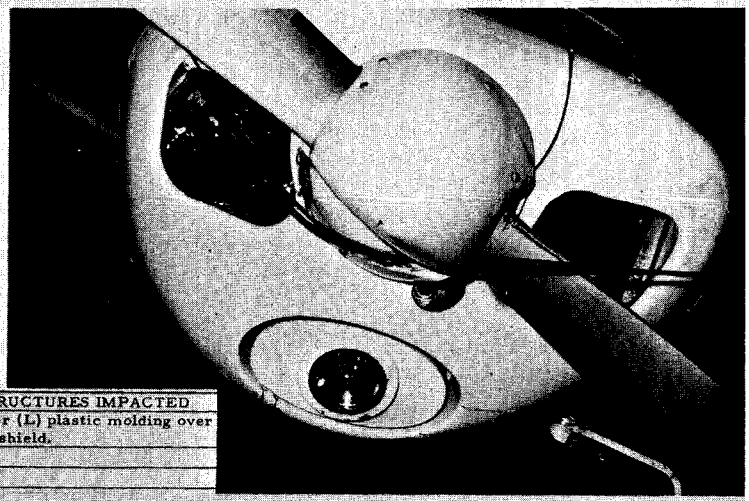


A. Aircraft after left wing impacted telephone pole.





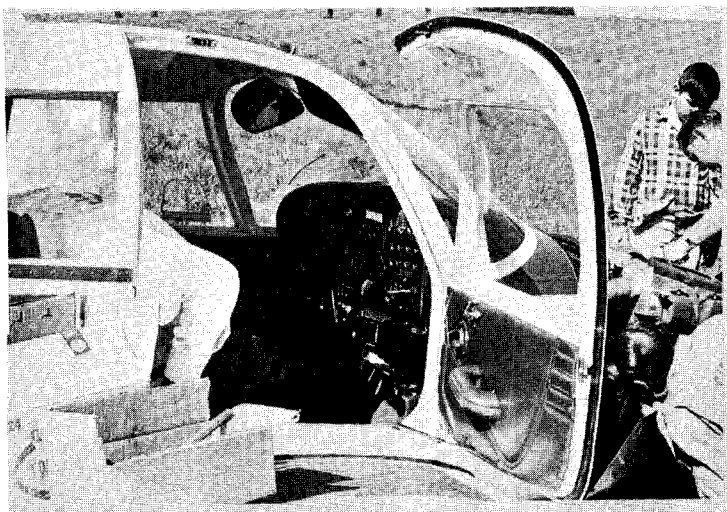
B. Five strands of steel telegraph wires stretched taut along sides of the fuselage.



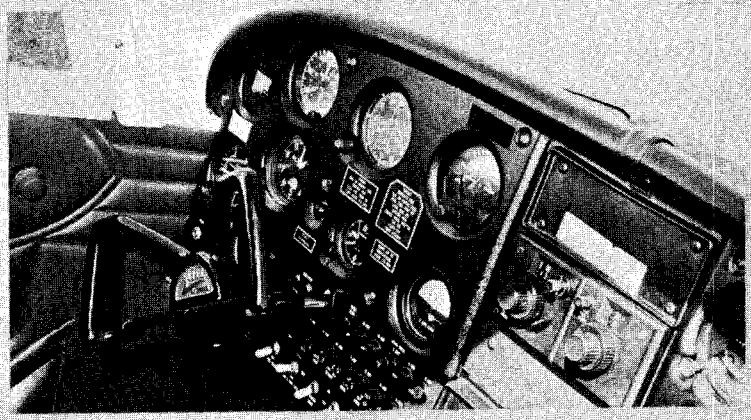
C. Front view showing wires hooked on propeller.

	INJURIES	STRUCTURES IMPACTED
Pilot: (S)	Head - Slight bump on forehead knocked his glasses off.	Upper (L) plastic molding over windshield.
	Trunk - None.	
	Extremities - None.	

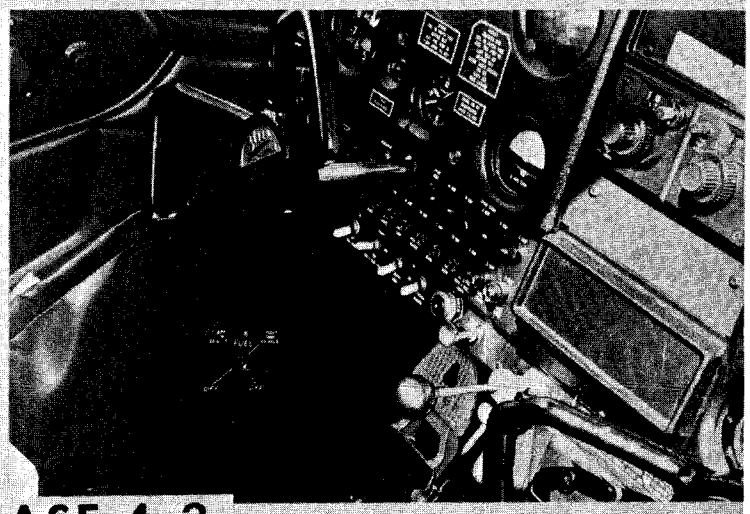
CASE 4-2



D. General view of cabin interior.



E. Upper left instrument panel. No damage from head impact.



F. Lower left instrument panel. No damage from knee impact.

CASE 4-3

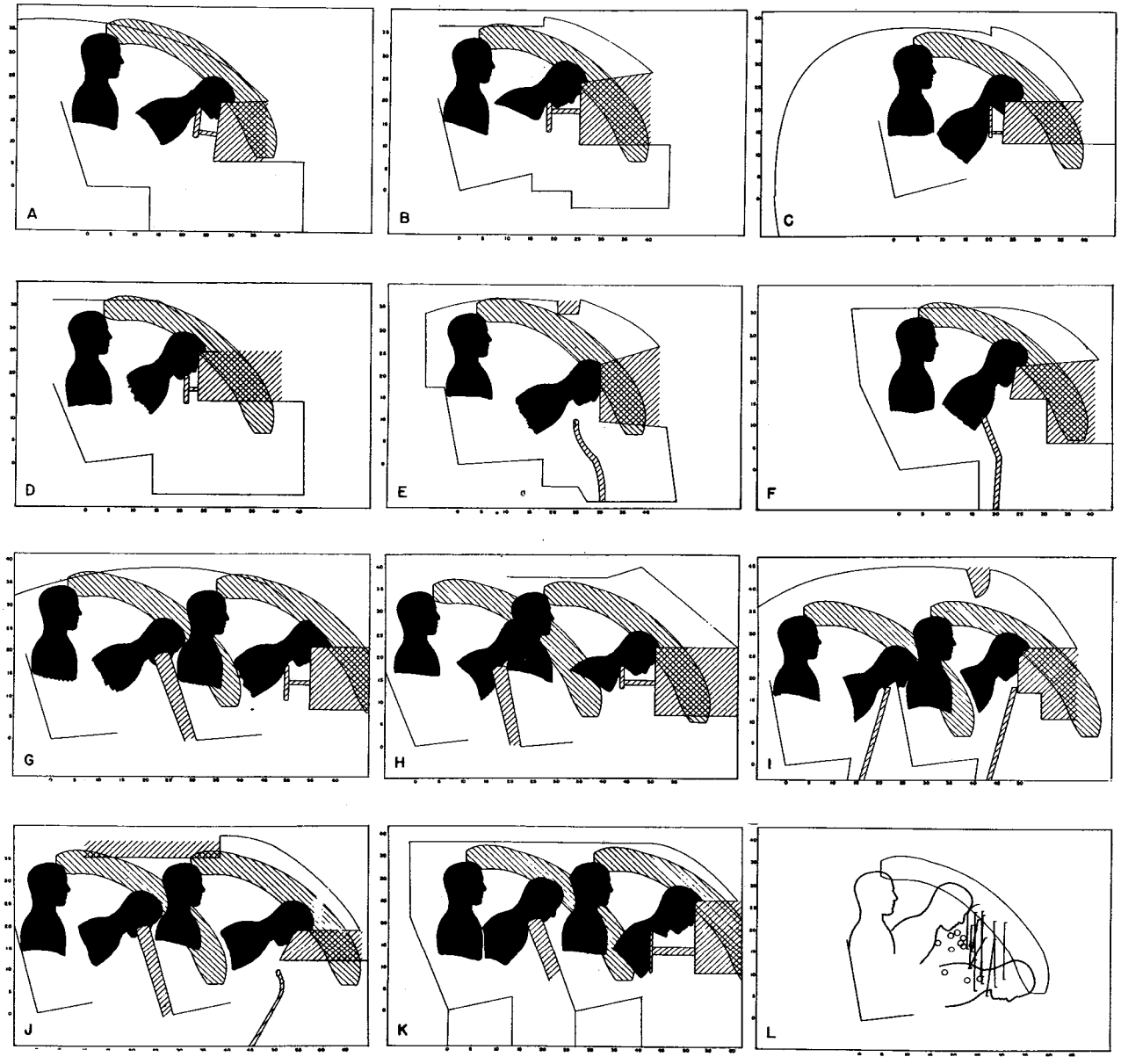


FIGURE 1. Minimum head clearance as related to 11 popular personal type aircraft.

In Case Number 5 a Piper Comanche PA 24–250 (1962) skidded 305 feet on muddy ground before coming to rest. Assuming a flight velocity of 65 miles per hour just before initial contact with the ground, one can calculate an average deceleration of less than ½ "g". However, since the pilot received a 5-inch laceration across the top of both eyebrows from striking the top edge of the instrument panel, we can safely state that at one point the deceleration slightly exceeded

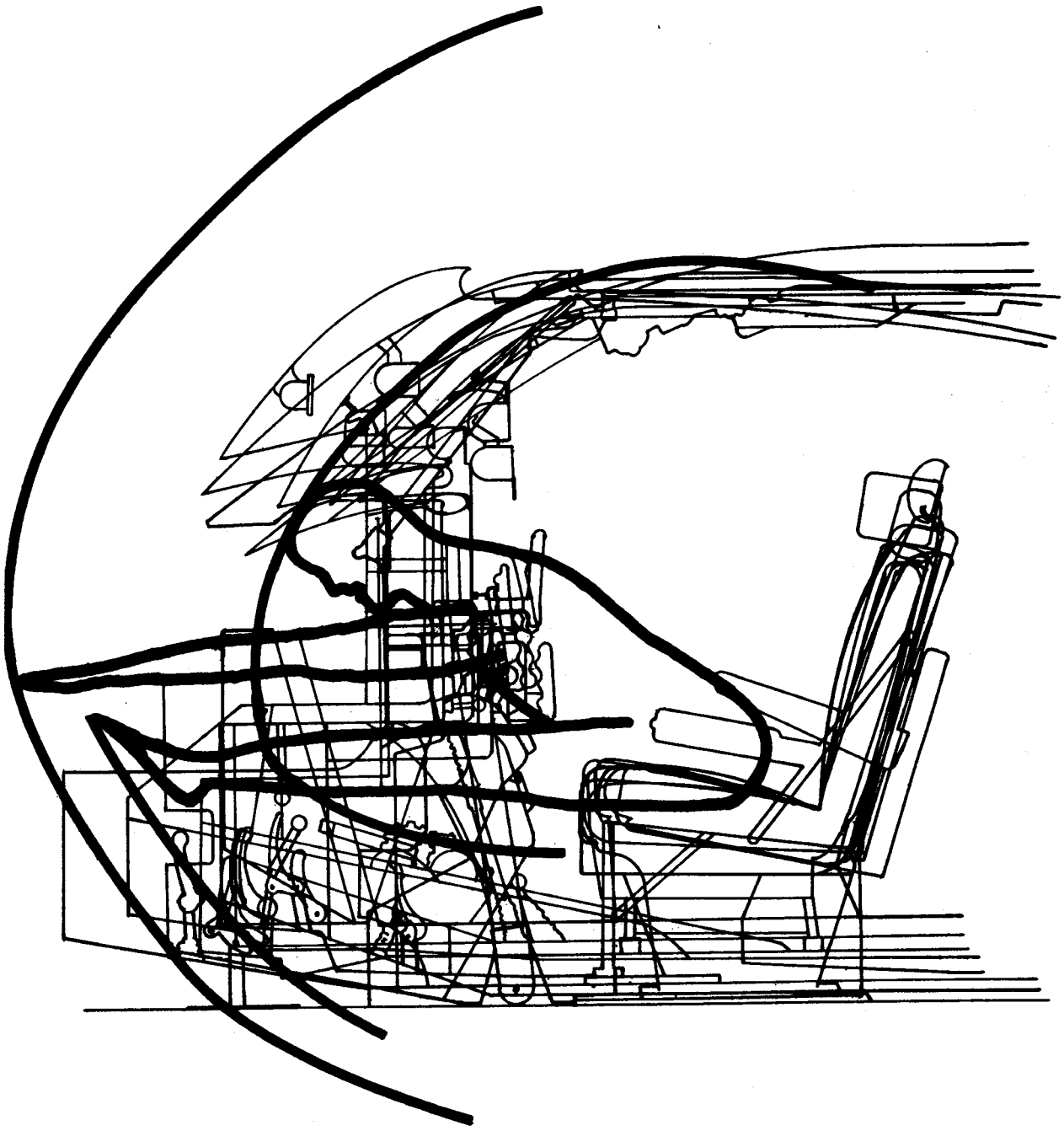
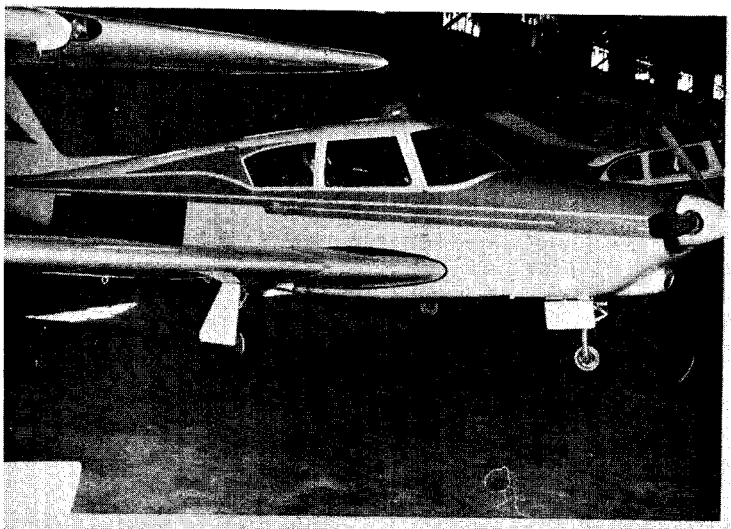
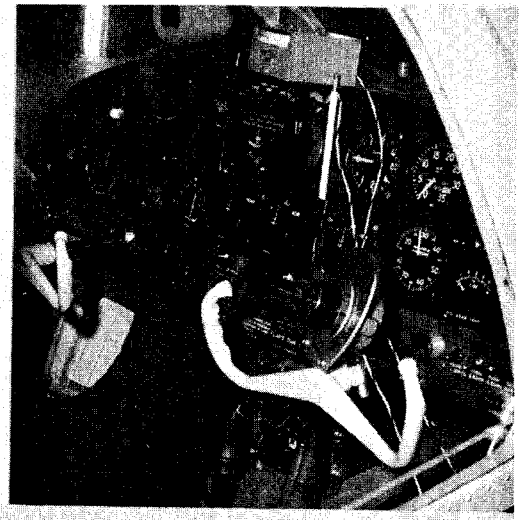


FIGURE 2. Area of forward flailing (95th percentile) with seat belt restraint, superimposed on scale drawings of 11 general aviation aircraft.

2.5 "g" (reference Case 4), probably during initial impact where the aircraft was changing direction. More severe facial injuries were probably not sustained since the pilot's head hit a relatively flat arc of the instrument panel (Case 5 C), and since a significant portion of the forward force of the head and trunk was dissipated when the chest struck the control yoke fracturing several ribs as well as the horns on the yoke.





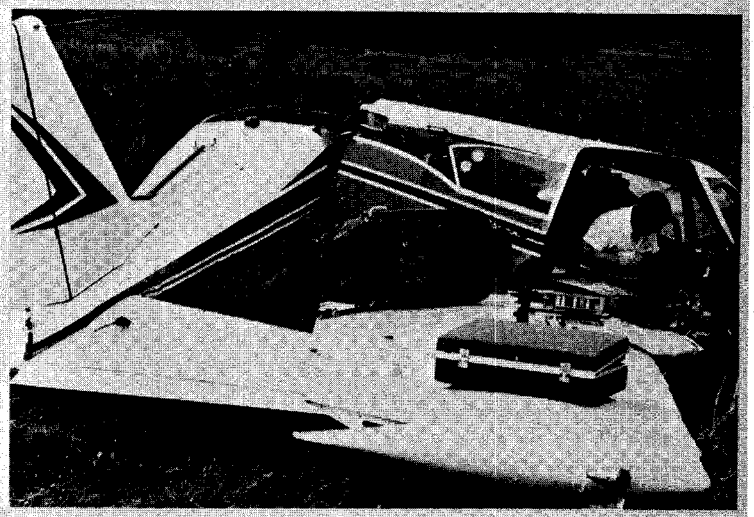
1963 PIPER COMANCHE

PIPER COMANCHE PA-24-250, a 1962 model aircraft with pilot and three passengers (R. F., L. R., R. R.), encountered bad weather and struck muddy ground in a flat attitude and skidded 305 feet over a small hill. All occupants were wearing seat belts and they held. No shoulder harnesses were in the aircraft.

ACCIDENT INVESTIGATED BY:
GALE BRADEN AND EDDIE LANGSTON
CAMI

CASE 5-1

A. Path taken by aircraft during 305-foot deceleration.

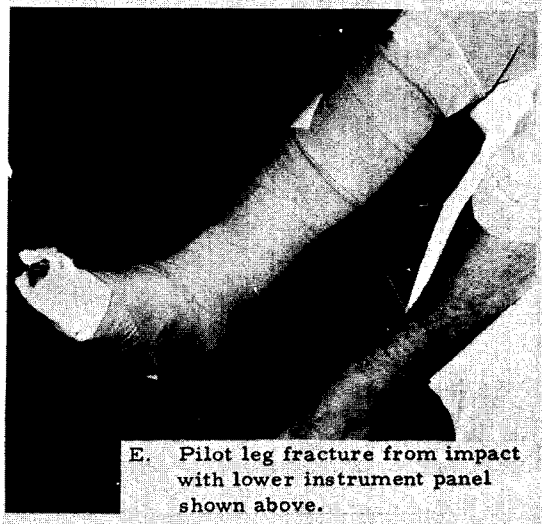


B. Final attitude of aircraft. Tail section separated at the rear of the cabin & turned 90°.

CASE 5-2

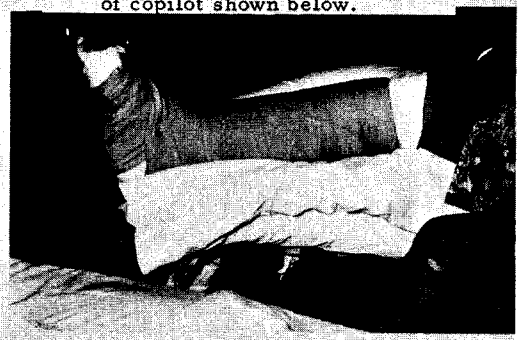
C. Left half of instrument panel showing head impact and broken control wheels.

D. Pilot with 5-inch laceration from contact with upper instrument panel.



E. Pilot leg fracture from impact with lower instrument panel shown above.

F. Lower left instrument panel. Heavy radio fractured right leg of copilot shown below.



	INJURIES	STRUCTURES IMPACTED
Pilot: (S)	Head - Large transverse lac. across both eyebrows & above nose.	Top edge of instrument panel.
	Trunk - Fx. ribs lower (L) chest.	Control wheel.
	Extremities - Fx. (R) talus.	Pedal area.
R. F.: (S)	Head - "V"-shaped lac. (L) eyebrow. Lac. nose, (R) upper eyelid & (R) brow.	Upper instrument panel.
	Trunk - None.	
	Extremities - Lac. (L) knee.	Lower instrument panel.
L. R.: (S)	Head - None.	
	Trunk - None.	
	Extremities - Fx. (R) ankle.	Wedged under front seat.
R. R.: (S)	Head - Fx. nose.	Back of front seat.
	Trunk - Chest pains (no Fx.).	Back of front seat.
	Extremities - Sprained ankles (R) & (L).	Under front seat.

CASE 5-3

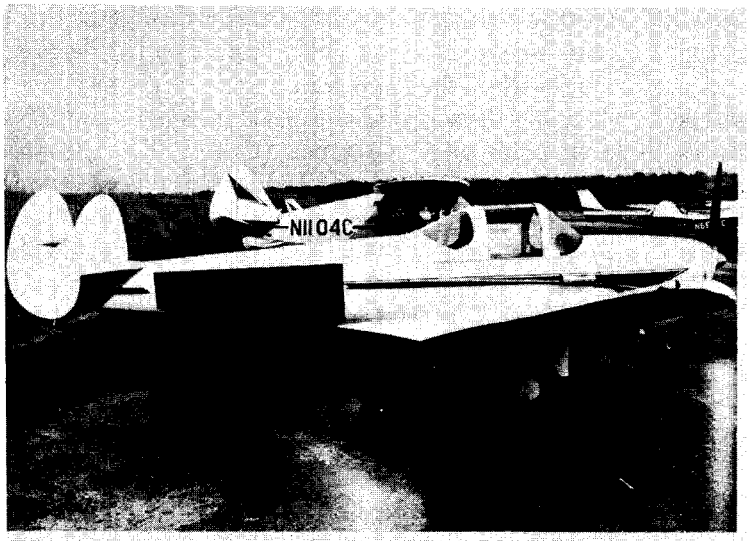
In Case Number 6, photographs are shown of the right front passenger with crushing fractures of the nose and right maxillary sinus along with severe lacerations of the nose and frontal sinus area (Case 6 K & L) received when he jackknifed over his seat belt and impacted the top edge of the instrument panel at the point indicated by the head outline (Case 6F). Since this Ercoupe 415–C (1946) skidded 114 feet before coming to rest, an average deceleration of slightly over one "g" can be calculated, assuming an impact velocity of 95 ft./sec. However, as discussed earlier, one can brace against a one "g" impact and it must be assumed that since he hit the ground at about a 30° angle, the deceleration forces were somewhat higher than one "g" during a few milliseconds time span. Again, as in Case 5, the chest contacted the control wheel and evidently the occupant was able to hang onto the rim with sufficient strength to deform the wheel toward the instrument panel (Case 6 G), probably reducing the head impact velocity to a point that barely prevented the fatal head injuries. It is impossible to calculate the exact velocity of head impact, but based upon the author's studies of tolerances of the human face to crash impact (to be discussed later), the author estimates that the head impact velocity could not have been more than 15 ft./sec. in this case. Since the stopping distance of the head was about one inch (¼ inch dent in panel +¾ inch crushing of facial bones), the deceleration of the head may be calculated to be 42 "g". The human face cannot tolerate this magnitude of deceleration force on two square inches of area (see tolerances of face discussed later). We begin to appreciate the head injuries which may occur at cabin decelerations as low as three "g" when the impact force must be absorbed on small areas of the head.

Case Number 7 describes a later model (1966) Cessna 150F that crashed with a calculated average deceleration of 6.93 "g". The pilot's seat belt held and his upper torso was thrown slightly to the right, allowing his face to impact the upper center instrument panel. Crash sled testing in this laboratory indicates that the seat belt restrained occupant will impact the instrument panel with a head velocity of nearly 40 ft./sec. during a 7 "g" deceleration of the aircraft. Fortunately for this pilot, he impacted his chest on a control wheel designed to fit the contour of the rib cage bending the control column to the right and down with only a slight contusion of the chest and right shoulder (Case 7 F) and slowing his head velocity to a point (estimated 18 ft./sec.) that he survived with very severe facial injuries. Especially worthy of note at this point is the needless deep laceration (8 inches long) across the chin and right cheek inflicted when his face slid down and engaged the thin cover plate over the radio (Case 7 E). Teeth marks in the same figure indicate that his upper teeth and hard palate were destroyed when he impacted the top edge of the instrument panel just above the key insert.

In Case Number 8 a 1959 Piper Comanche PA 24–250 wiped its landing gear off by striking an earthen embankment around a farm pond and slipped over the embankment into the pond. The deceleration was again determined to be in the 5 to 6 "g" range. The pilot and copilot were thrown forward, impacting their heads at the two points clearly indicated on the instrument panel (Case 8 E), causing severe, but survivable, facial lacerations. Post-mortem examination revealed that the two front seat occupants were rendered unconscious and drowned when the plane sank. An autopsy was not performed on the rear seat passenger, but since rear seat occupants usually receive less severe injuries it is very probable that he also drowned.

Crash Case Number 9 was almost identical to the previous case described, the difference being that this Piper PA 22–135 (1959) aircraft did not end up in the water and all five occupants survived. Total ground contact stopping distance was 84 feet after contact with the fence and it is doubtful if the maximum deceleration force exceeded 5 "g". Head impact depressions of the two front seat occupants were clearly visible in Case 9 C and D. There were no trunk or leg injuries and the three children in the rear seat received only bruises.

In evaluating Crash Cases 4 through 9 (all of which must be classed as minor) in terms of the four principles of packaging presented earlier, we can conclude that general aviation aircraft pretty well meet the first principle (container or cabin integrity) as long as the crash impact does not exceed 6 or 7 "g". However, the other rules for safe packaging have been almost completely ignored, the exception being that means are provided for restraining the long, flexible, fragile contents only at their central points—



1946 ERCOUPE

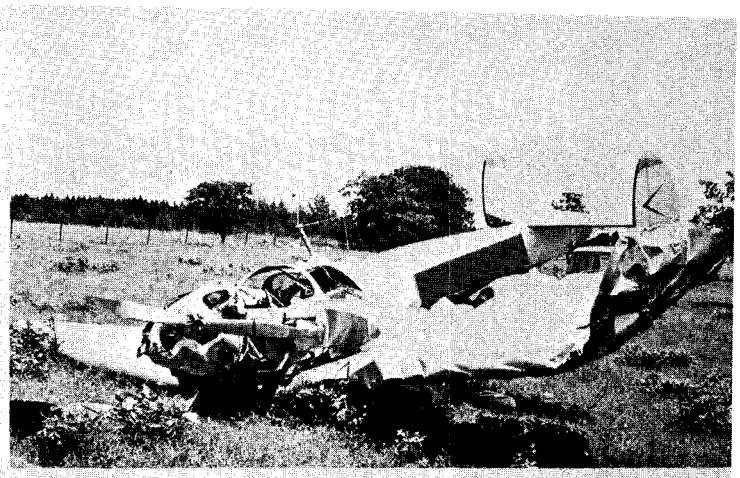
ERCOUPE 415-C, a 1946 model aircraft with pilot and one passenger (R. F.), circled low over a farm house, reduced power to talk to someone on the ground, and crashed at a 30° angle on a hard pasture land, skidding 114 feet before coming to a stop. The impact force threw both occupants forward and slightly to the left. Seat belts (attached to the fuselage) were in use and held. There were no shoulder harnesses in the aircraft.

(Note: Aircraft does not have rudder pedal.)

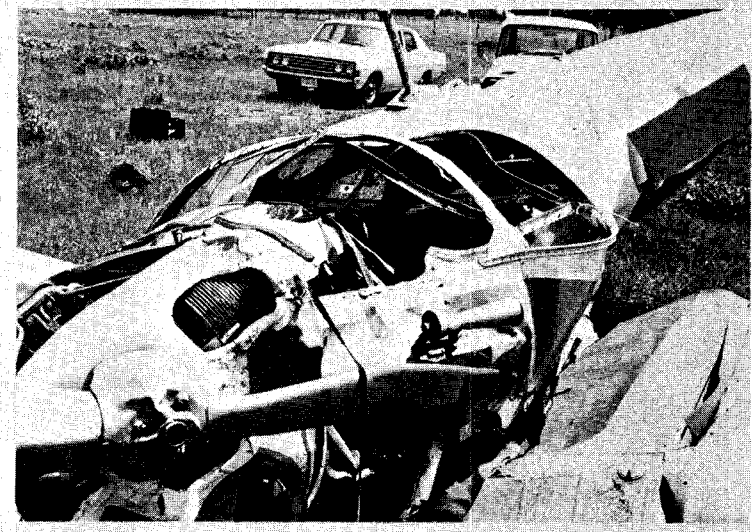
ACCIDENT INVESTIGATED BY:
GALE BRADEN
CAMI

CASE 6-1

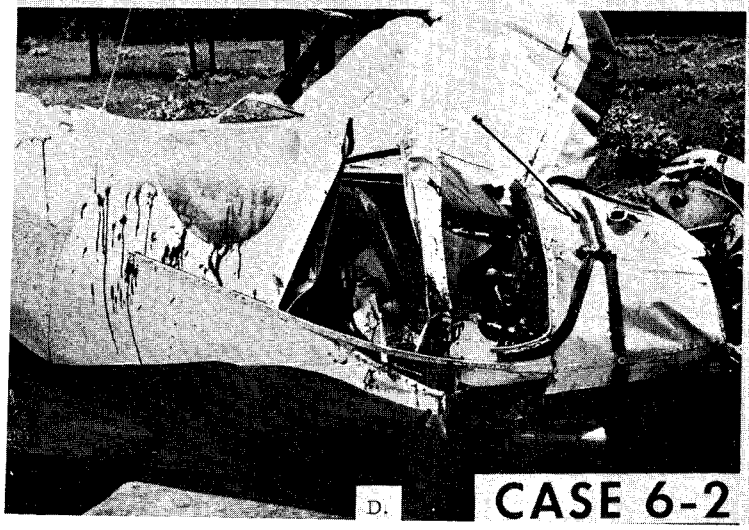
A. Distant view of resting aircraft & part of its 114-foot skid mark.



B.



C.

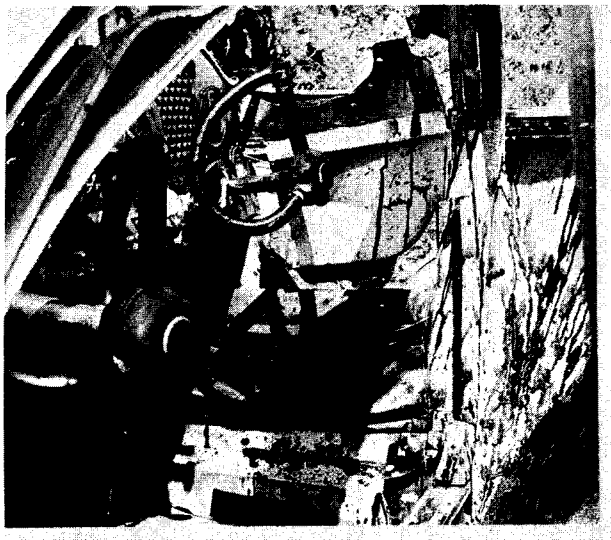


D.

B C D

Close-up views of the exterior of the aircraft. The cabin maintained its integrity. The plastic windshield disintegrated & some outward buckling of the sides of the cockpit may be noted.

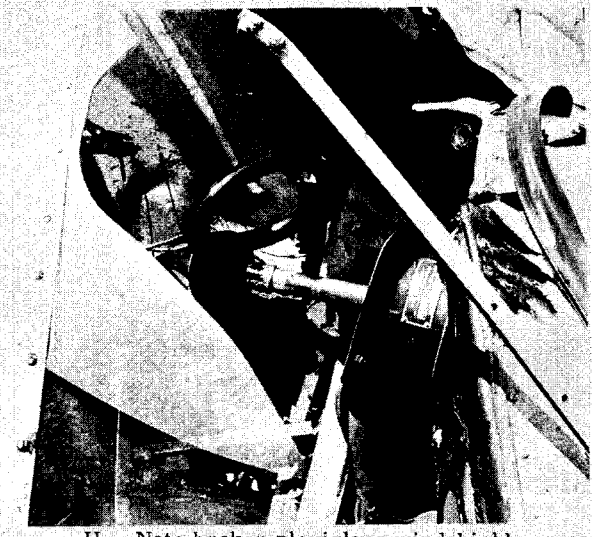
CASE 6-2



E. Internal view of cockpit. Note control wheel rims bent forward.

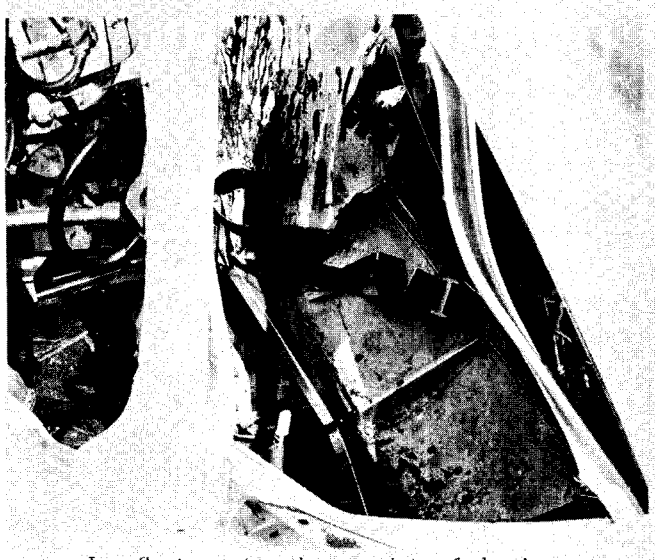
F. Head outline & dent in upper right instrument panel indicate head impact of copilot.

G. Area of body impact of pilot.



H. Note broken plexiglass windshield.

CASE 6-3



I. Seat construction consists of aluminum buckets for cushions shown in J.

J. Seat cushions.

K & L Side & frontal views of facial injuries suffered by copilot when his head hit the top corner of the instrument panel (Figure F).

	INJURIES	STRUCTURES IMPACTED
Pilot: (S)	Head - Lac's. scalp & forehead.	Windshield.
	Trunk -None.	
	Extremities - Lac's. both wrists, open Fx. (R) radius & ulna, closed Fx. (R) hand. Lateral ligament tear (L) ankle.	Instrument panel, after hands tore free of control wheel. Left cockpit wall.
R. F.: (S)	Head - Crushing Fx's. nose & (R) maxillary sinus. Severe lac's. nose & (R) frontal sinus area.	Top edge of instrument panel.
	Trunk -None.	
	Extremities - None.	

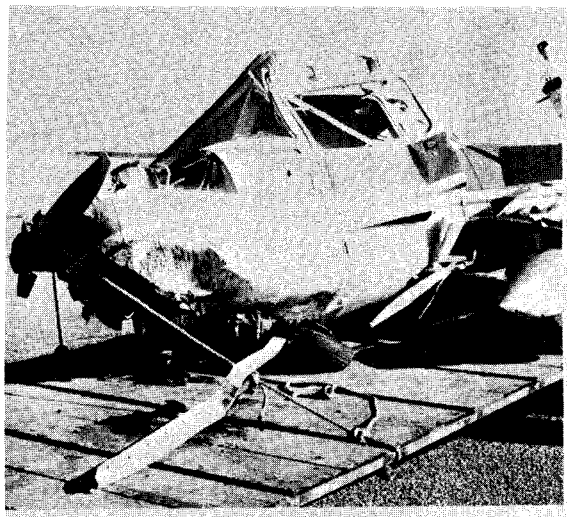
CASE 6-4

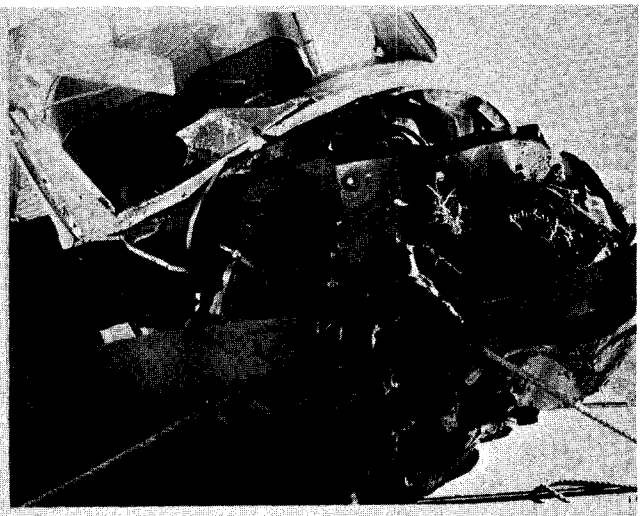
1966 CESSNA 150

CESSNA 150 F, a 1966 model aircraft with pilot only, was observed circling a farm house. Aircraft pulled up - stalled - crashed at a steep angle, left wing first. Engine was pushed to the right. Seat belt was in use. No shoulder harness was in the aircraft. Pilot's head and trunk were thrown slightly to the right.

ACCIDENT INVESTIGATED BY:
DON ROWLAN AND TERRY WALLACE
CAMI

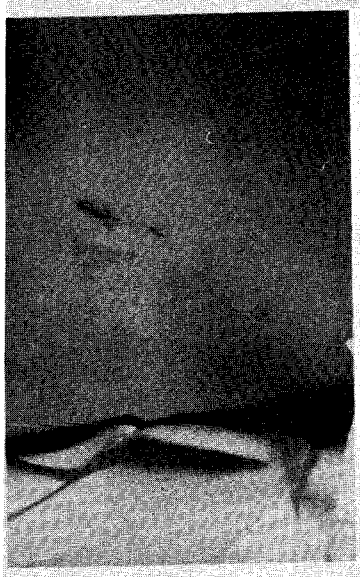
CASE 7-1



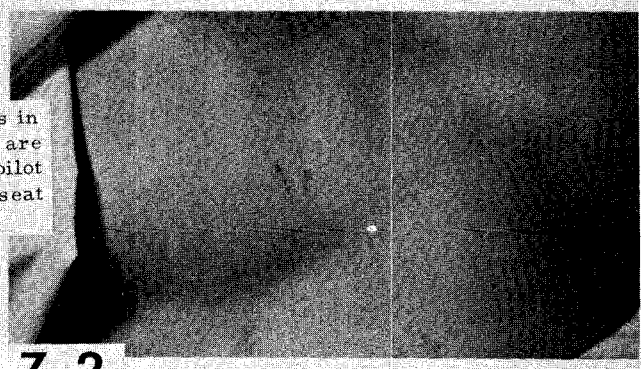


A & B Slight damage to the motor & cabin are indicative of a minor crash impact.

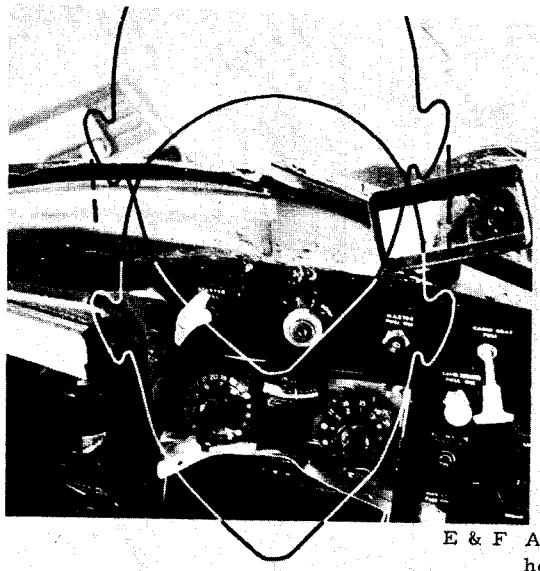
	INJURIES	STRUCTURES IMPACTED
Pilot: (5) Head -	Evulsed Lac. over (R) eye, both eyes swollen shut, all upper teeth & soft palate destroyed.	Upper center instrument panel.
	Deep Lac. 8" long across chin & cheek.	Radio cover plate.
Trunk -	6" contusion mid-line of chest & (R) shoulder.	Control wheel.
	Seat belt marks on abdomen & pelvis.	Seat belt.
Extremities -	Arms & legs, minor abrasions & bruises.	Instrument panel.

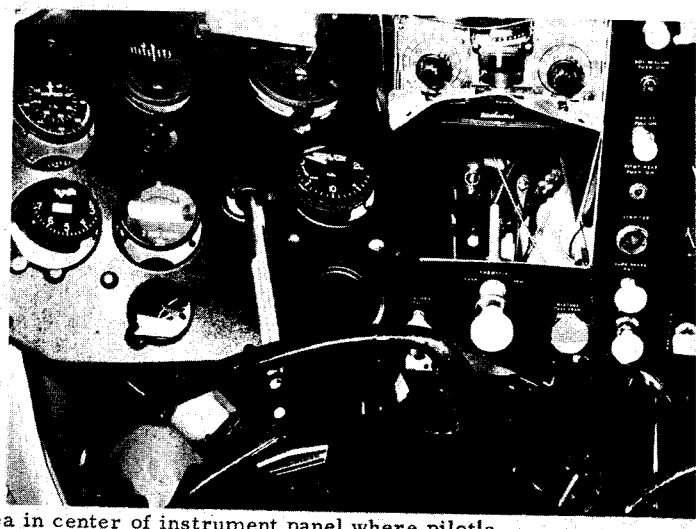


C & D Minor abrasions in the pelvic area are proof that this pilot was wearing a seat belt.

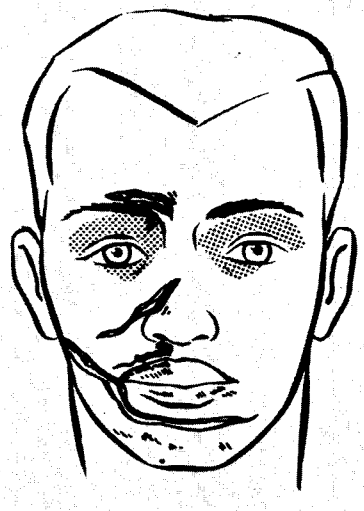


CASE 7-2



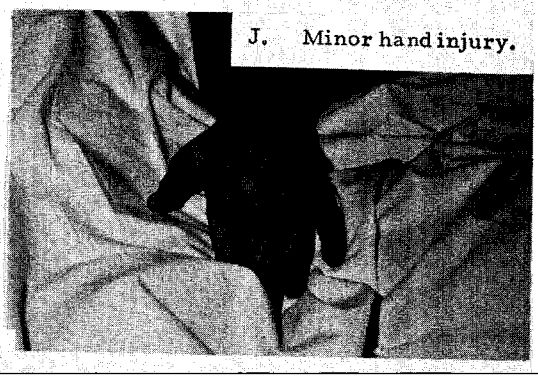


E & F Area in center of instrument panel where pilot's head struck. Note teeth enamel above key insert and sharp edge of radio cover plate.



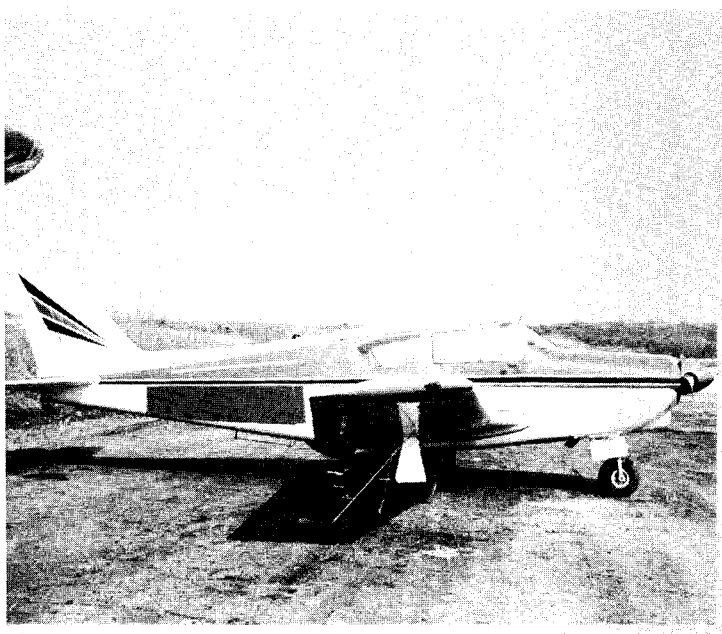
G & H Artist sketch & actual photograph of severe facial injuries inflicted.

I. Minor abrasion on pilot's chest indicating contact with the control wheel.



J. Minor hand injury.

CASE 7-3



1959 PIPER COMANCHE

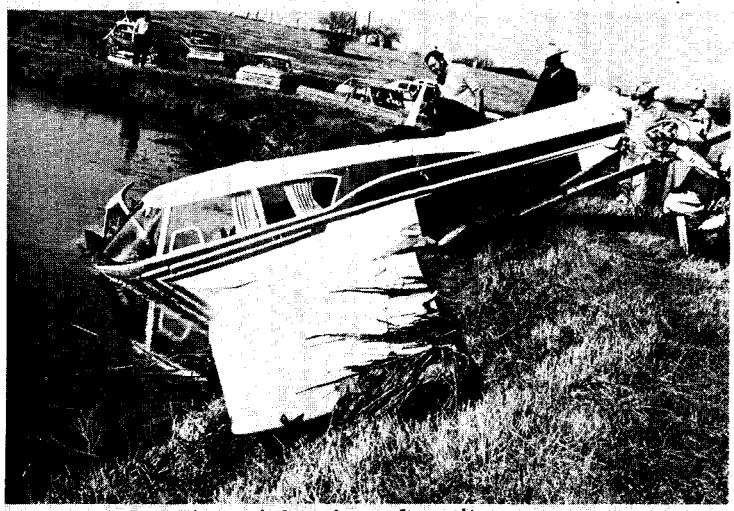
PIPER COMANCHE PA-24-250, a 1959 model aircraft with pilot and two passengers (R. F. and ?R.), failed to clear a fence on takeoff, struck the fence with its landing gear, and traveled 420 feet before making ground contact. The gear and nose struck on the earthen dam of a farm pond. The aircraft then bounced over the dam and sank in the pond about 20 feet from the bank, after floating for two or three minutes. The aircraft was equipped with seat belts, but only the R. F. was in use and it held. No shoulder harnesses were installed. Occupants were thrown forward and to the left.

ACCIDENT INVESTIGATED BY:
GALE BRADEN
CAMI

CASE 8-1

A. Blacktop landing strip with 4' fence across the end. Landing gear of aircraft hooked fence on take-off.

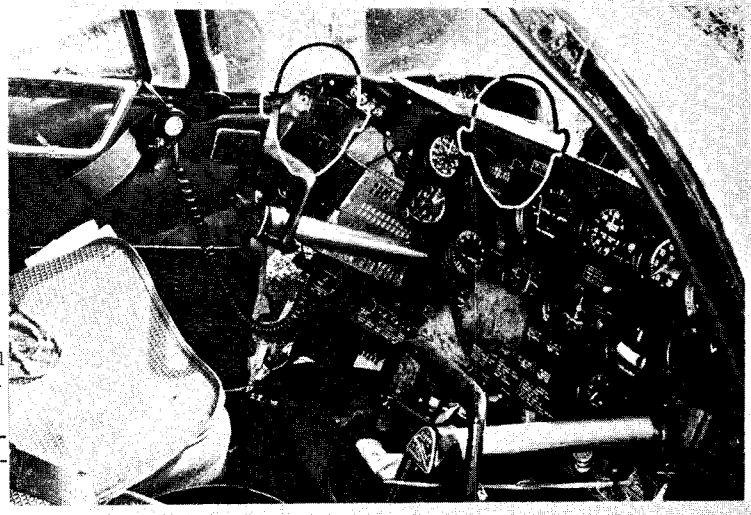
B. After traveling 420 feet in the air, aircraft impacted this dirt embankment, tore off its gear, and slid over into the pond.



C. View of the aircraft as it was pulled out of the pond. Note cabin is entirely intact.

CASE 8-2

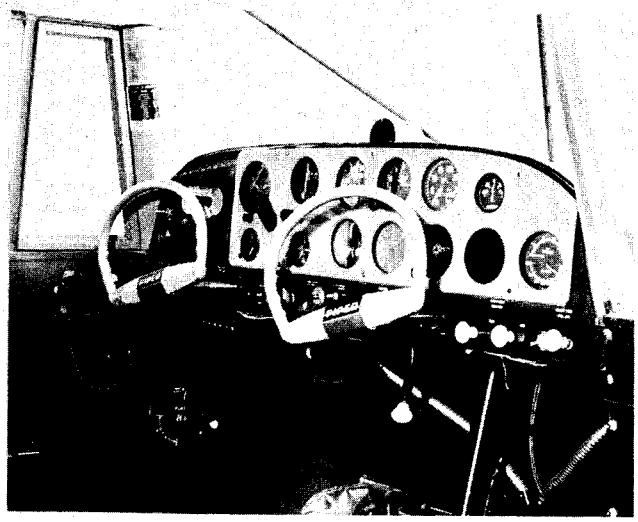
D. General appearance of cabin interior.



E. Head outlines indicate dented areas at top edge of the instrument panel produced by head impacts of two front seat occupants - all were knocked unconscious & drowned.

	INJURIES	STRUCTURES IMPACTED
Pilot: (F)	Head - Irregular V-shaped lac. to bone (L) front parietal scalp 4 cm. & 7 cm. Lac. (L) side of neck 2 cm.	Upper (L) instrument panel. Knocked unconscious & drowned.
	Trunk - None.	
	Extremities - None.	
R. F.: (F)	Head - 4 cm. lac. (L) lateral inferior mandible. 2 cm. lac. (L) lateral inferior mandible.	Top center of instrument panel. Knocked unconscious & drowned.
	Trunk - None.	
	Extremities - None.	
?R: (F)	Injuries unknown - drowned.	

CASE 8-3



1953 PIPER PA-22

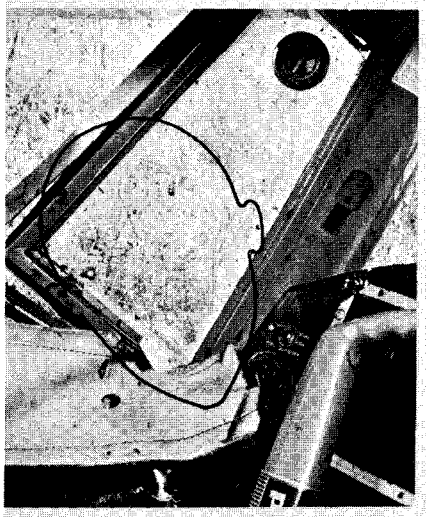
PIPER PA-22, a 1953 model aircraft with pilot and four passengers (R. F., L. R., C. R., and R. R.) (three children in the rear seat) had taken off and was about two miles from the airport. The motor started missing and the pilot had started to return to the airport when the motor stopped and he attempted to land in a field. The (L) wing tip and landing gear (L) struck the top strand of a four-foot high fence. The aircraft traveled 21 feet and struck the ground, skidded 36 feet, left the ground for 30 feet, impacted again and skidded an additional 48 feet. The aircraft came to rest on the (L) wing and nose. Seat belts were in use and held. No shoulder harnesses were installed. Occupants were thrown to the (L) and forward.

ACCIDENT INVESTIGATED BY:
BILL REED AND LEE LOWREY
CAMI

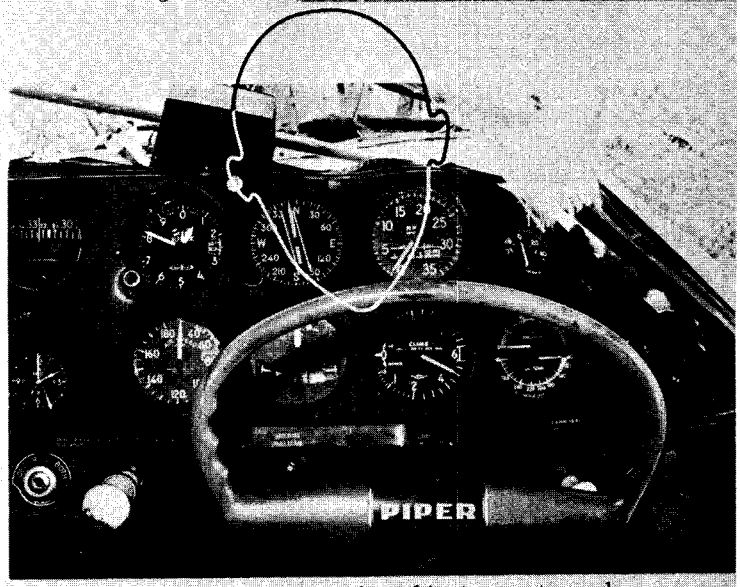
CASE 9-1

A. Side view of aircraft after impact.

B. Close-up showing left wing damage & slight fuselage crushing.



C. Area of pilot's head impact.



D. Dent at the top edge of instrument panel caused by copilot's head impact.

	INJURIES	STRUCTURES IMPACTED
Pilot: (S)	Head - Cerebral concussion. Lac's face & mouth. Cut & bruised chin. Lac. behind (L) ear.	(L) "A" post & vent window.
	Trunk - None.	
	Extremities - None.	
R. F.: (S)	Head - Mult. small lac's. face, nose & scalp.	Top of instrument panel (center)
	Trunk - None.	
	Extremities - None.	
L. R., C. R., & R. R.: (S)	Minor bruises.	

CASE 9-2

the lap belts applied around the pelvic structure. The lap belt, if worn and if it does not fail, restrains only the pelvic area and allows the rest of the body to continue in motion until stopped by impacting some portion of the container. In a number of cases in this study it was noted that even the lap belt is an ineffective restraint because of faulty installation. In numerous aircraft the lap belt goes across the thighs and straight down to the floor (Figures 3 and 4) instead of across the iliac crest and then back at a 45° angle to the floor.

FIGURE 3. Subject wearing seat belt in 1968 Cessna 150.

During deceleration the occupant is free to move forward until the belt is at nearly a 45° angle with the floor before the belt offers any restraint. By this time he is sliding off the front edge of the seat (Figure 5) and the forward motion added to belt stretch allows him to penetrate the firewall.

In general aviation aircraft design, engineers have completely ignored the fourth rule of safe packaging (inside of container must be designed to cushion and distribute impact forces over maximum surface area and yield to increase deceleration time). The head, trunk, arms and legs flailed against a conglomeration of rigid edges, angles, points, and knobs causing numerous injuries at body impact velocities of 15 ft./sec. and less in the five very minor accidents just presented. In contrast, the rewards of the safety improvements of the interiors of late automotive vehicles are clearly demonstrated in six automotive crashes shown in Figures 6 through 11. Occupants were subjected to "g" forces ranging from 3 to 12 with minor or no injuries even

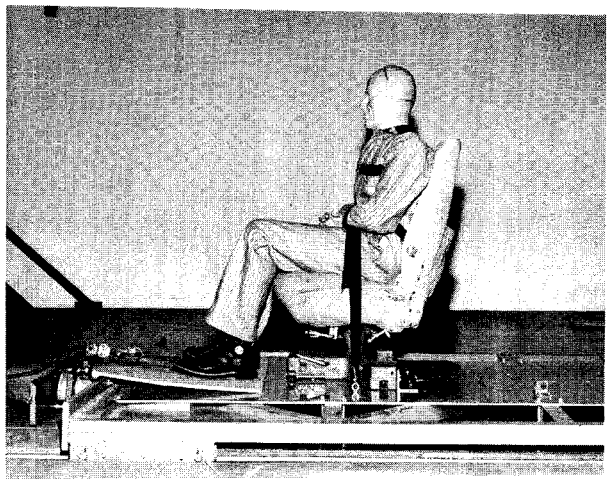


FIGURE 4. Dummy with seat belt attached straight down over thighs before crash test.

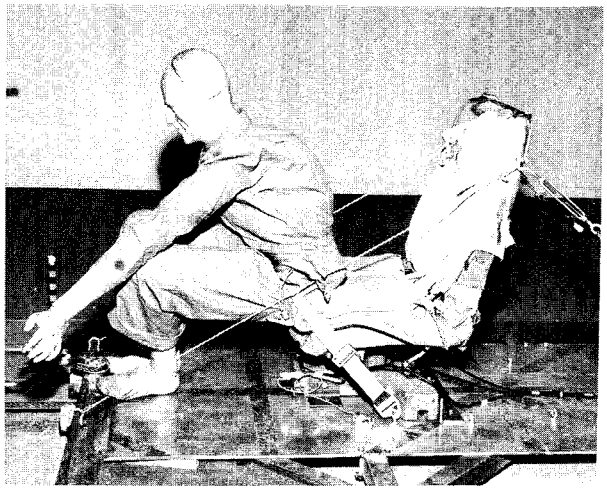


FIGURE 5. Position of dummy after crash test. Extreme forward motion is allowed by improper seat belt installation.

though none of them were wearing seat belts. Each automotive crash case presents on a single page the angle of impact, object impacted, direction of motion, number of occupants, presence and use of seat belts, direction occupants were thrown, structures impacted by the body, and body injuries.

Before presenting crash cases of a little more severity than these, it might be well to discuss some of what is known of human body tolerances to impact. The author has presented extensive data in a previous study [57] defining human tolerances of the frontal portion of the head (face and forehead) to impact. He has shown

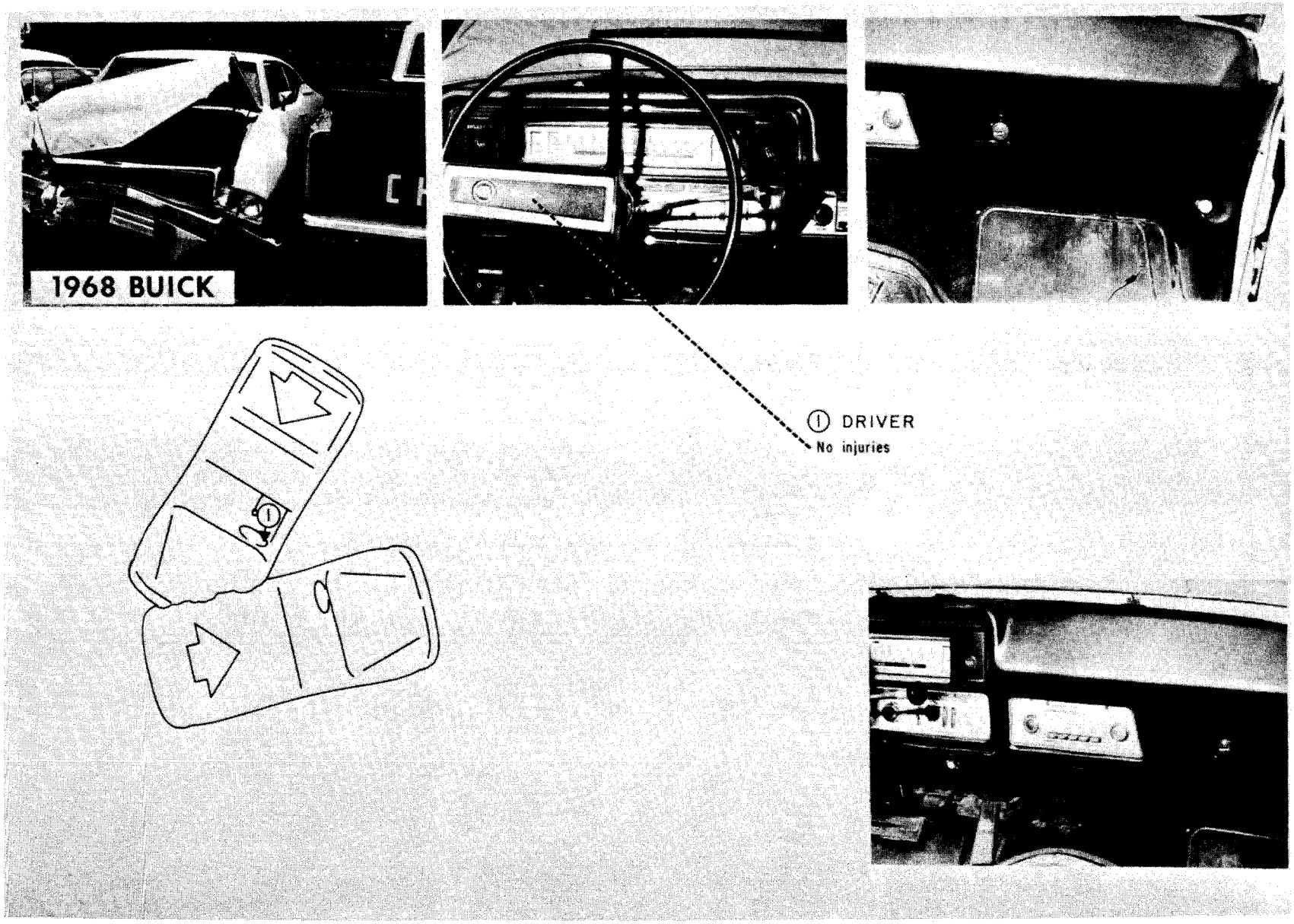


FIGURE 6. Automotive accident of a calculated 3 "g" impact force.