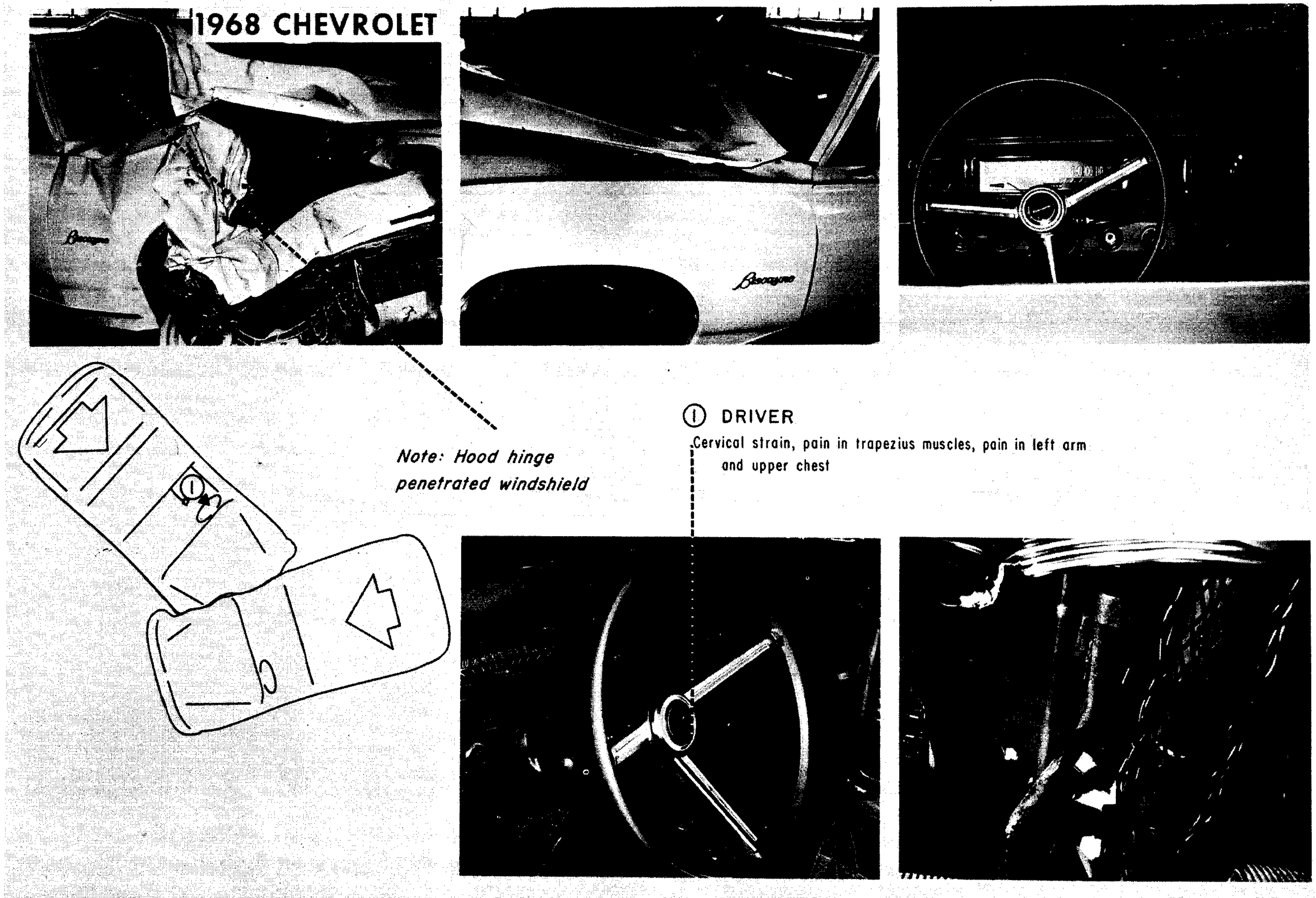


FIGURE 7. Automobile accident in which driver was subject to 7 "g" forward deceleration.

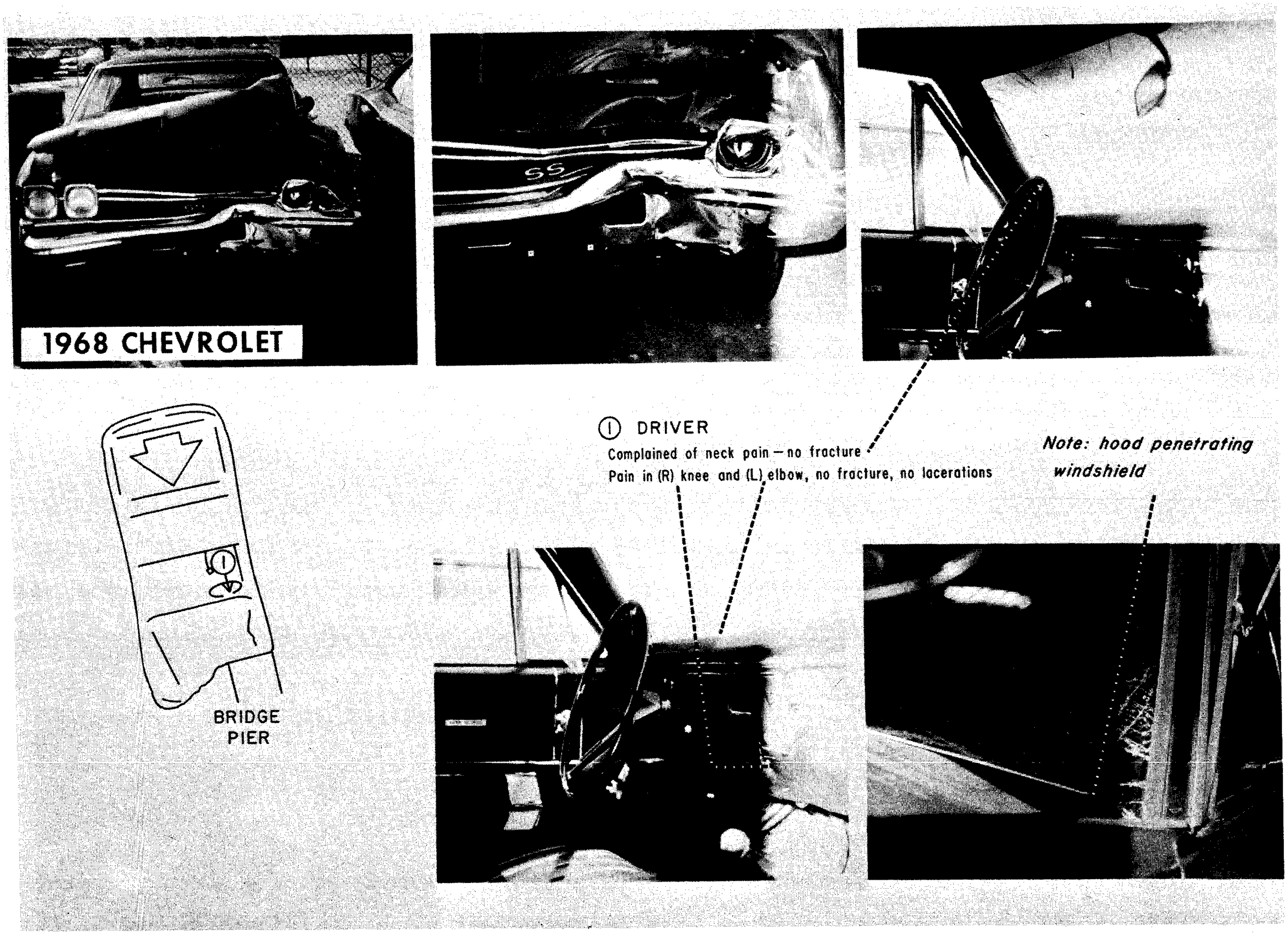


FIGURE 8. Automobile accident that subjected driver to 9 "g" deceleration.

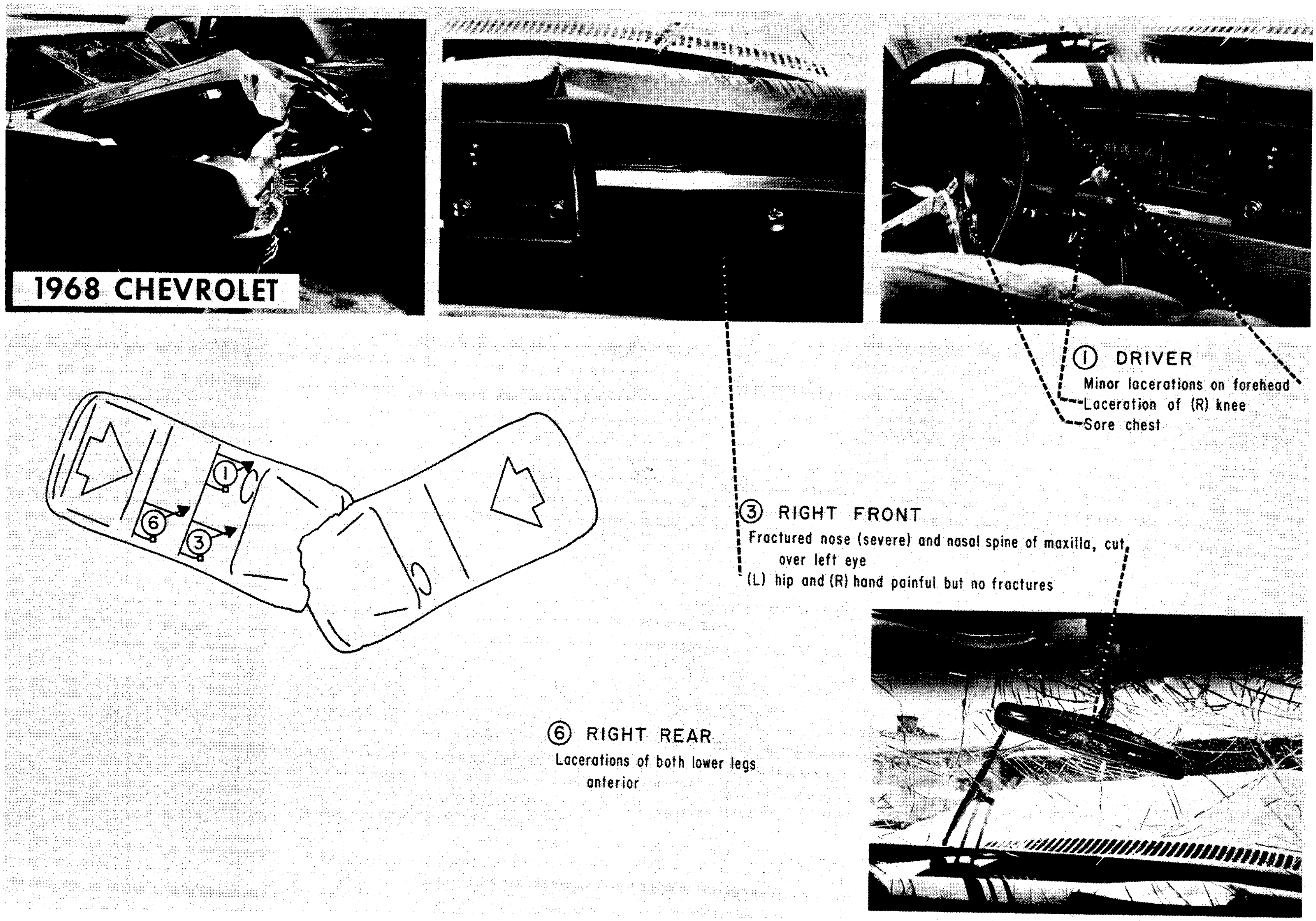


FIGURE 9. Effects on occupants in a 10.5 "g" automotive crash.

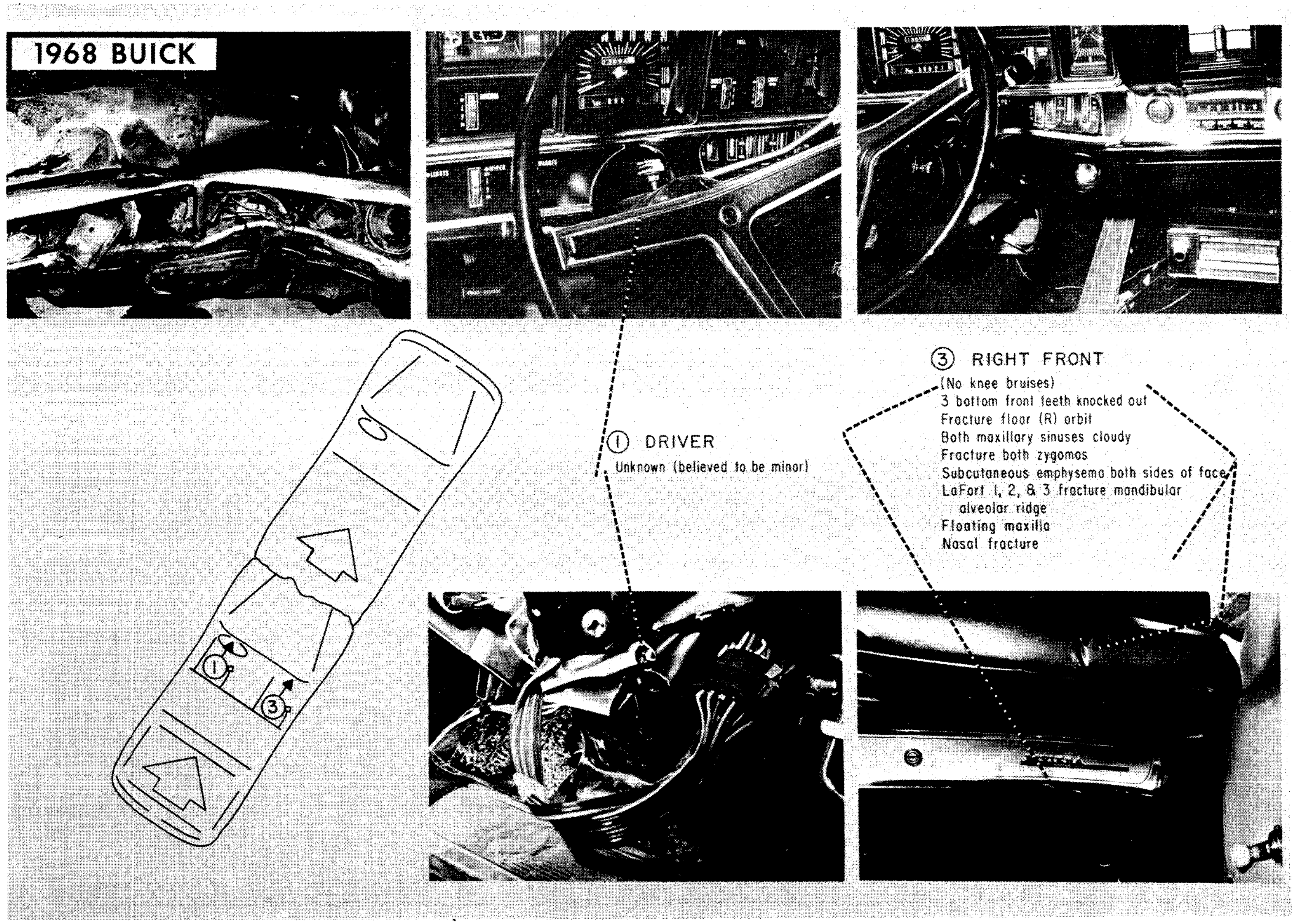


FIGURE 10. Driver impact against right door and dash in a 12 "g" intersection crash.

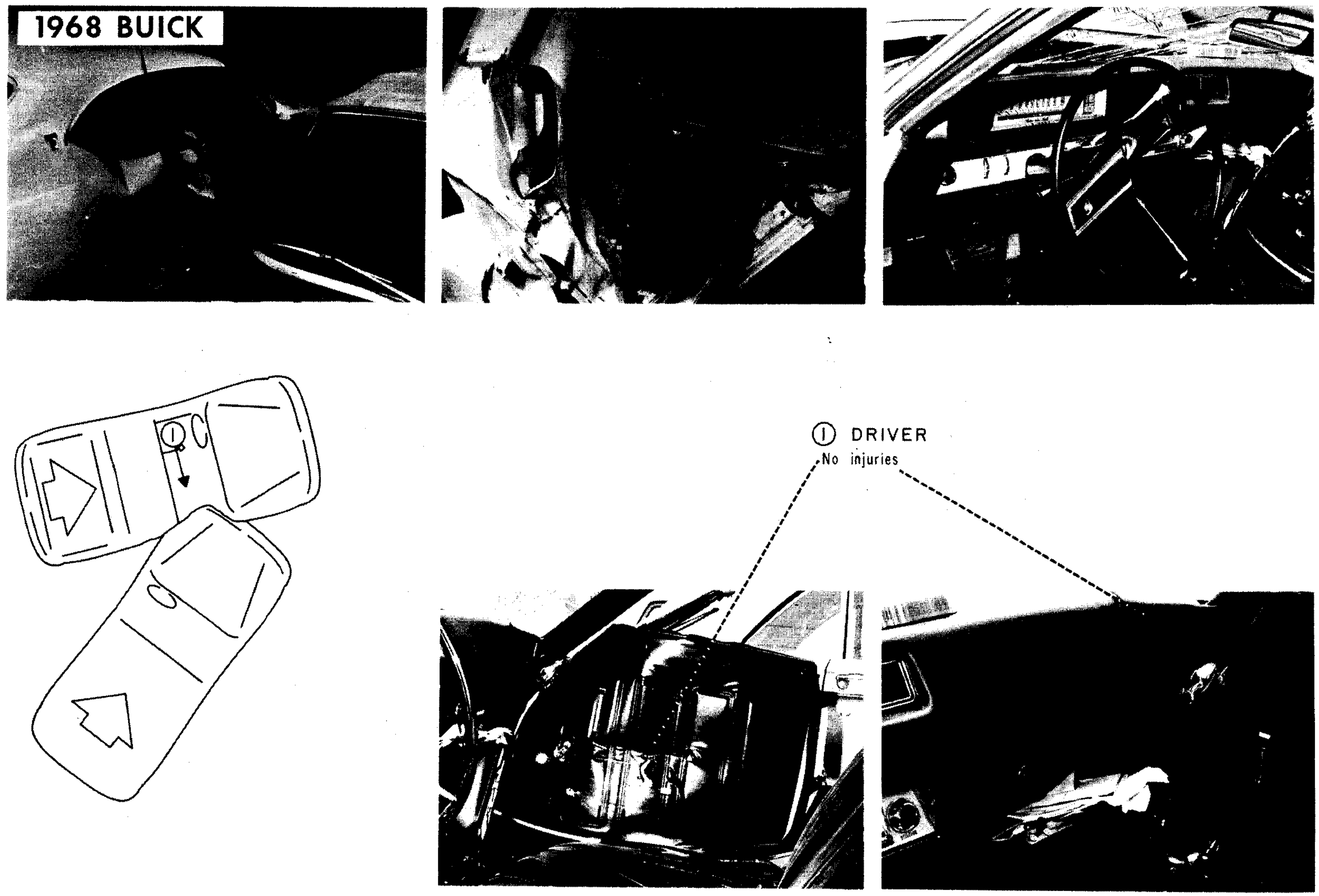


FIGURE 11. Automobile collision of 12 "g" magnitude in forward direction.

that a single square inch of the forehead is capable of withstanding an 80 "g" impact without fracture—*PROVIDED* the force is evenly distributed over the contour of the area impacted. If this area of contact is increased to 3 square inches, the frontal skull of most adults can withstand 200 "g" without fracture. Other portions of the face explored include the zygomas, nasal area, maxilla, and mandible and tolerance limits are shown in Figure 12.

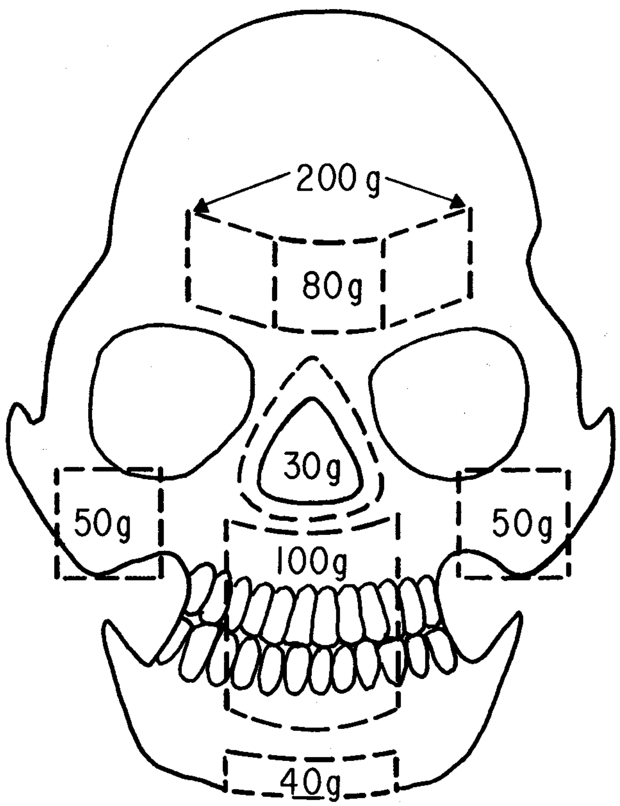


FIGURE 12. Tolerances of the human head to crash impact.

He then became curious as to whether or not these impact tolerance areas were additive. A rigid cast was made for one cadaver head to provide even distribution of force over the entire frontal face and forehead. Impact tests exceeding 300 "g" produced no signs of soft tissue laceration or bone fractures. Every tooth and even the thin turbinate bones of the nose remained undamaged (Figure 13).

This study shows conclusively that it is possible through engineering design of the inside of the container to completely eliminate lacerations and fractures of the head and face during head impact of extremely high forces (over 300 "g"). A separate study by the author [58] shows that this can be accomplished utilizing a fairly firm, slow-return padding material to distribute impact forces evenly over the contour of body structures being impacted along with a ductile backing structure that will yield and extend the deceleration time. In addition, there is evidence in the literature [59] [60] that brain injury and even concussion may be prevented with head impacts up to 300 "g", *provided* skull deformation is prevented through the use of force distribution. The principle itself is not new as even the Knights of King Arthur's Round Table wore suits of armour to distribute the blow of their opponents' sword edge and prevent body penetration by distributing the load. For the same reason we have invented bullet-proof vests, football helmets, and even shoes. Since this simple principle has been known for such a long time, it is difficult for one to understand why manufacturers of people-shipping containers have neglected the use of it. Lack of protective design has been the direct cause of over 300,000 deaths and better than 20,000,000 serious head injuries in transportation vehicles over the past ten years. The automotive manufacturers in the past two or three years have begun using a dash panel of ribbon steel covered with slow-return padding (Figures 14 and 15) that is proving effective in preventing head injuries.

Forty other different materials and combinations of materials for instrument panel design have been evaluated recently to determine their ability to absorb occupant energy.[61]

Continuing our crash case analysis, in Case Number 10, a 1959 Cessna 182 B nosed over into a lake from a height of 18 feet after hooking its vertical stabilizer on a telephone wire. The two occupants jackknifed forward over their seat belts and the pilot's head struck the top edge of the 1/8 inch thick aluminum plate which covers the front of the instrument panel (Case 10 C). A knife-like penetration wound (Case 10 D) through the bridge of his nose and both eyes back into the brain caused almost instant death and was his only injury. The impact force is not known but must, of necessity, have been relatively low as attested to by the lack of leg injuries and the fact that the seats and seat belts did not fail. It was unfortunate for the pilot that this knife-like edge contacted the bridge of his nose and eye areas—probably the weakest

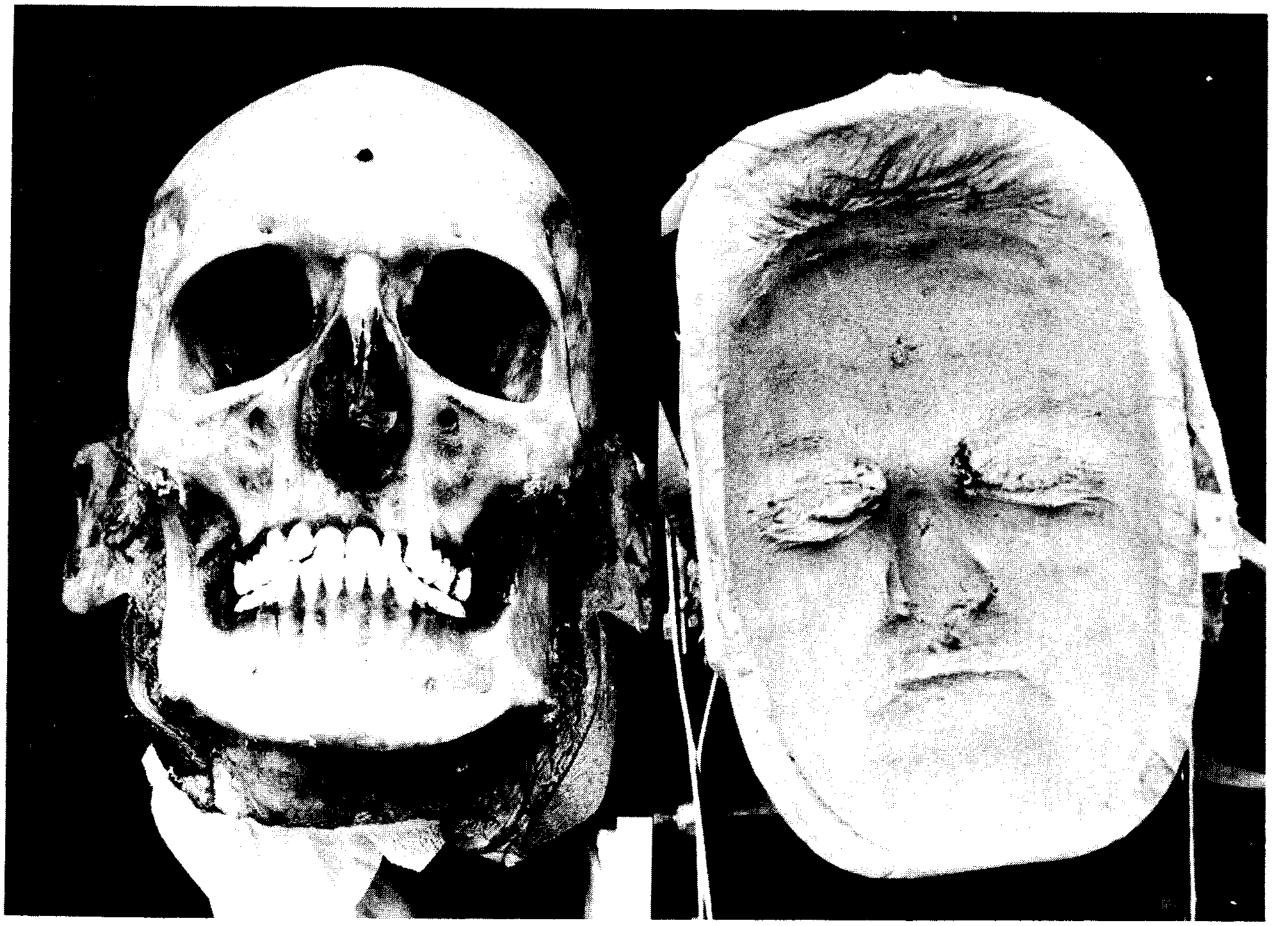


FIGURE 13. Full-face (maximum area) crash test exceed 300 "g" deceleration.

FIGURE 14. An example of a padded dash panel in a late-model automobile.

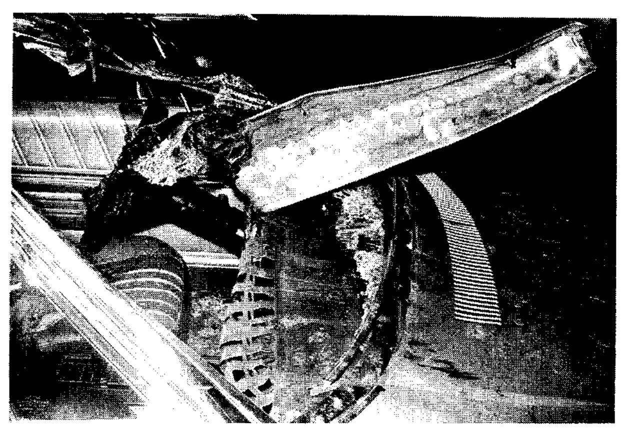
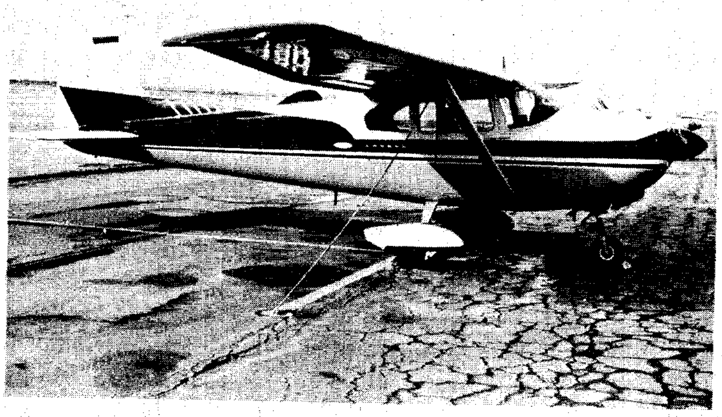


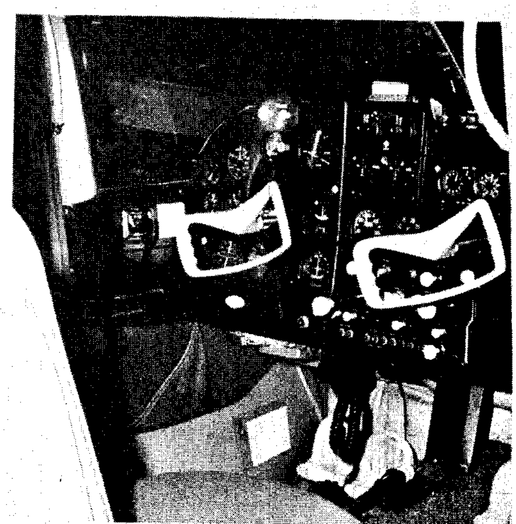
FIGURE 15. Steel ribbon design of dash structure under padding has good yield characteristics.

part of the face, but even if it had contacted the frontal skull (the strongest structure of the anterior head), it would have produced a fatal skull penetration with a head impact velocity as low as 5 ft./sec. (3+mi/hr.). In the above discussion of facial tolerances it was stated that a one-square-inch area of the forehead could withstand an 80 "g" impact. In this case the 1/8 inch sheet metal could not have made contact with more than a two-inch strip of the flattened portion of the forehead or a total area of contact of 1/4 square-inch. Skull fractures can be expected with slightly over 20 "g" impact forces on a 1/4 square-inch area and since the sheet metal impacted by the head deformed only 1/2 inch, a head velocity impact of 5 ft./sec. stopping in 1/2 inch would produce a rate of change of velocity of 600 ft./sec.^{2}, or nearly 20 "g". This discussion only serves to illustrate the fragility of the human head and face when impacted against small rigid objects even at very low velocities. Since head impact velocities of 40 to 50 ft./sec. are commonplace in even moderate crashes, the present high rate of deaths from head injury should be expected. In Case 10 A and B the aircraft appears to have sustained extensive damage during impact—the entire front cabin and engine missing—but most of this destruction can be attributed to recovery operations. The fact that the top of the instrument panel was within striking distance of the head bears out the theory that the cabin was intact when it entered the water.

Three "extreme" and seven "minor" accidents have been discussed thus far. The next four cases are of crashes of a little more severity and will be classed as "moderate". Moderate here is applied to crashes of the 8, 9 and 10 "g" deceleration range and the terminology selected on a basis of a study of automobile crashes of comparable intensity. An automobile traveling 60 miles per hour and striking a movable object such as another vehicle at an intersection and pushing it 15 feet would produce decelerative forces on the occupants of about 9 "g". Numerous accident cases involving late model automobiles in which occupants were tossed about with crash forces of 19 to 42 "g" are in our files and the occupants received minor or no injuries (Figures 16 through 26).

Case Number 11 shows a 1965 Mooney M–20–E aircraft after it crashed in muddy soil with a calculated impact force of 8 "g". A number of factors in this aircraft should be noted and discussed. For the first time we are beginning to see signs of failure of the shipping container (cabin) itself. As a single-engine aircraft crashes at an angle, the aircraft forward of the cabin may be crushed or deflected upward, downward, or to the side. Obviously, any crushing of the forward structure is beneficial as it reduces the deceleration forces ultimately transmitted to the cabin and its occupants as long as the cabin area itself is not compromised by penetration of structure. In this case there is evidence (Case 11 A and B) that the engine was forced up during some stage of the deceleration (probably as the aircraft flipped over) until it was at right angles to the axis of the aircraft and pushed the instrument panel back toward the front seat occupants. It should be noted, however, that there is no apparent structural failure with separation at the ends of the instrument panel. It is also worthy of note that the Mooney Corporation has installed a thin layer of padding on the top of the instrument panel (Case 11 C) in this aircraft and they are to be congratulated as it probably saved this pilot from fatal head injuries. On the other hand, the significant contribution of the padding to safety was partly nullified when the heavy compass was mounted on top of the instrument panel. A severe cerebral concussion was caused by this instrument when the pilot impacted it with his head (Case 11 D). In the same figure it is obvious that the pilot received his severe scalp lacerations on the broken plexiglass windshield and a fractured mandible with the loss of several teeth on the right horn of the control wheel which his body had bent up into the facial impact area. These plexiglass windshields have caused numerous severe lacerations, some fatal, as will be seen in other cases presented later in this report. Late-model automobiles are equipped with thin, strong, laminated glass windshields which have greatly reduced the head penetration and severe laceration problems. The control wheel in this aircraft is poorly designed from the standpoint of crash injury prevention. The horns frequently break off and sometimes penetrate the chest. Mounting a heavy protruding instrument with a reset knob protruding even further in the center of the control wheel significantly increases the chance of serious to fatal chest injuries. Beech redesigned their control wheel to fit the chest contour and eliminated the horns and protrusions 20 years ago. Cessna later developed a similar, well-designed control wheel (refer to Case 7). It should be noted, however, that both of these companies have gone back to the horned control wheel in some of their latest aircraft. The heavy radio with protruding knobs in the center of the instrument panel and the row of extended heavy aircraft controls (power, mixture, pro-





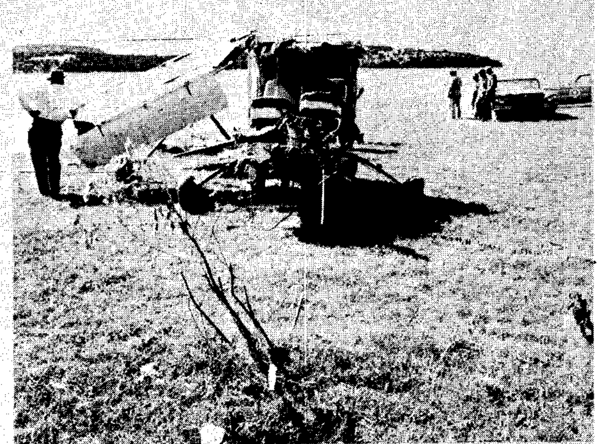
1958 CESSNA 182

CESSNA 182 B, a 1959 model aircraft with pilot and one passenger (R. F.), was flying over a lake (approximately 18 feet from the water), flew under a telephone wire and hooked the vertical stabilizer on it, nosing over into the water. Both occupants were wearing seat belts and both belts held. No shoulder harnesses were in the aircraft. Pilot and passenger were thrown straight forward. Impact forces are not known but must, of necessity, have been very low, impacting water from only 18 feet.

ACCIDENT INVESTIGATED BY:
JIM SIMPSON AND DON ROWLAN
CAMI

CASE 10-1

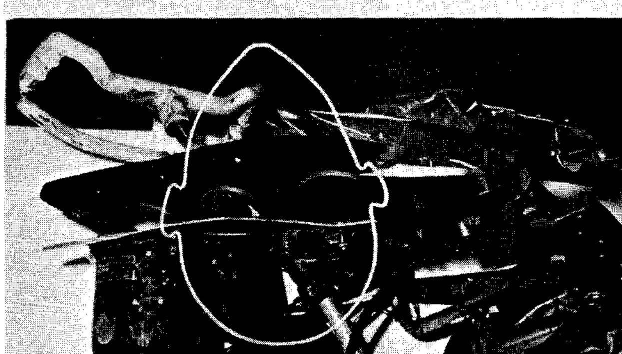
A. Side shot of wreckage retrieved from the lake.



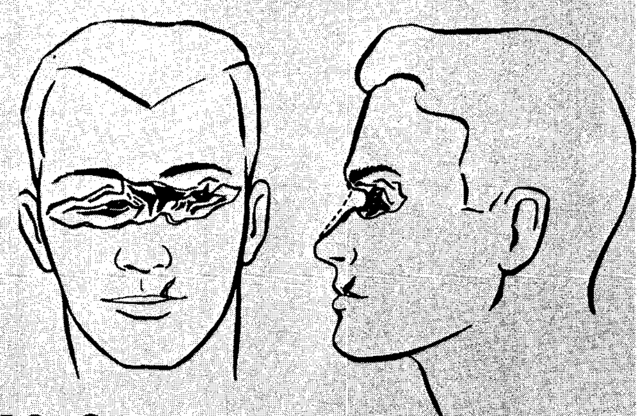
B. Front view of wreckage showing seats & seat belts still in place.

		INJURIES	STRUCTURES IMPACTED
Pilot: (F)	Head	Fatal, crushing, knife-like blow through both eyes & bridge of nose into the brain. Small cut on (L) upper lip.	Top left edge of instrument panel.
	Trunk	None.	
	Extremities	None.	
R. F.: (F)	Head	4.5 cm. Lac. of forehead just above eyes. Nasal bridge extensively Fx.	Top edge of instrument panel.
	Trunk	Aspiration of water & mud.	Unconscious & drowned.
	Extremities	Compound comminuted Fx's. (R) fibula & tibia & (L) femur.	Lower edge of instrument panel.

D. Fatal & only injury of pilot, inflicted by impact shown in C.



C. Left half of instrument panel retrieved from lake showing head outline of head impact of the pilot against the top edge of the 1/8"-thick aluminum instrument panel.



CASE 10-2

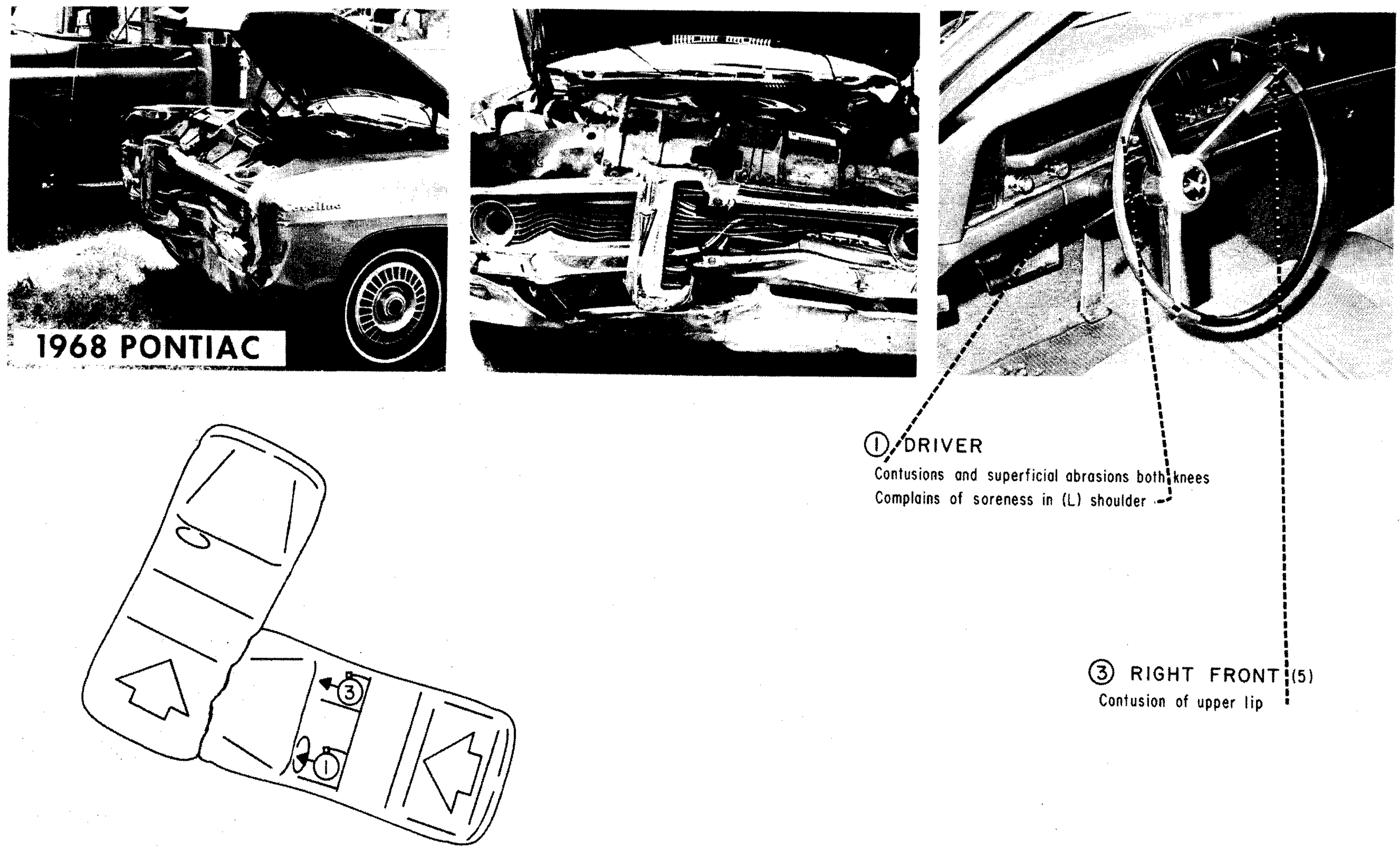


Figure 16. Automobile accident—calculated 19 "g".

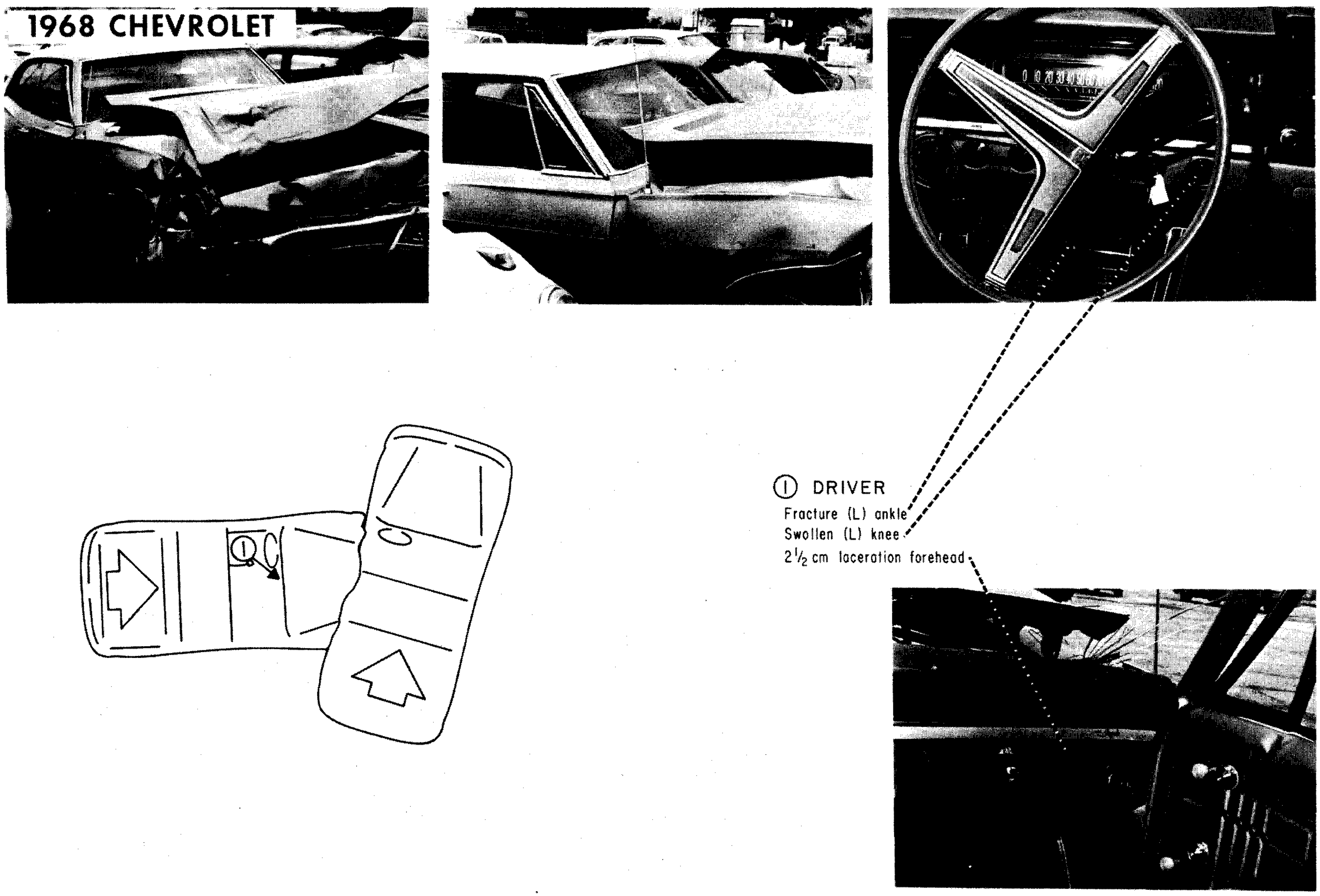


FIGURE 17. 19 "g" impact.

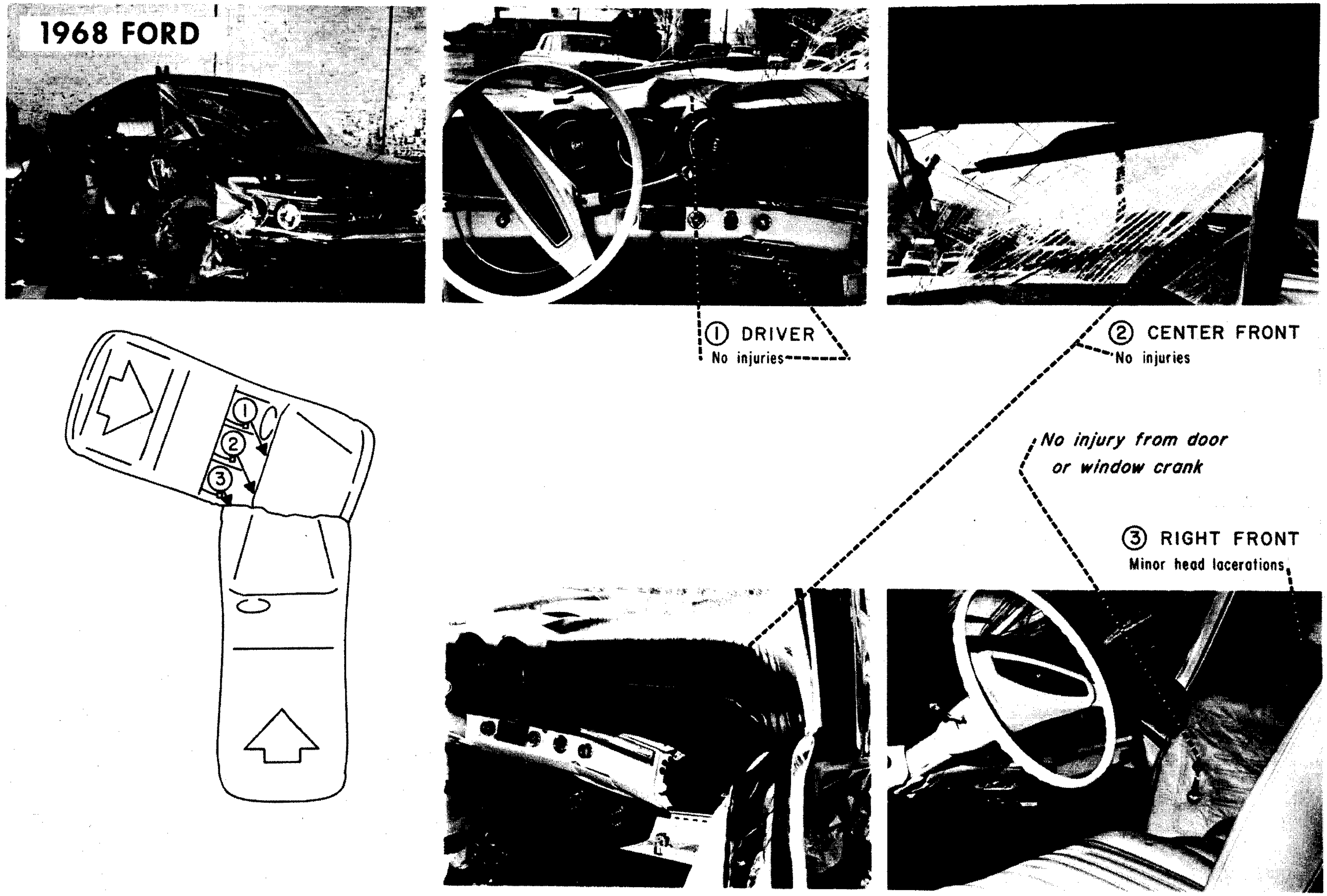


FIGURE 18. 20 "g".

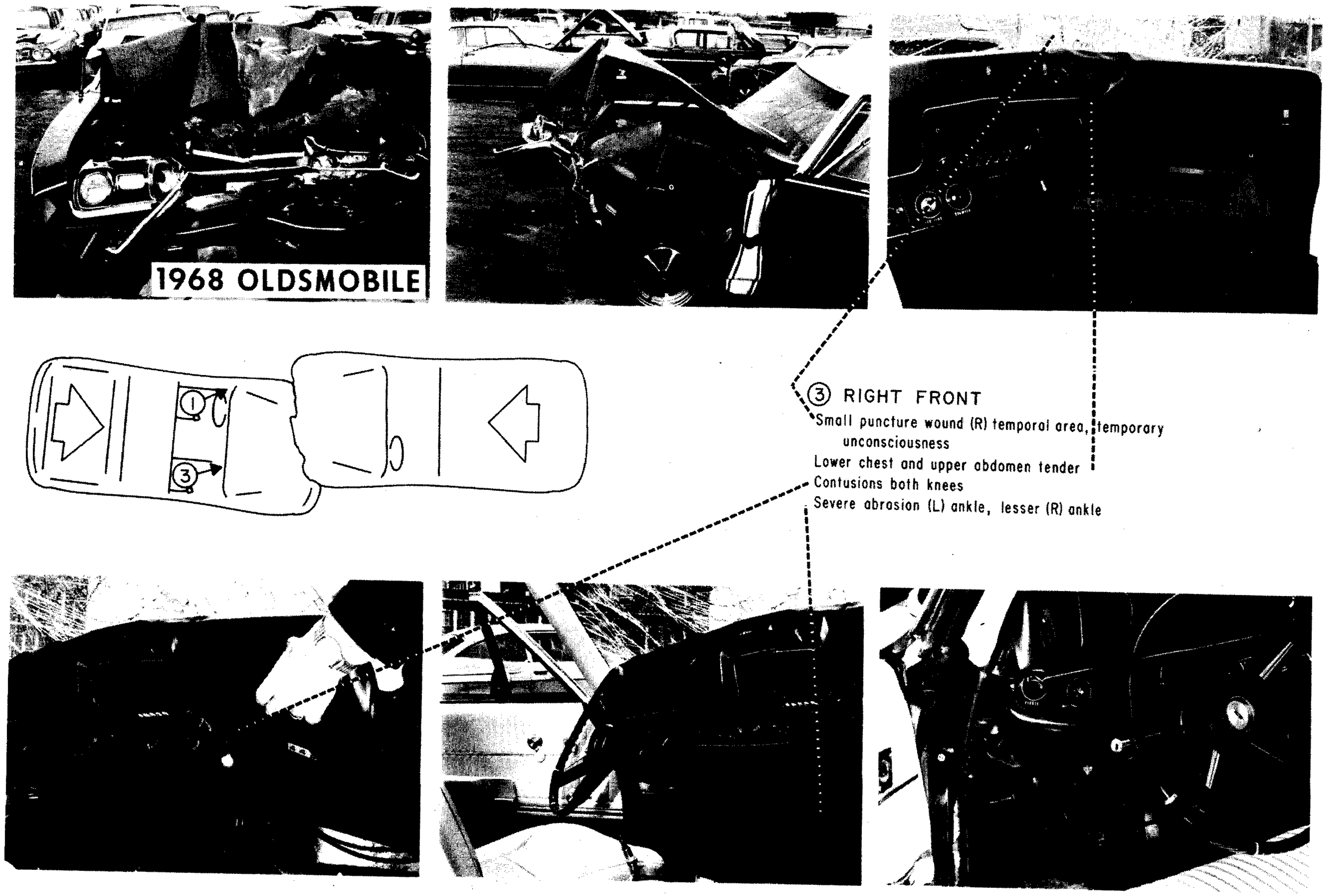


FIGURE 19. Deceleration =22 "g".

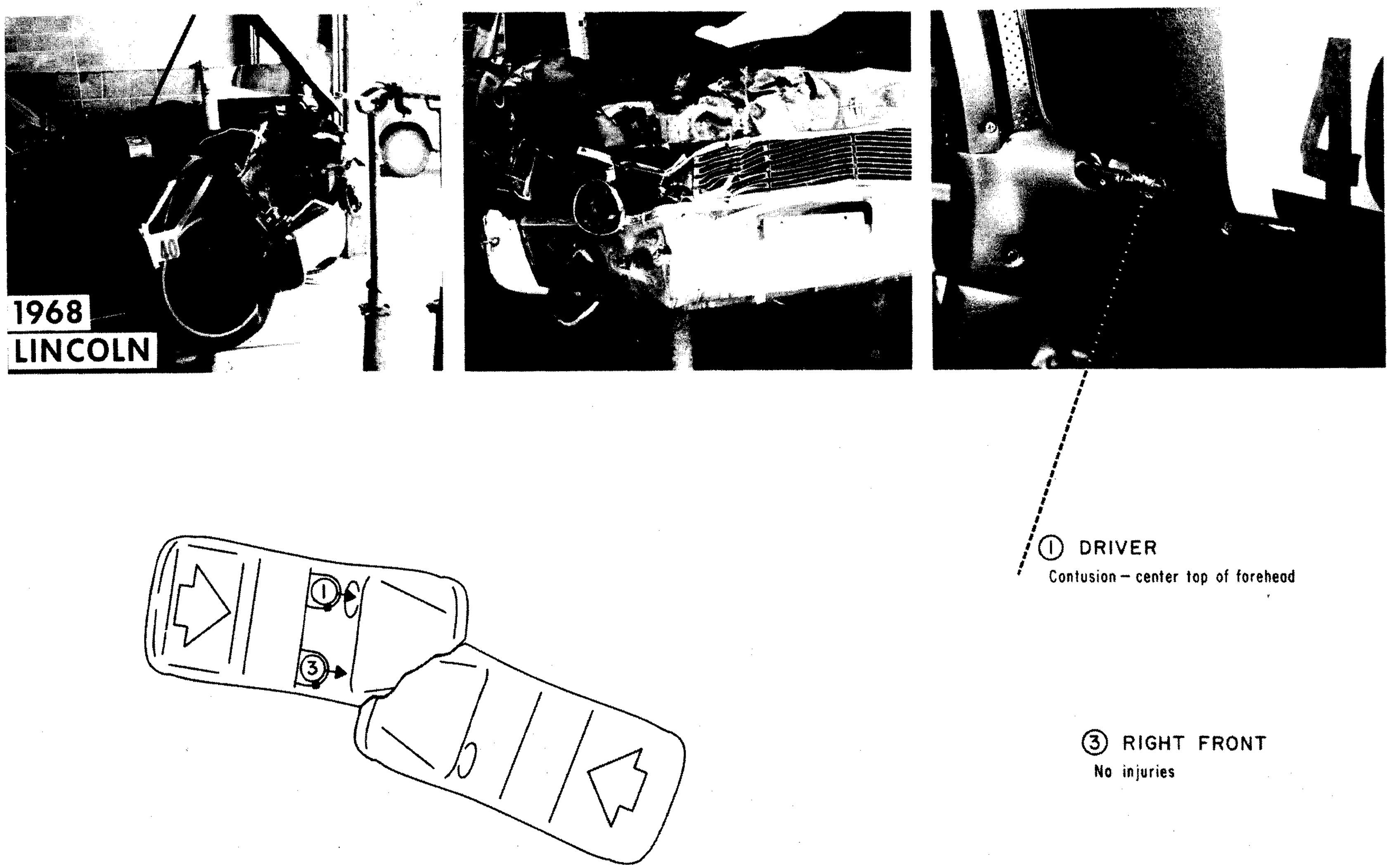


FIGURE 20. Deceleration =23 "g".

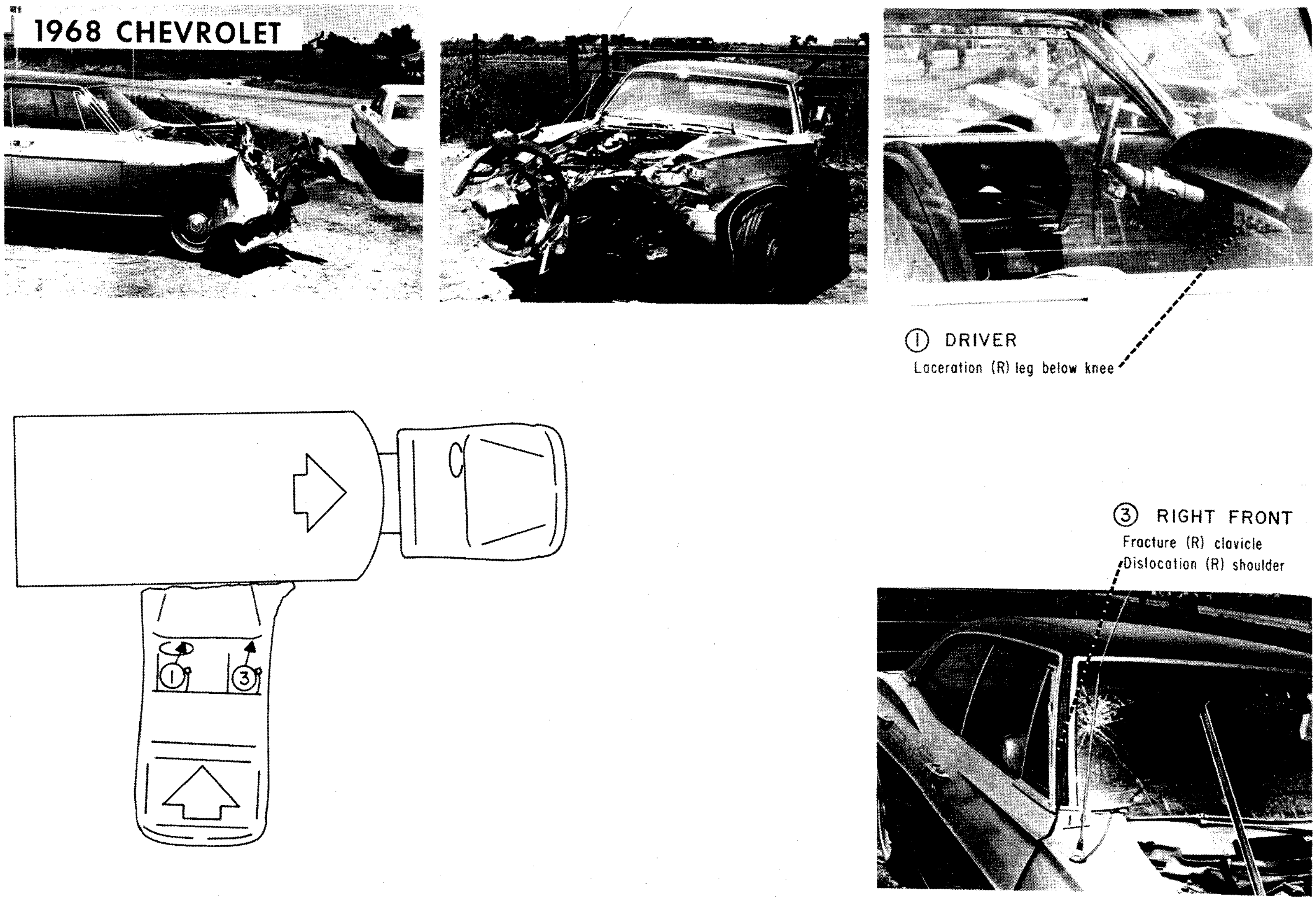


FIGURE 21. Deceleration =23 "g".

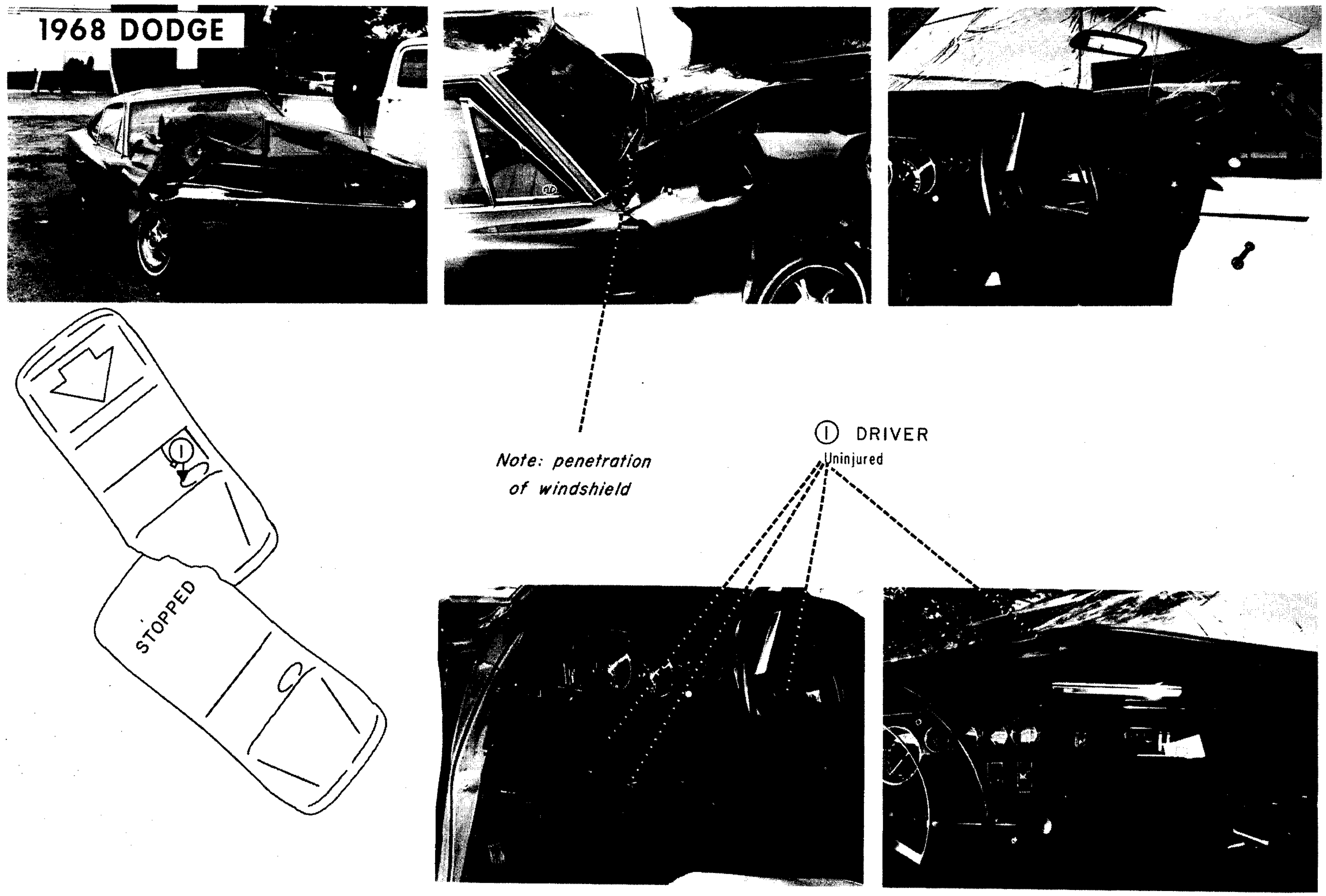


FIGURE 22. Deceleration =24 "g".

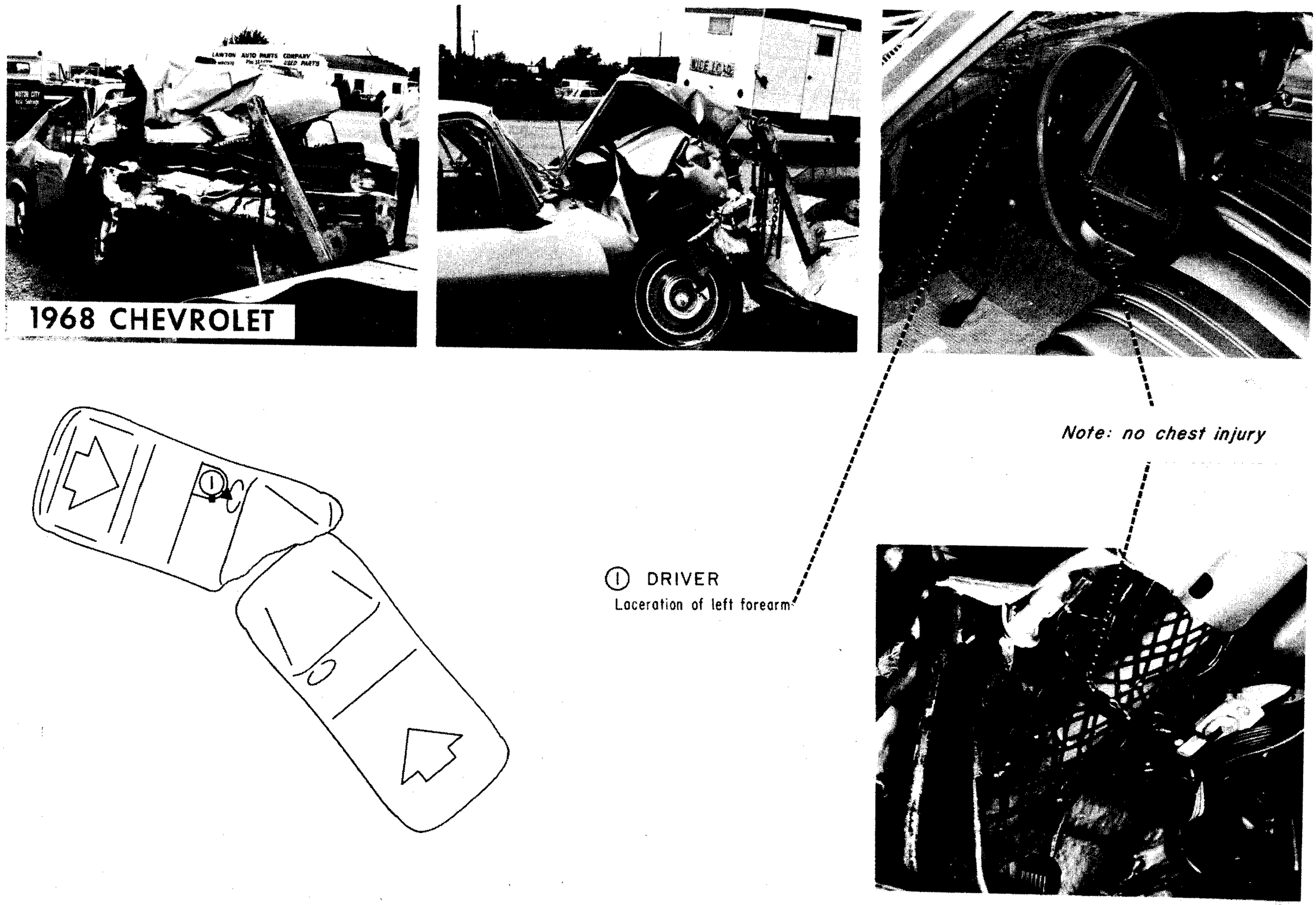


FIGURE 23. Deceleration =26 "g".

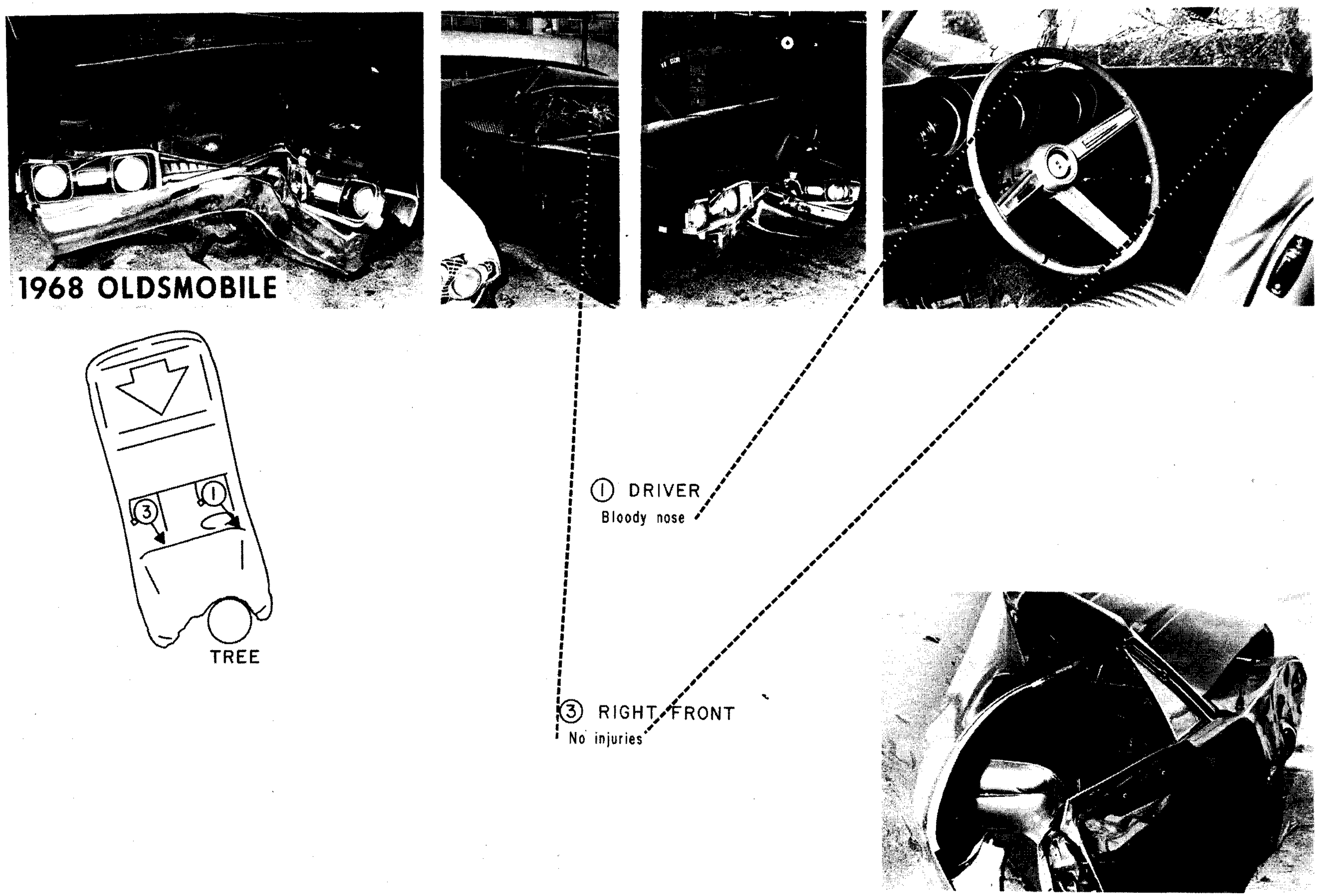


FIGURE 24. Deceleration =26 "g".

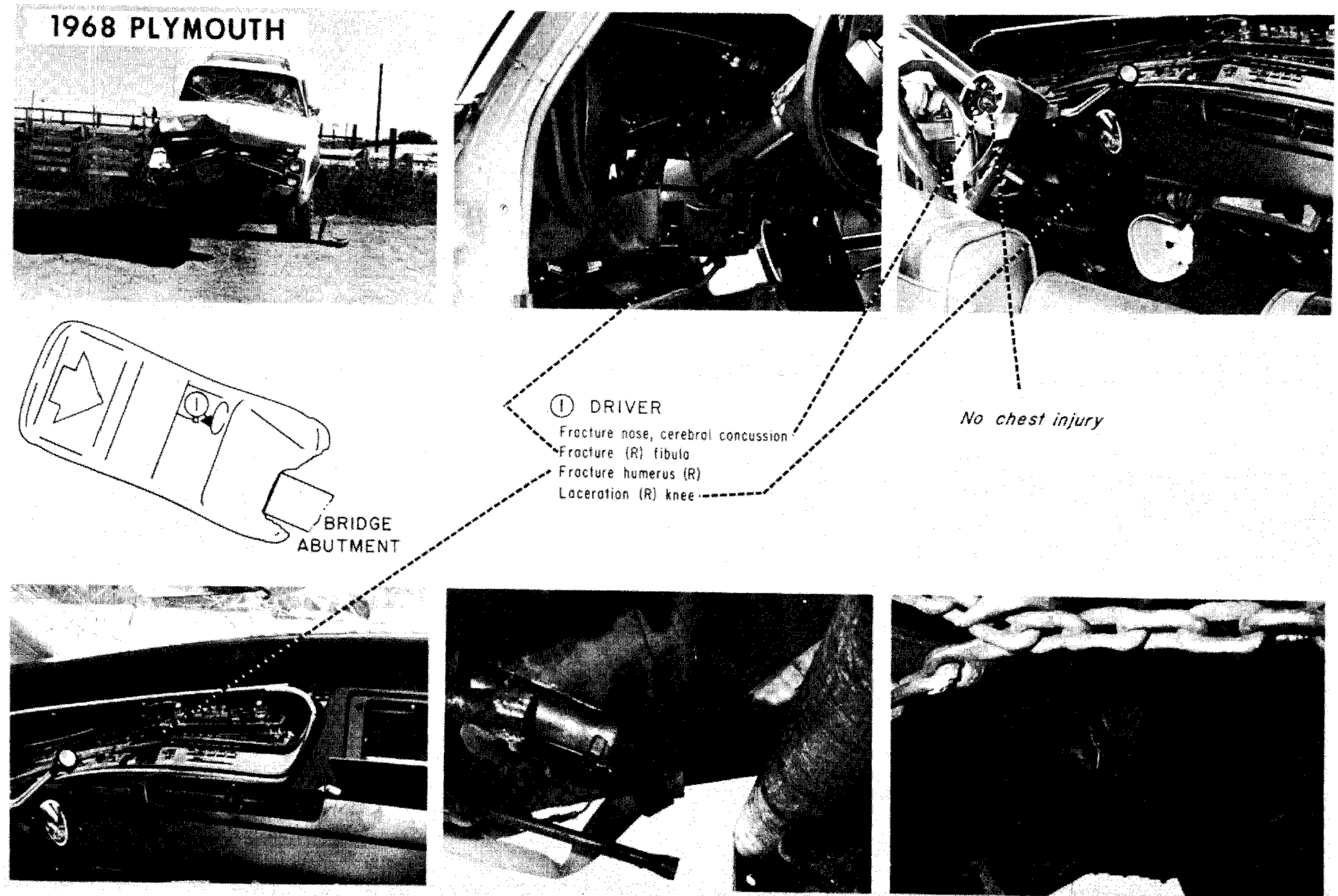


FIGURE 25. Deceleration =38 "g".

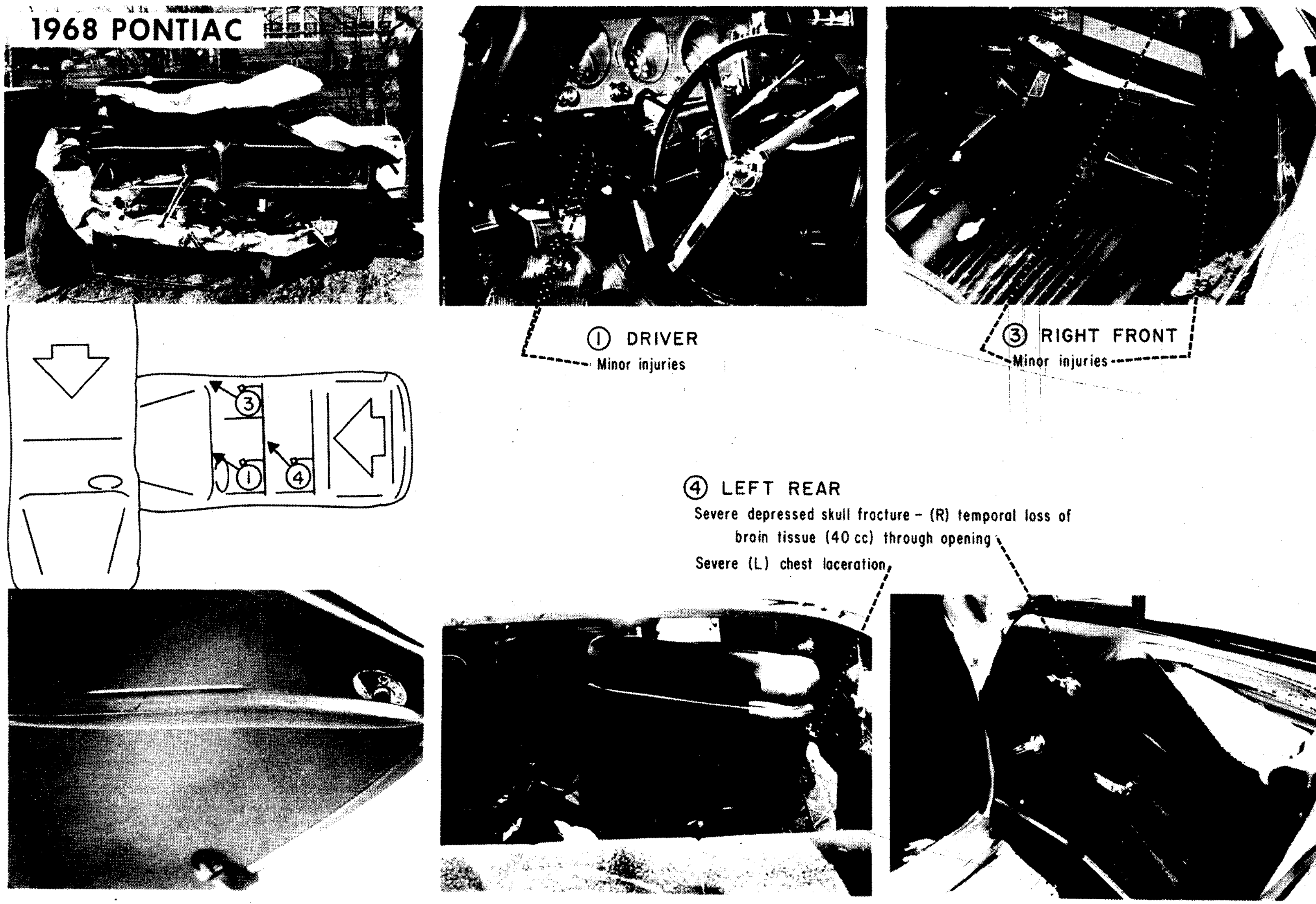


FIGURE 26. Deceleration =42 "g".

peller controls, etc.) on the lower left instrument panel (Case 11 E and G) were directly responsible for a fractured arm, fractured pelvis, and dislocated hip and knee in this accident. The author feels that the manufacturers of general aviation aircraft could significantly reduce leg and pelvic injuries by copying the design trends of the automobile manufacturers (Figure 27).

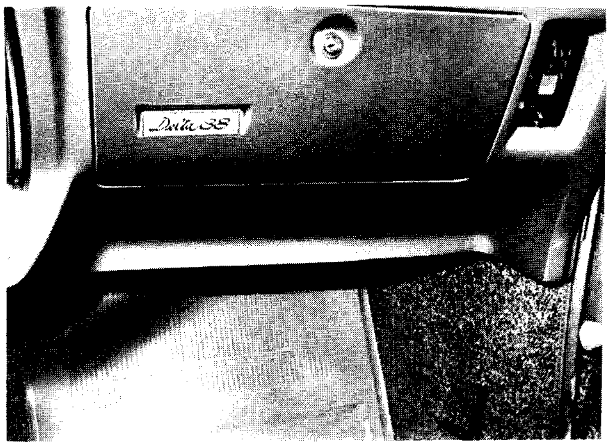
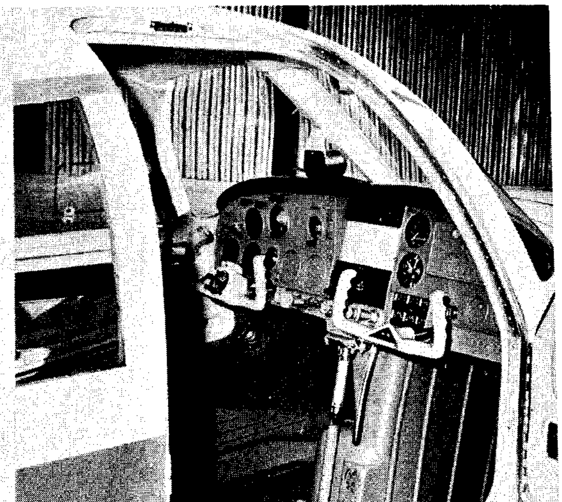


FIGURE 27. Knee impact area in late-model automobile.

In Case Number 12 there has been a complete separation of the cabin structure at both ends of the instrument panel (Case 12 B and C) as a result of the impact. Since this 1955 Piper Tripacer PA 22–150 has doors on both sides, the only structure preventing the engine and instrument panel from being pushed back into the faces of the front seat occupants is the "A" post on each side of the windshield. The inboard half of each seat belt was attached to the seat while the outboard half was attached to the fuselage. Attaching lap belts to seats loads the seat tie-down attachments unnecessarily, often causing them to fail and the package contents are no longer even partially restrained. Seat attachments in this case did fail (Case 12 I, J. K and L), allowing the two front seat occupants to smash their faces into the formidable structure of the upper instrument panel and their knees and legs into the prong-studded lower panel (Case 12 D). Facial injuries were more severe in this case than in Case 11, partially because there was no padding on the instrument panel and partially because the crash impact force was slightly greater as attested to by the significant increase in lower leg injuries. The bare survival of these two occupants could probably be attributed to well-designed control wheels for chest impact without injury. Note in Case 12 F and G these control wheels are smashed flat against the instrument panel and probably slowed the upper bodies just enough to prevent fatal crushing head injuries. Federal Aviation Regulations (FAR) Part 23 requires that all general aviation aircraft have a tie-down strength to withstand a forward static loading of 9 "g". Since this seat did fail at its attachment, one might assume the crash forces involved in this case exceeded 9 "g". However, a recent research report published by the National Aviation Facilities Experimental Center (NAFEC)[62] shows the unreliability of predicting dynamic strength from static testing and the author believes that the maximum crash force in this case was well below 9 "g" as measured dynamically. A cabin deceleration of 8.5 "g" would have produced head strike velocities in excess of 50 ft./sec. and the head injuries from impacting this instrument panel would have been fatal to both occupants.

The total weight of the radio equipment in this aircraft was approximately 30 pounds. Radio equipment incorporating miniaturization technology is available today. By substitution of this new equipment, communication weight could be greatly reduced and the pounds saved utilized to strengthen the forward areas of the cabin as Beech Aircraft Corporation did so successfully nearly 20 years ago.

Again referring to FAR Part 23, vertical tie-down strength for seats is required to meet a 3 "g" static pull force. In Case Number 13 a 1955 Piper Tripacer PA 22–150 ran off the end of a runway into some loose soil, collapsed the nose gear, and skidded 75 feet almost to a stop when it flipped over onto its back (Case 13 A and B). Deceleration of the cabin was less than 1.4 "g" as evidenced by the fact that the pilot was not thrown forward with sufficient force to bump his head (refer to Case 4). The pilot found himself hanging uninjured, upside down in his seat belt, but when he released his seat belt, he and the seat fell down to the top of the cabin and the pilot bumped his head as he fell (Case 13 C). Note in Case 13 E that the inboard half of his seat belt was attached to the center of the seat. It is difficult for the author to understand how a seat meeting the FAR requirements of 9 "g" forward and 3 "g" upward based on the weight

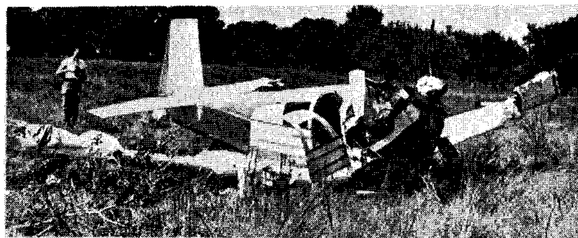



1965 MOONEY MARK 21

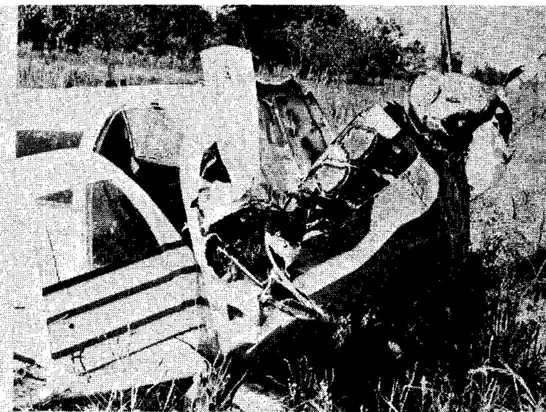
MOONEY M-20-E, a 1965 model aircraft, had taken off at night with pilot, an automobile accident patient on a stretcher (R. F.), and a nurse in the rear seat. At about 200 feet altitude the motor faltered; the aircraft cut through the tops of some small trees, crashed (R) wing first in muddy ground, and flipped over onto its back. Pilot was wearing his seat belt and it held. Stretcher patient (R. F.) was not strapped down and the nurse in the rear seat was not wearing her seat belt. No shoulder harnesses were in the aircraft. All occupants were thrown forward and slightly to the (R).

ACCIDENT INVESTIGATED BY:
LEE LOWREY, EDDIE LANGSTON,
AND
JACK BLETHROW
CAMI

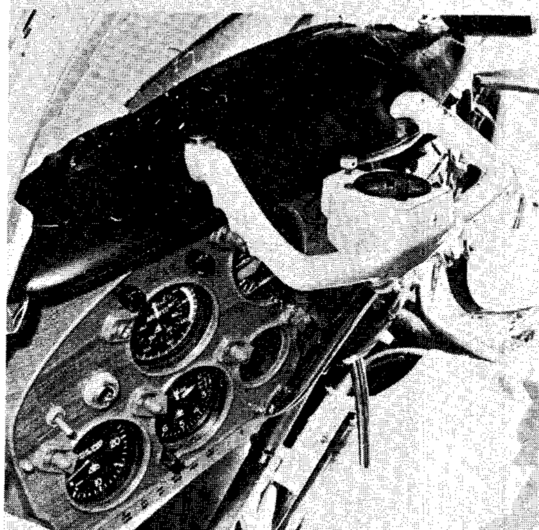
CASE 11-1



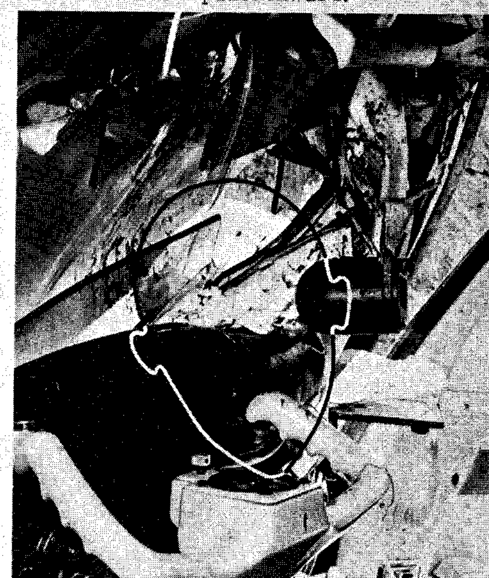
A. General appearance of wreckage.



B. Motor forced upward, pushing instrument panel inward.



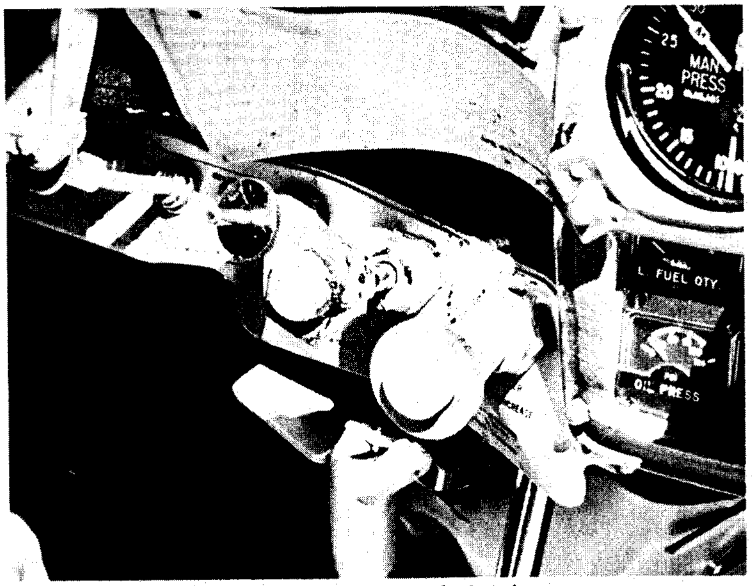
C. The left control column has been bent upward by chest impact of the pilot until the control horns rest against the light padding.



D. Pilot's head struck the broken plexiglass windshield, heavy compass, & right horn of the control wheel.

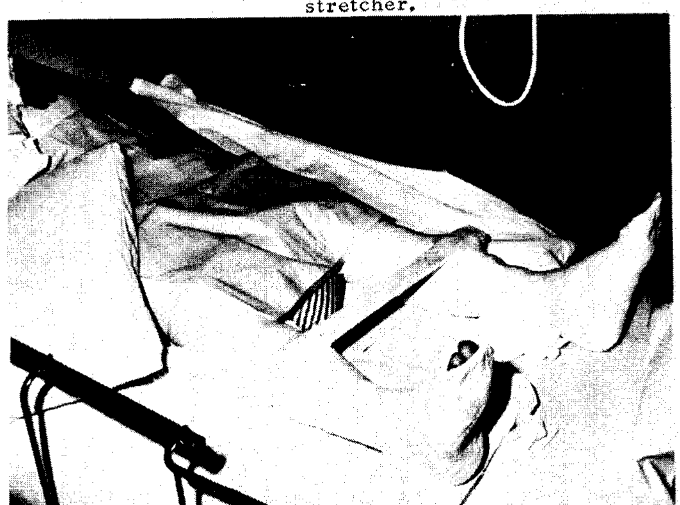
INJURIES	STRUCTURES IMPACTED
Pilot: (S) Head - Cerebral concussion.	Padded dash to (R) of control column.
Fx. mandible (R) & chipped teeth.	(R) horn of control wheel.
Severe lac's. of the scalp.	Windshield (broken).
Trunk - Contusions of chest	Control wheel hub.
Fx. (L) pelvis (acetabular) posterior.	Lower instrument panel (L).
Extremities - Lac's. & compound Fx's. (R) forearm.	Center of instrument panel.
Dislocations (L) hip & (L) knee.	Lower instrument panel (L).
Bimalleolar Fx. (L) ankle.	Pedal area.
R. F.: (F) Thought to be dead before impact.	
C. R.: (S) Fx. cranium, brain concussion. Other injuries unknown.	Probably hit bottom of stretcher

CASE 11-2



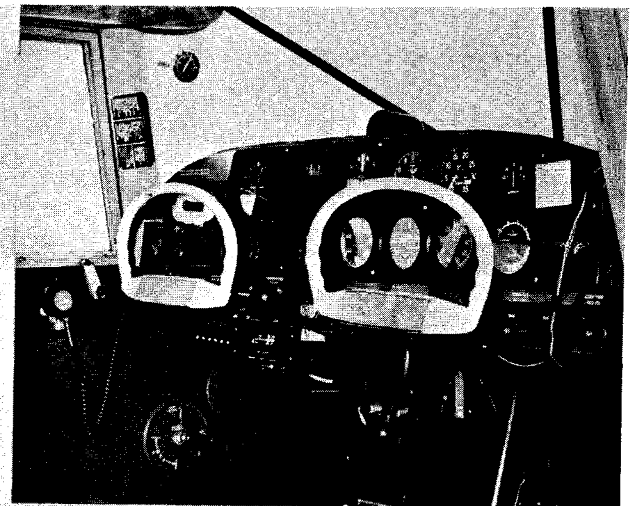
F. Damage to right half of instrument panel from unrestrained stretcher.

E & G Lower left instrument panel showing knobs bent and broken by pilot's legs.



H. Pelvic & lower leg injuries.

CASE 11-3

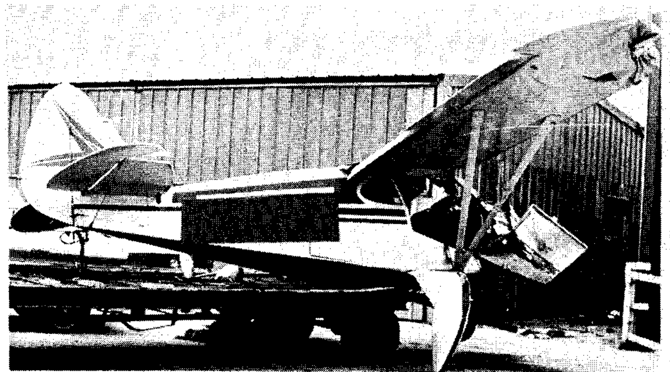


1955 PIPER TRIPACER

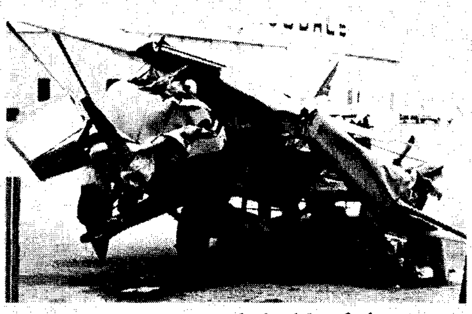
PIPER TRIPACER PA-22-150, a 1955 model aircraft with pilot and one passenger (R. F.), was landing at an airport after a commercial jet had taken off. Aircraft was caught in the wake turbulence and crashed on the runway, (L) wing hitting first. Both occupants were wearing seat belts which were attached inboard to the seat and outboard to the fuselage. Seats tore loose. No shoulder harnesses were in the aircraft.

ACCIDENT INVESTIGATED BY:
GALE BRADEN AND TERRY WALLACE
CAMI

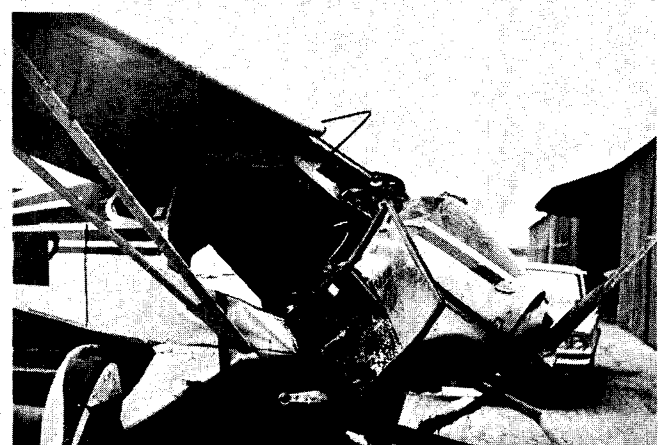
CASE 12-1



A. Aircraft from right side after removal from crash site. Note that most of the aircraft appears to be undamaged.

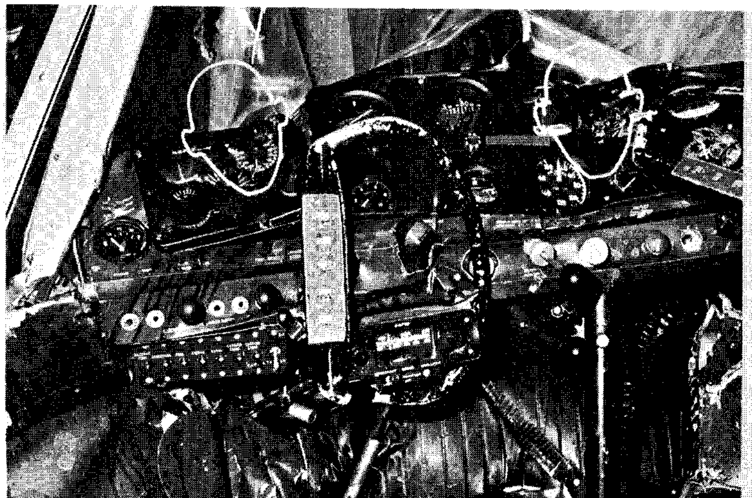


B. View from left side of aircraft showing that only the structure between the rear door & motor protected the pilot from being crushed.

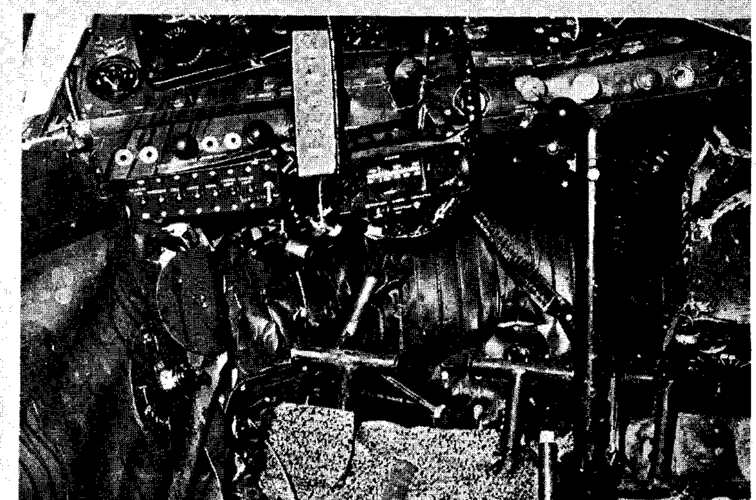


C. Close-up of right side of aircraft shows complete failure of right "A" post. (Only structure resisting backward displacement of motor & instrument panel on that side).

CASE 12-2

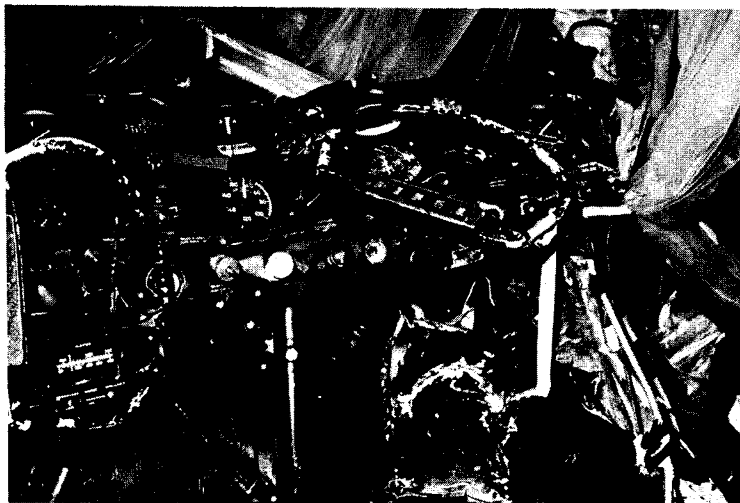


D. Head outlines indicate instrument panel depression areas produced by head impacts of the two front seat occupants. Note control wheel crushed into instrument panel.

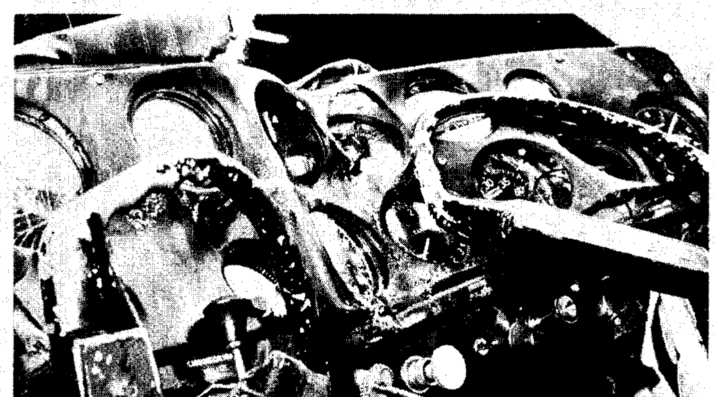


E. Lower left instrument panel conglomerate, responsible for numerous leg and ankle fractures & lacerations.

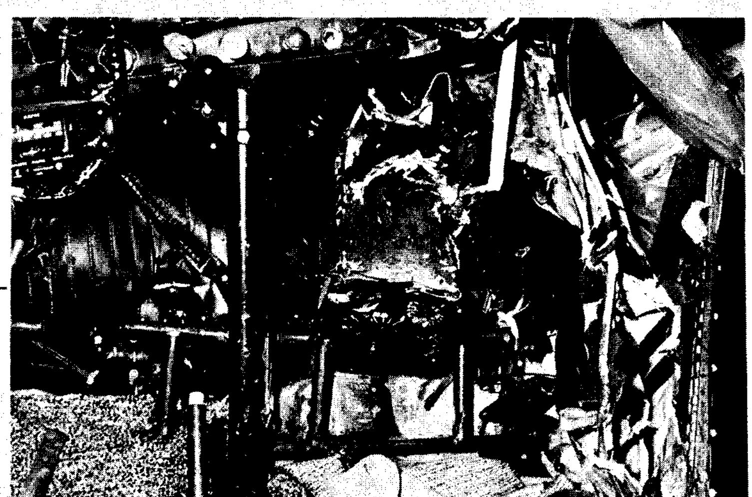
CASE 12-3



F. Right half of instrument panel.

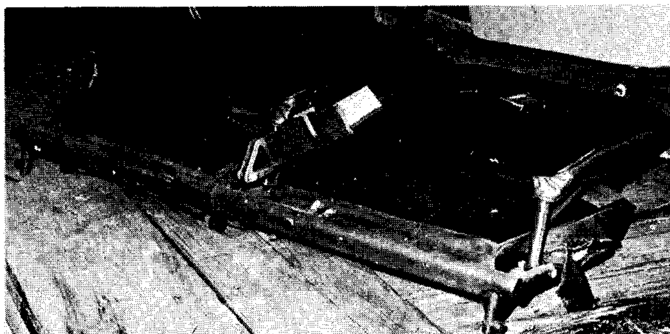


G. Close-up of copilot's head imprint.



H. Close-up of heavy radio structure on copilot's side causing four lower limb fractures.

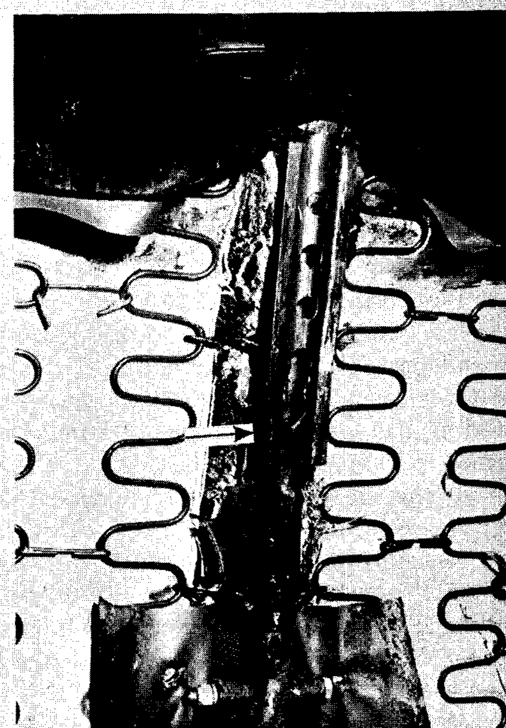
CASE 12-4



I. Inboard halves of seat belts were attached to the seat in this aircraft, transferring heavy belt loads to fragile seat tie-down structure.

J. End attachments of seat to side of cabin failed.

K. Adjustment pin & center tie-down flanges. Notice that the thin tie-down flanges are spread open, allowing the seat to leave the track.



L. Tie-down & adjustment structure on bottom of seat. The thin metal on either side of the adjustment holes bent & allowed seat to tear loose.

	INJURIES	STRUCTURES IMPACTED
Pilot: (S)	Head - Acute subdural hematoma (R). Severe lac. lip (R). Front teeth knocked out. Lac. (R) forehead.	Top edge of instrument panel in upper (R) corner of radio.
	Trunk - None.	
	Extremities - Comminuted Fx's. tibia & fibula (R) & (L).	Lower instrument panel & pedal area.
	Avulsed Fx. (R) ankle.	
	Lac's. & Fx. (R) forearm.	Control wheel.
R. F.: (S)	Head - Face swollen round, abrasions. Deep lac. on chin. Concussion lasting 3 weeks. Fx's. nose, (R) maxilla, (R) zygoma, (R) infraorbital ridge.	Instrument panel.
	Trunk - None.	
	Extremities - Compound Fx's. ulna & radius (R) & (L). Fx's. (R) talus, (R) tibia, (L) fibula, (R) patella.	Lower instrument panel.

CASE 12-5

of two occupants and the weight of the seat could fail with only one occupant in such a minor deceleration. It is possible, since this aircraft was nearly 15 years old, that deterioration of the seat attachments may have been a factor. However, since general aviation aircraft keep on flying until they disintegrate in a crash, seat tie-down attachments should be designed for long usage. If the restraint system fails under these minor conditions, certainly it is of little or no benefit in even a hard landing, let alone a minor crash.

In Case 14 a young male pilot crashed in a 1946 Piper J–3C–65 at the edge of a blacktop road and slid 26 feet before coming to rest. The pilot jackknifed over his seat belt and buried his face in the soft aluminum instrument panel making a rounded dent between 4 and 5 inches deep (Case 14 C). This rounded soft surface depressed in a manner similar to the light aluminum semi-cylinder at the top edge of a Piper Pawnee instrument panel (to be discussed later in Cases 23 and 24). The head dent also closely approximates the head strike imprint in the Pawnee panel made by impacting an instrumented dummy head at a velocity of 30 ft./sec. (Figure 36). If the pilot's head struck at even 40 ft./sec., it would indicate that the major crash impact force did not exceed 7 to 8 "g". The almost complete lack of injuries to the trunk* and appendages (Case 14 E, F and G) tend to bear out these conclusions. The pilot would have survived if the top seam of the fuel tank had not formed a narrow protruding ridge as the head forced the instrument panel downward. The high concentrated loading on this narrow structure was sufficient to cause a fatal skull fracture. The pilot also received a severe fracture of his right ankle (Case 14 G) inflicted by the diagonal tubular brace located directly above the ankles when the feet are located on the pedals.

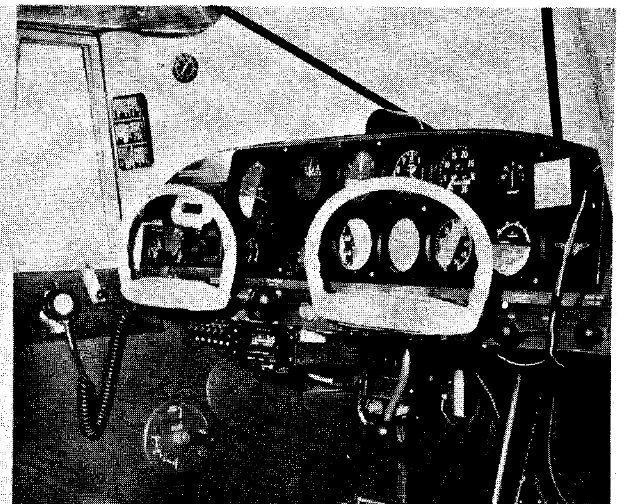
A second 1946 Piper J–3C–65 crash with two occupants aboard the aircraft is shown in Case 15. Many similarities between this accident and the one presented as Case 14 may be worthy of notice. Comparing Case 14 B and Case 15 A, it will be noted that both cabins maintained their integrity to a fair degree. In Case 15 C we see a head print in the instrument panel almost identical to the one seen in Case 14 C. The top seam of the fuel tank has formed a sharp edge (see arrow) against which the front seat occupant hit and fractured his skull. One significant difference is the fact that the heavy compass near the center of the panel remained in place in Case 15 and caused severe crushing injuries of the lower face (see injury table) while in Case 14 it broke loose from its mounting before or during head impact and the occupant suffered only a fractured mandible.

The rear seat lap belt failed at its attachments allowing the occupant of this seat to be thrown forward over and on top of the front seat occupant. His body weight may have added to the force of head impact of the front seat occupant. The fatal head injuries of the rear seat occupant were inflicted by the broken windshield and rigid edge for attachment of the windshield (Case 15 E). Failure of the rear seat belt attachments cannot be taken as indicative of severe crash forces since the ends of the seat belt are fastened by $3/32$ inch wire loops to a $3/4$ inch floating tube running through the canvas seat bottom. Ends of this tube are in turn fastened to the fuselage by similar wire fasteners. Failure of these latter attachments allowed the seat belt attachments to slip off the end of the tube. As in Case 14, the front seat occupant received a severe fractured ankle, almost severed (Case 15 G) from the tubular cross brace (Case 15 F) in the lower cockpit.

Referring to data showing tolerances of the human head to crash impact (presented earlier in this report), the author is of the opinion that the extensive head injuries received by the front seat occupant when his head struck two small rigid areas could have occurred progressively at a head impact velocity not exceeding 40 ft./sec. Lack of severe facial tissue disfigurement (Case 15 D) and the absence of abdominal injuries from the seat belt tend to confirm this estimate. For these reasons, the author estimates that the major crash forces in this accident did not exceed 8 or 9 "g".

In all cases discussed thus far, with the exception of the first three (nonsurvivabe), all occupants should have survived without any injury whatsoever, providing they had been wearing shoulder harness restraint and properly anchored lap belts. All 11 of these accidents involved crash impact forces of 10 "g" or less. Armstrong[63] reports human voluntary tolerance

*Sutures in Case 14 E are from embalming procedure.

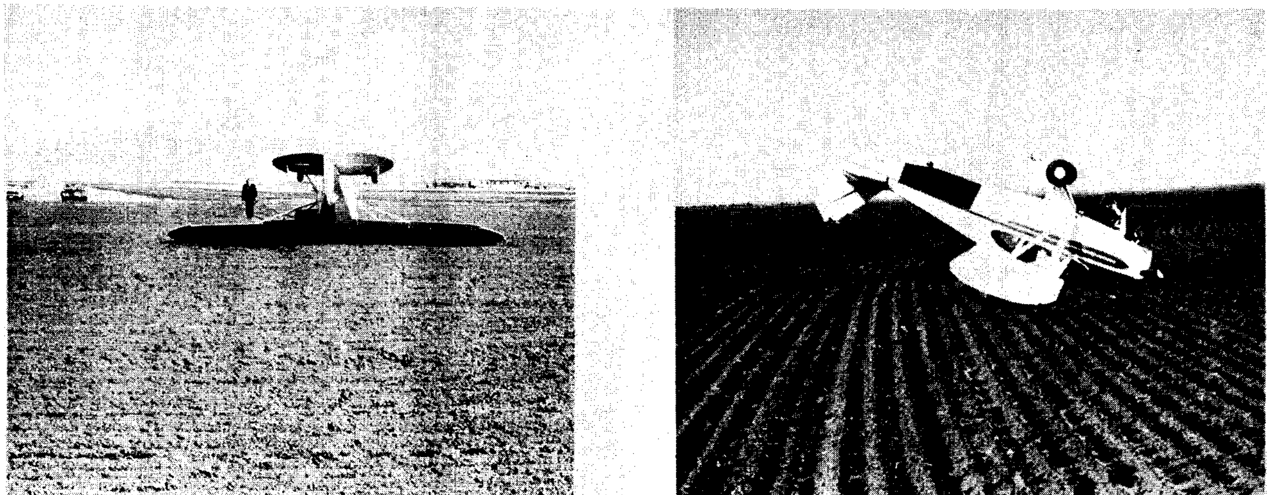
 

1955 PIPER TRIPACER

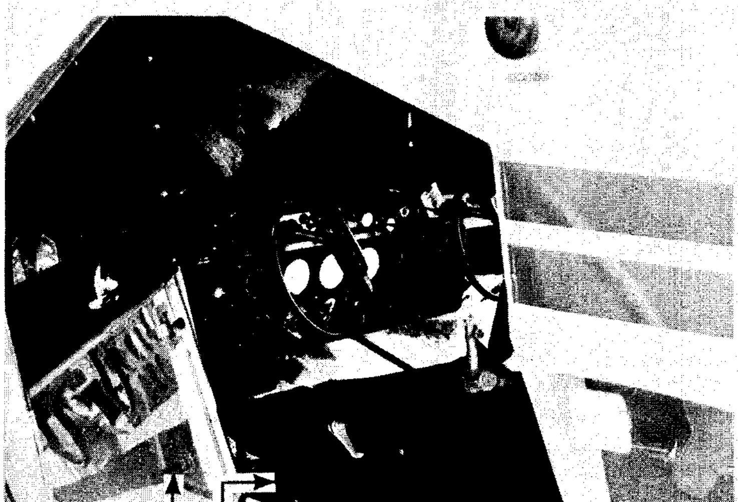
PIPER TRIPACER PA-22, a 1955 model aircraft with pilot only, had just taken off when the windshield fogged over. The pilot tried to set the aircraft back down on the runway. The aircraft rolled off the end of the runway, hit a dirt embankment and collapsed the nose gear. The aircraft skidded 75 feet on its nose and flipped over. The seat belt was in use and held. No shoulder harness was in the aircraft. The forces were not sufficient to cause head impact with the instrument panel. The seat tore out and fell when the pilot released his seat belt.

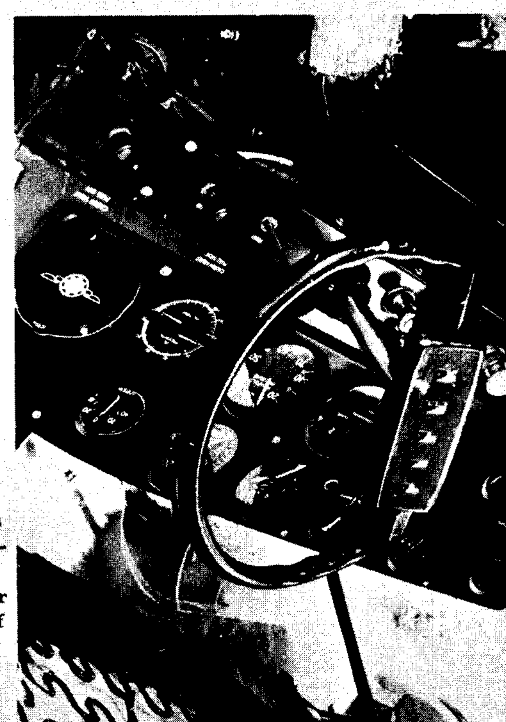
ACCIDENT INVESTIGATED BY:
DON ROWLAN AND EDDIE LANGSTON
CAMI

CASE 13-1



A & B Two views of aircraft that simply flipped over onto its back without damage.

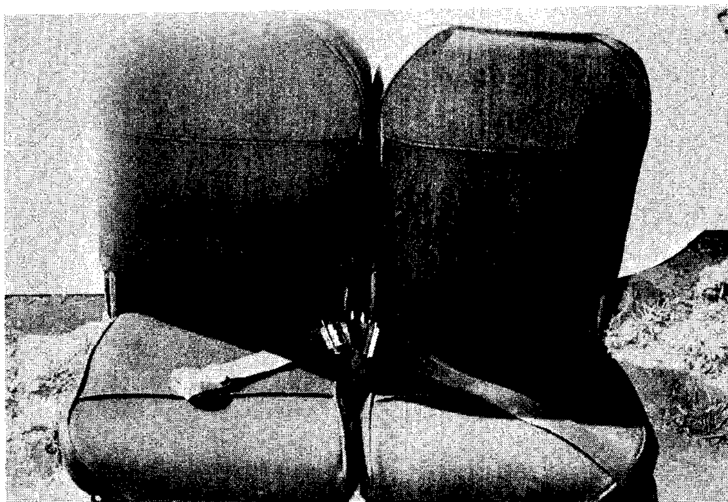




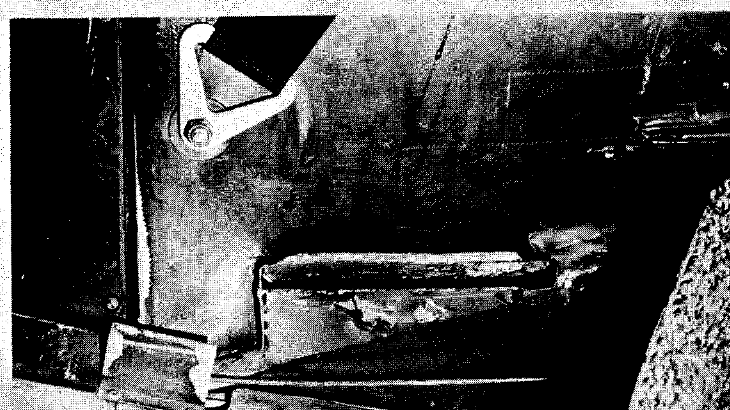
C & D Views of instrument panel and control wheels show no signs of damage & indicate deceleration forces were not of sufficient magnitude to cause pilot to be thrown forward. However note seat has torn free & is lying in the top of the aircraft.

INJURIES		STRUCTURES IMPACTED
Pilot: (S)	Head - Not injured in crash but bumped head severely when he released his seat belt in inverted position & fell on his head.	Radio.
	Trunk - None.	
	Extremities - None.	

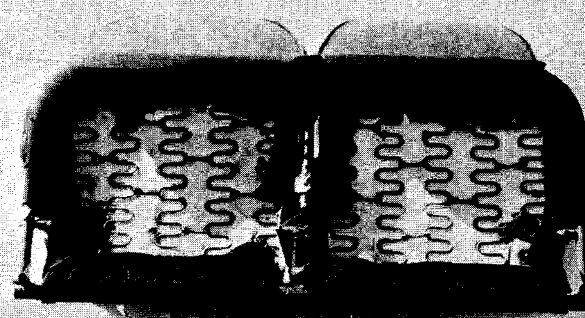
CASE 13-2



E. Seats failed in this minor incident (1) because seat belts were attached to the seat.

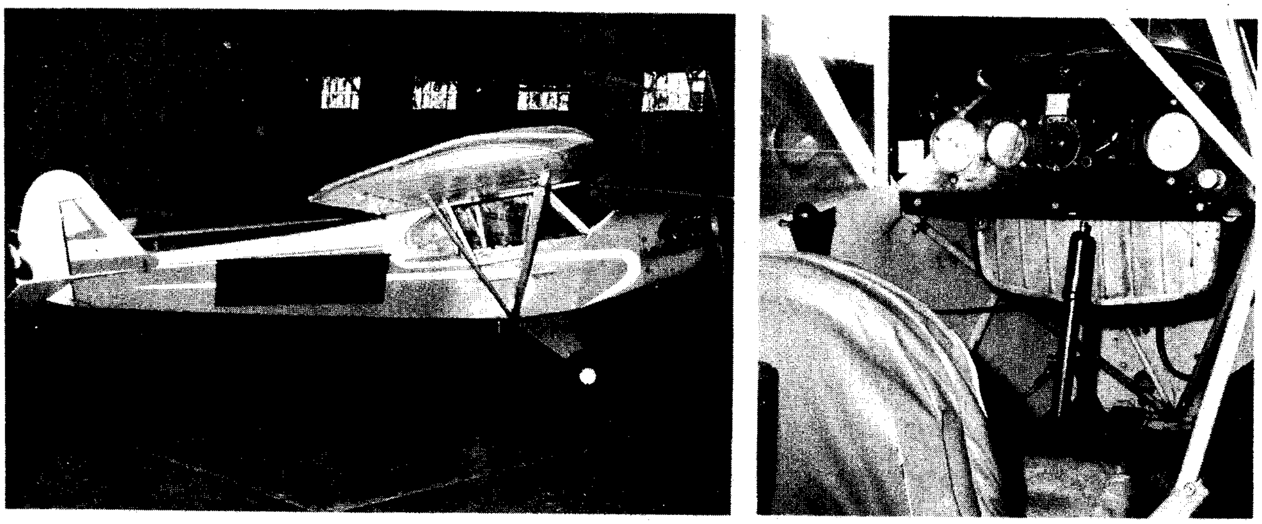


F. (2) wall track for end of seat allows seat to slip out.



G. and (3) center seat tie-down structure is inadequate.

CASE 13-3

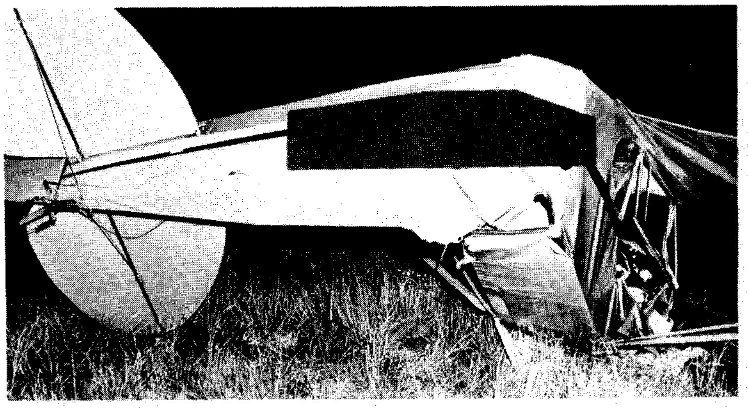


1946 PIPER J-3

PIPER J-3C-65, a 1946 model aircraft with only the pilot flying from the front seat, made a touch-and-go landing, pulled up sharply, made quick left turn, nosed down and crashed on a highway. Pilot was wearing his seat belt and it held. No shoulder harness was in the aircraft. Major impact force threw the pilot forward and slightly to the left.

ACCIDENT INVESTIGATED BY:
EDDIE LANGSTON AND LEE LOWREY
CAMI

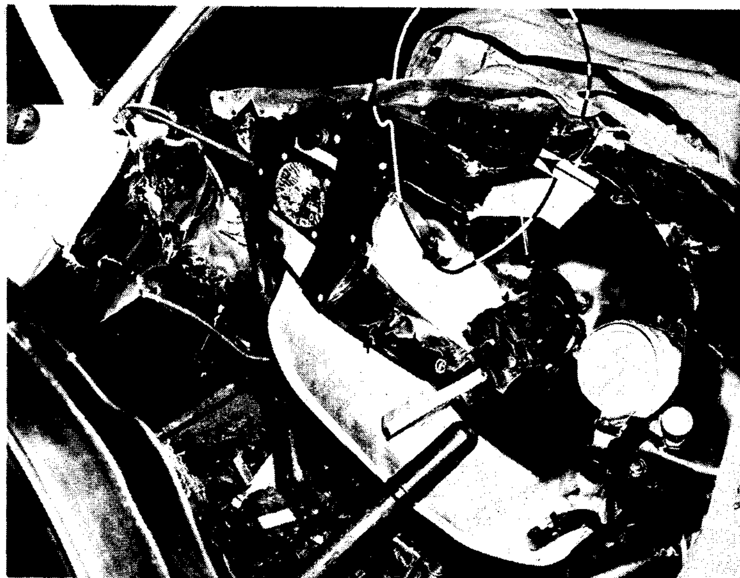
CASE 14-1



A. Rear view of aircraft wreckage.

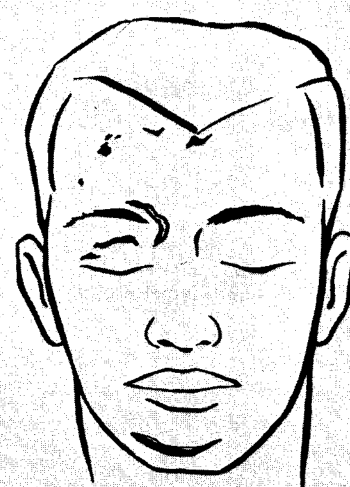
B. Front view showing tubular framework of this aircraft prevented cabin collapse.

CASE 14-2



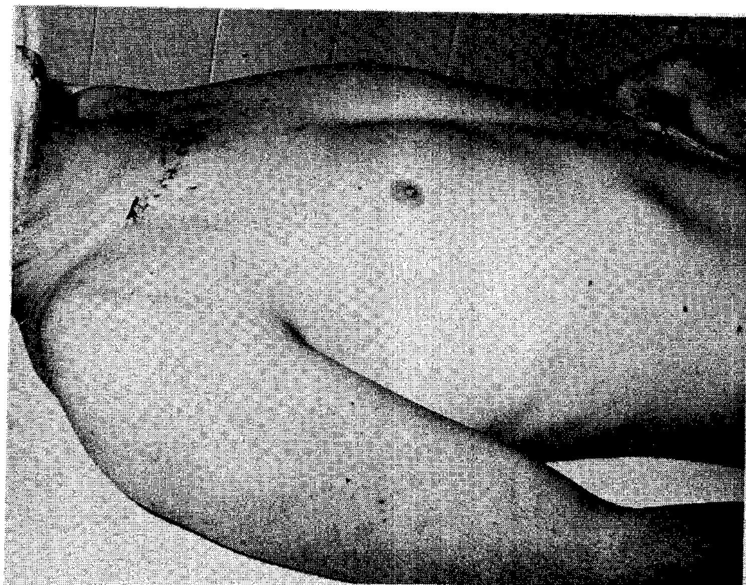
C. Impression in the top center of the instrument panel that caused fatal head injuries.

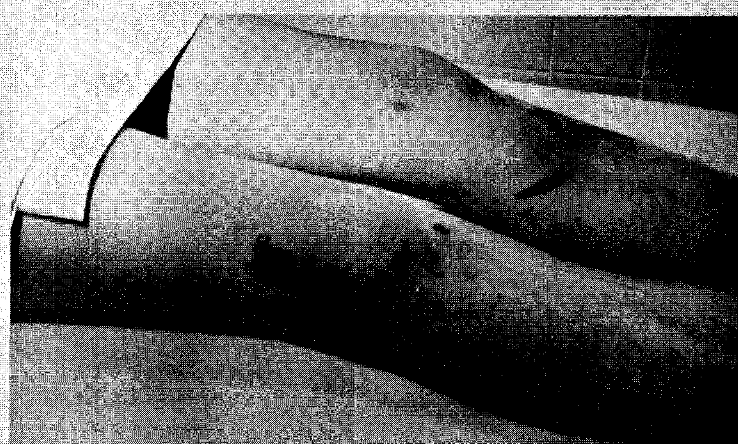
	INJURIES	STRUCTURES IMPACTED
Pilot: (F)	Head - Small lac. over (R) eye. Lac. of chin & Fx. mandible. Front teeth broken off. Bleeding from both ears.	Upper left instrument panel.
	Trunk - None.	
	Extremities - Fx. (R) ankle.	Diagonal tubular frame structure directly over ankle.

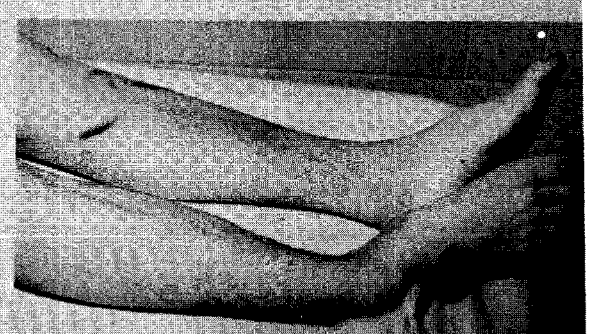


D. Artist sketch of facial injuries.

CASE 14-3

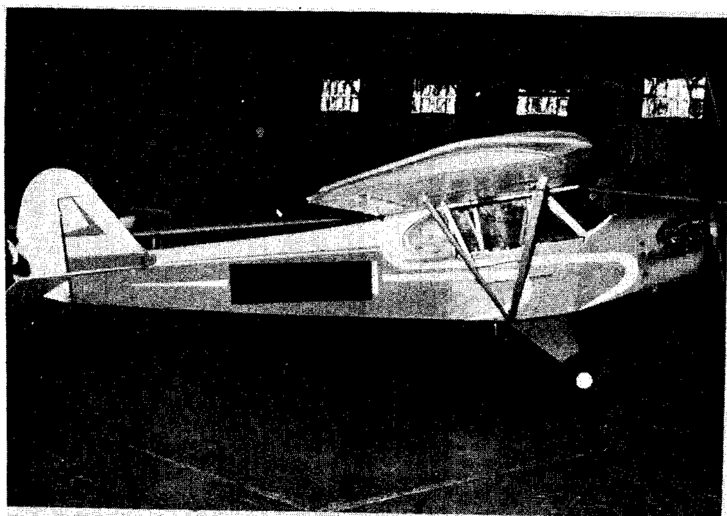
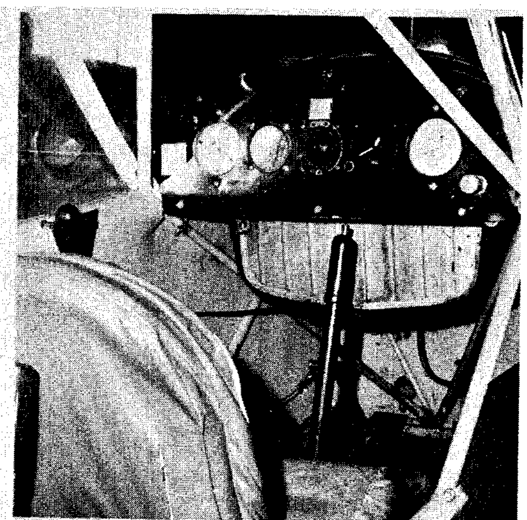






E, F & G Body pictures to show complete lack of body injuries with the exception of a broken ankle.

CASE 14-4

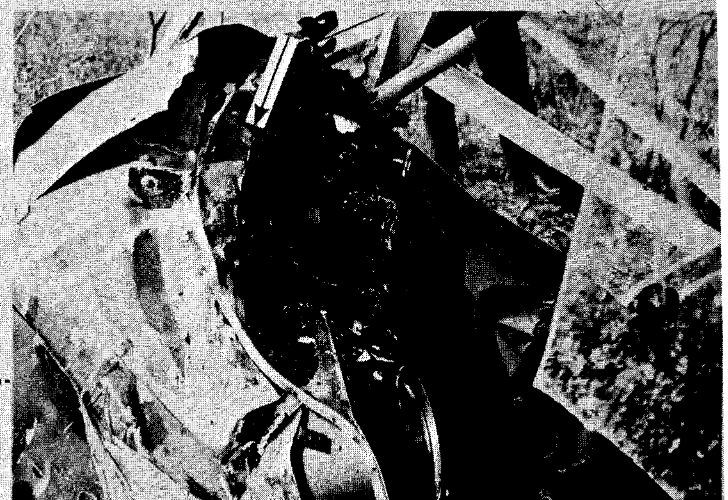
1946 PIPER J-3

PIPER J-C3-65, a 1946 model aircraft with pilot (rear) and one passenger (front), was flying low over the land hunting coyotes. Aircraft pulled up suddenly and crashed in a near vertical position. Both occupants were wearing seat belts. Front seat belt held, but rear seat belt failed at the attachment point, allowing the pilot to be thrown on top of and over the front seat passenger. No shoulder harnesses were in the aircraft.

ACCIDENT INVESTIGATED BY:
BILL REED AND LEE LOWREY
CAMI

CASE 15-1

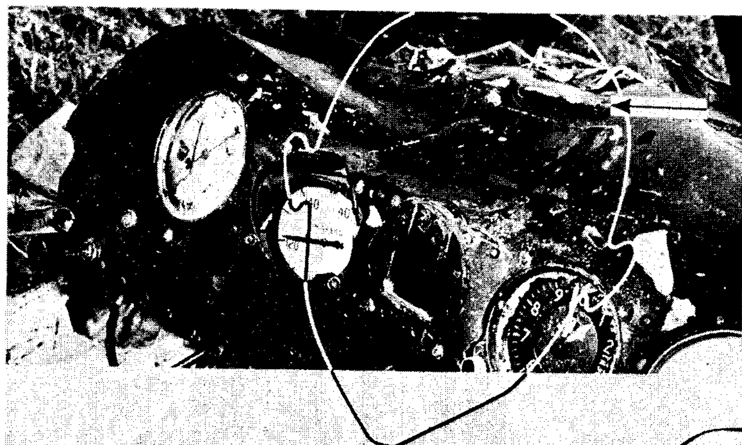
A. Photograph of wreckage from side showing cabin space not compromised.



B. Close-up of instrument panel. Note edge of heavy compass protruding & top seam of gasoline tank pressed into instrument panel cover forming a rigid knife-life edge.

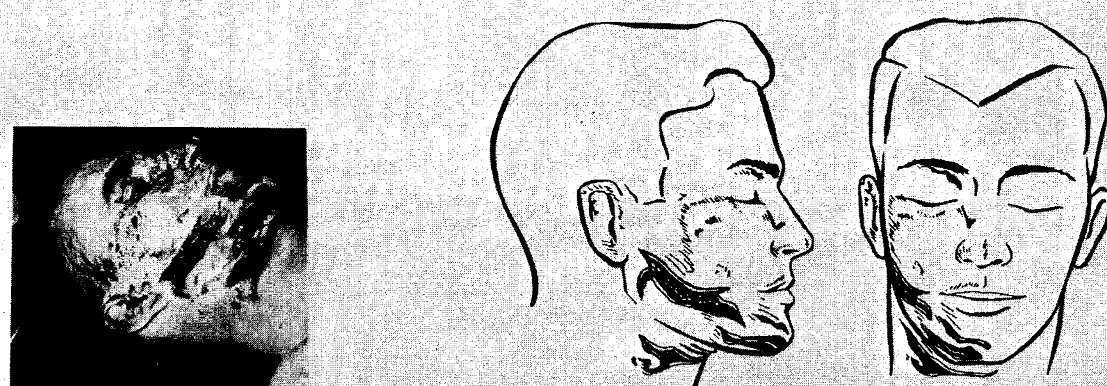
INJURIES	STRUCTURES IMPACTED
Pilot: (F) Head - 4 deep lac's. (R) jaw, (R) neck, under (R) chin.	Windshield.
Fx. mandible (R) teeth driven back.	Top of instrument panel just aft of windshield junction.
Fx. base of skull.	
Trunk - Fx. rib 7 (R). Lac's. liver & spleen. Lac's. pleura & lungs.	Probably back of front seat.
Extremities - Fx's. both ankles,	Jammed under front seat.
Fx. (R) arm & (L) hip.	Unknown.
Front: (F) Head - Extensive Fx's. maxilla, mandible, nasal bones, & orbital bones. Massive skull Fx's. Linear lac. forehead. Lac. bridge of nose & chin.	Instrument panel.
Trunk - None.	
Extremities - Fx. lower (L) leg.	Diagonal tubular frame structure in front of leg.

CASE 15-2



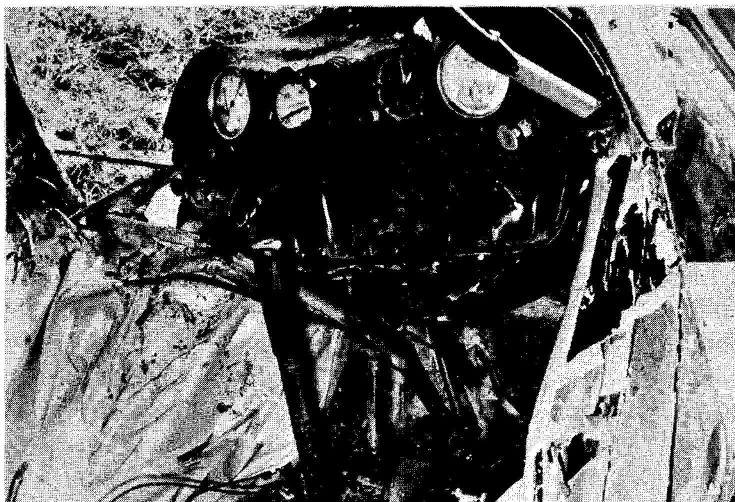
C. Head outline shows area on instrument panel where front seat occupant impacted his face.

D. Photograph & artist sketches of head injuries of front seat passenger.



E. Pilot (rear seat) head injuries. Note lacerations from broken windshield.

CASE 15-3



F. Lower instrument panel showing tubular cross brace that passes over the ankle.

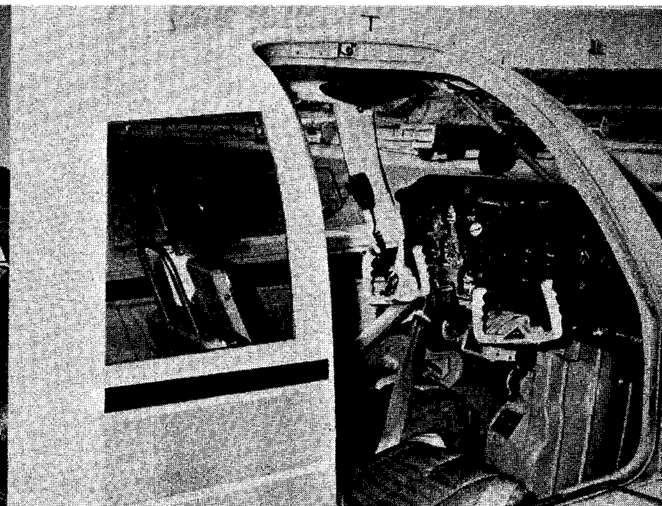
G. Typical ankle fracture from cross brace.

CASE 15-4

to decelerations wearing the single shoulder strap—seat belt combination to be 17 "g"; however, actual tolerance is probably nearly 30 "g". Stapp [64] has established the upper limits of human tolerance to forward impact while wearing a double shoulder harness and seat belt to be about 40 "g". Snyder [65] reconfirmed these data with experimental crash testing using baboons as subjects. Leveau [66] first invented and patented the shoulder harness concept in 1903, and yet nearly 70 years later, it is difficult to understand why today, this principle of restraint is rarely found in use in any type of transportation vehicle. Only in the past two years has shoulder harness restraint equipment become mandatory in automotive vehicles, but very few people are utilizing them. Beech Aircraft Corporation installed a double harness—seat belt combination in all of their aircraft in the early 1950's, but some of their customers wanted them removed. Cessna [67] has had nut plates for easy attachment of shoulder harnesess in most of their general aviation aircraft since 1950 and has offered the shoulder harness as optional equipment. The Beech harness installation was thoroughly tested with a 200-pound dummy and found to effectively restrain the occupant up to 25 "g". These facts have not been publicized and very few pilots know this equipment is available. Other aircraft companies [68] are now putting in shoulder harness attachment points, primarily because they are required by some of their overseas customers. Those interested in retrofitting current aircraft (not equipped with attachment points) with shoulder harness should refer to Young's [69] report and FAA Advisory Circular [70] showing how attachments may be made simply. Many needless deaths and serious injuries have occurred simply because the contents of the packages were not properly restrained.

Case Number 16 describes the crash impact of a 1969 Mooney Executive aircraft. Judging from increase in severity of facial and appendage injuries (Case 16 I, J, P, Q and R) and the fact that the shipping container (cabin) has failed to a greater degree and spilled part of its contents (Case 16 B and D), one would have to conclude that the impact forces were somewhat greater than in the previously-described cases. If the major deceleration forces of the cabin had been as great as 15 "g", the head impacts of the two occupants against the instrument panel would have exceeded a velocity of 100 ft./sec. (70 mi./hr.). Since the depth of the head imprints measured less than 6 inches, the average deceleration of these two heads was in the order of 10,000 ft./sec.^{2}, or over 300 "g" which approaches the tolerance limits of the human face and head with the load distributed evenly over the facial contours. In this case, the impact loads were concentrated by irregular structures and the crushing injuries inflicted would be expected. Also note that both seat belts and seat attachments did not fail. The author concludes that the crash forces in this case were less than 15 "g" and, since the rear cabin structure is intact, it is likely these two men could have survived this crash had they been wearing shoulder harnesses. Special attention should be called to the head impact areas outlined in Case 16 H. Note that these two depressions are down on the face of the instrument panel, the right one being lower than the left, and not on top as would have been expected, indicating that the instrument panel was moving or had moved away from the front seat occupants before they made their head strikes. In other words, the cabin structure had failed and most of the failure occurred on the right side of the cabin, allowing the right end structure of the instrument panel to fail (Case 16 B). The left side of the cabin of this aircraft does not have a door (Case 16 A) and for that reason has more structural strength. This weakness of cabin structure around the door area has been observed throughout this crash investigation study with the exception of aircraft manufactured by Beech Aircraft Corporation who, through the use of light channel, greatly increased the strength of the Beech aircraft cabins in the early 1950's. Attention was called to the poor design of the control wheel of this aircraft in Case 11. Here we see it again—the protruding clock in the center of the wheel has left its mark and the horns have broken off (Case 16 K and L).

In Case Number 17, a 1952 Piper Tripacer PA-22 with four occupants crashed at a shallow angle (about 15°) on a blacktop road and skidded 159 feet before coming to rest. One's first impression, after viewing the wreckage (Case 17 B and C), would be that this accident should be in the nonsurvivable class. However, since three of the four occupants did survive, two with minor injuries, it must be assumed that only



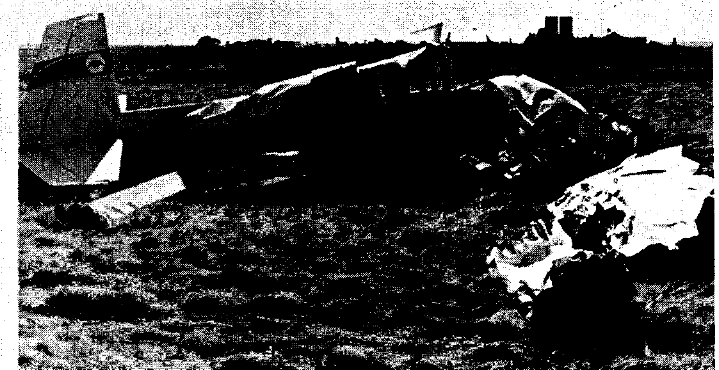
1969 MOONEY EXECUTIVE

MOONEY EXECUTIVE 21, a 1969 model aircraft with pilot and one passenger (R. F.), was observed going into a right spin after engine failure. The aircraft crashed (R) wing low in a grassy pasture (hard ground). As the (R) wing hit the ground the right side of the cabin was torn open and both occupants were thrown forward and to the right into the instrument panel. Seat belts were in use and held. No shoulder harnesses were in the aircraft.

ACCIDENT INVESTIGATED BY:
DON ROWLAN
CAMI

CASE 16-1

A. Left side of aircraft after impact.

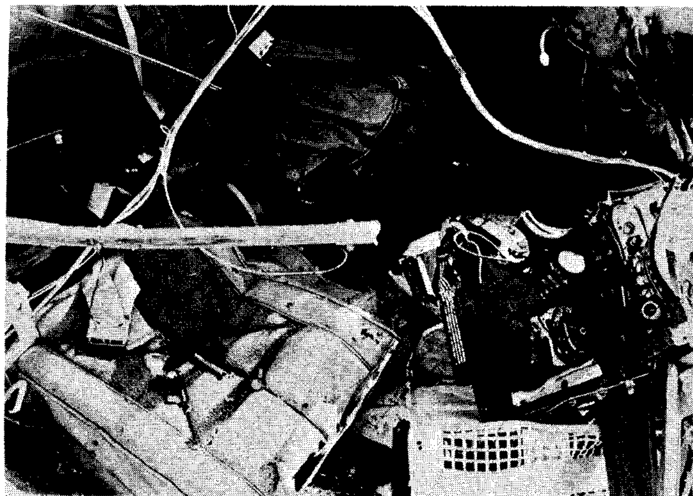


B. Right view shows cabin structure failed & opened up.

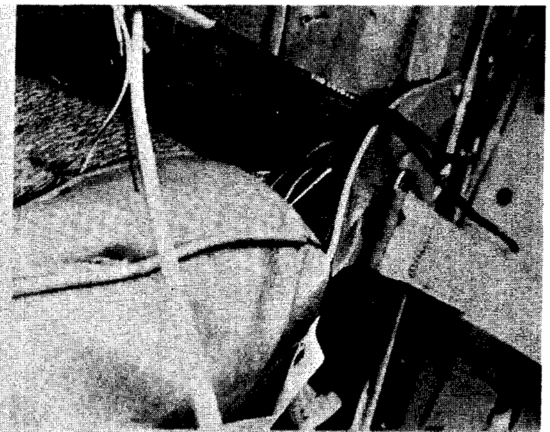
C. Pilot's body still retained by seat belt.

D. Copilot's body partly ejected through opening.

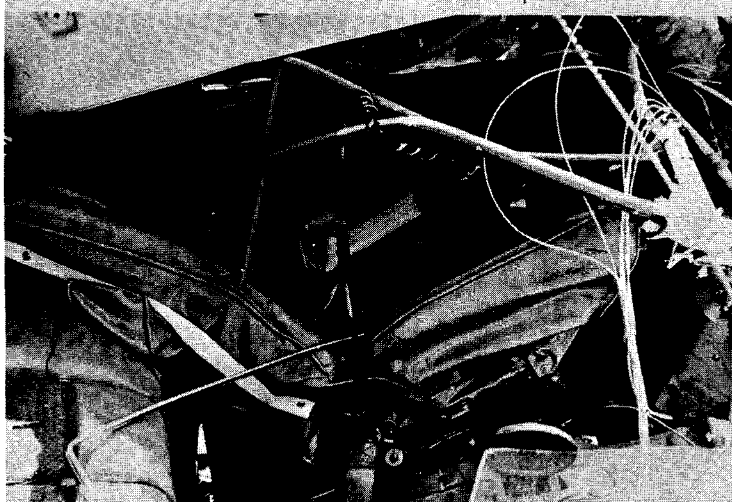
CASE 16-2



E. General appearance of cabin interior.

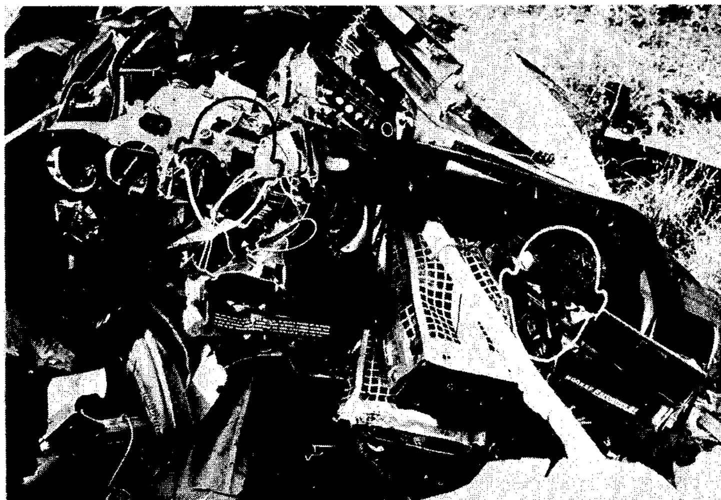


F Seat belts are attached to the seats.



G. Seat track pulled loose from floor.

CASE 16-3



H. Structures impacted by heads of front seat occupants.

I. Crushing injuries of pilot's head.

J. Copilot head injuries.

	INJURIES	STRUCTURES IMPACTED
Pilot: (F)	Head - Mult. & extensive facial & skull Fx's.	Instrument panel.
	Trunk - Fx's. pelvis mult., separation of membranous urethra & rectum. Tears in mesentery & small bowel, with traumatic separation of small bowel. Lac's. liver & spleen; Fx's. of ribs & destruction of interventricular system of heart.	Control wheel, radio, seat belt, seat structure (below).
	Extremities - Fx's. humerus (R), (L) thumb, 5th finger on (R) hand, both ankles. Mult. severe lac's. & abrasions.	Instrument panel & pedal area.
R. F.: (F)	Head - Fx's. facial bones, mandible, basal skull Fx. with subdural hemorrhage.	Instrument panel.
	Trunk - Lac's. of heart & aorta. Fx's. of ribs, mult. Flail chest.	Control wheel & radio.
	Extremities - Fx. (R) humerus, (R&L) legs & ankles, bilateral.	Lower instrument panel & pedal area.

CASE 16-4

K. Broken control wheel with center-mounted altimeter & reset knob.

L. Chest injury inflicted by altimeter & reset knob shown in K.

M. Tubular control column broken off.

N. Chest injuries from control wheel horns & broken column.

O. Shoulder injury inflicted by circular instrument.

CASE 16-5

P, Q & R Severe lacerations & fractures inflicted when arms & legs flailed into broken structures.

CASE 16-6

a small portion of the deceleration occurred during the initial impact with the blacktop road while the rest was gradual during the 159-foot slide. Since three seat belts held and only one, the pilot's, failed in the seat structure (Case 17 E), it is plausible to conclude that the tubular failure of the pilot's seat may have resulted from the extensive fuselage break-up and not from the initial impact force per se. However, since his restraint did fail, he was thrown forward, striking his head on the instrument panel (Case 17 D) with sufficient force to cause multiple lacerations and brain hemorrhages and as his chest struck the control wheel the small diameter control column folded over to form a spear (Case 17 E) that penetrated the vital thoracic organs and caused his death. On the other hand, a woman, seated in the right front seat, was restrained by a lap belt that did not fail. She received no facial injuries, only a fractured left radius and there is no head imprint on the right side of the instrument panel. It is obvious that she threw her left arm up in front of her face and by so doing kept her head from impacting the lethal construction of the instrument panel. Since her leg injuries were relatively minor, it is doubtful if the major impact force of this crash exceeded 10 "g".

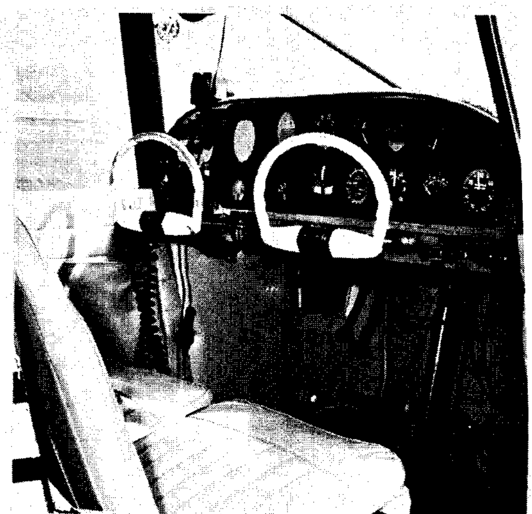
While the aircraft crash discussed as Number 18 is an older aircraft (1940 Aeronca Chief), it serves to show numerous design parameters contributing to the high death and injury rate. Many of these design "mistakes" are still present in late model general aviation aircraft; namely, lack of cabin integrity (Case 18 A), instrument panels with knife edges, heavy instruments and protruding knobs that destroy the face and head even at low impact forces (Case 18 B), a control wheel and column lacking in load distribution qualities and/or of a construction that allows the outer rim to break away, leaving a small area for concentrated loads that can penetrate the chest or cause fatal injuries without pentration. In this instance the rim not only broke away and the hub penetrated the chest (Case 18 F), but the wire spoke design opened like an umbrella within the chest making removal from the body most difficult. In spite of the severe destruction of the fuselage and the multiple facial injuries, this crash was well within limits of human survival—probably not more than 12–15 "g".

The engineering changes for crash safety made by Beech Aircraft Corporation in 1953 in the Bonanza;[71] namely, reinforced channel sections surrounding the cabin, a heavy keel forward of the cabin, a safety-type control wheel, instrument panel mounted on shearable shock mounts, strong seat tie-down to basic structure and the installation of shoulder harness (Figure 28) are in direct contrast to all the safety features lacking in most other general aviation aircraft.

The degree to which these improvements are paying off is well illustrated in Case Number 19. This 1954 Bonanza E–35 (with two front-seat occupants) impacted two large trees (12-inch diameter) at a velocity of 100 miles per hour. The impact force was sufficient to uproot the trees (Case 19 B) and the fuselage continued on to impact vertically on its nose. Note that even though the initial crash force was sufficient to tear off the wings, engine and rear fuselage, the cabin is still intact (Case 19 A and C). Since the impact point with the trees was 12 feet above the ground and the aircraft decelerated in an arc of a ¼ circle as it pushed the trees over, it is possible to calculate an average deceleration from 150 ft./sec. to zero in 18 to 20 feet to be approximately 19 "g". It may be assumed that the decelerations during initial impact with the trees and the final impact with the ground would have been somewhat greater than the average—perhaps 20–25 "g". In spite of the high deceleration forces, both occupants received only minor injuries (see injury table), compared to those presented in this report thus far of occupants of crashes of much lower magnitude. Injuries would probably have been prevented altogether in this accident had the occupants been wearing their shoulder harnesses more securely. The author feels that this crash again illustrates that *Crash Safety Can Be Engineered.*

To illustrate the significance of recent crash safety design in automotive vehicles as contrasted to the lack of it in general aviation aircraft, a single automobile accident will be presented at this time. An 18-year-old male driving a 1969 Mercury two-door on a freeway at night claimed he fell asleep and his car ran off the road. The path of his car and a general view of the crash site are shown in Figure 29.

The automobile actually flew through the air a distance as measured on the horizontal of 117 feet. During its flight it cleared a cable hang-

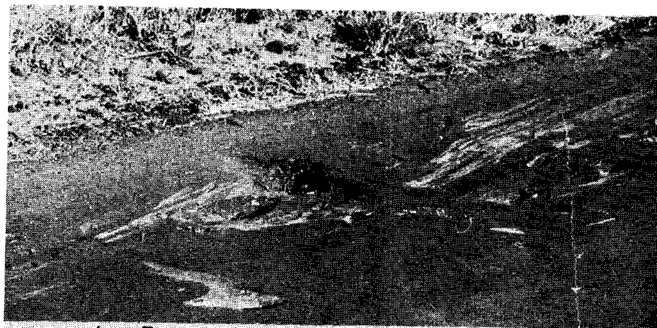


1952 PIPER TRIPACER

PIPER TRIPACER PA-221-35, a 1952 model aircraft with pilot and three passengers (R. F., L. R., R. R.), took off and climbed to an approximate altitude of 400 feet, stalled and crashed on a blacktop road left wing first at a shallow angle and skidded 159 feet down the road. Pilot and all three passengers were wearing seat belts. Pilot's seat belt failed at the attachments; the other three held. No shoulder harnesses were in the aircraft. All four occupants were thrown forward and to the left.

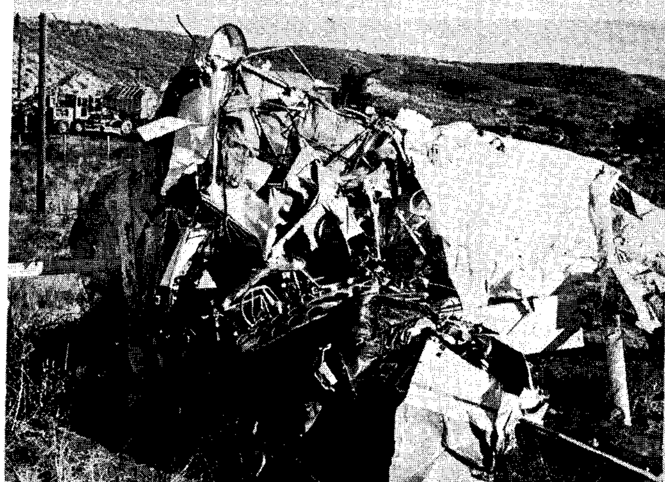
ACCIDENT INVESTIGATED BY:
TERRY WALLACE AND GALE BRADEN
CAMI

CASE 17-1



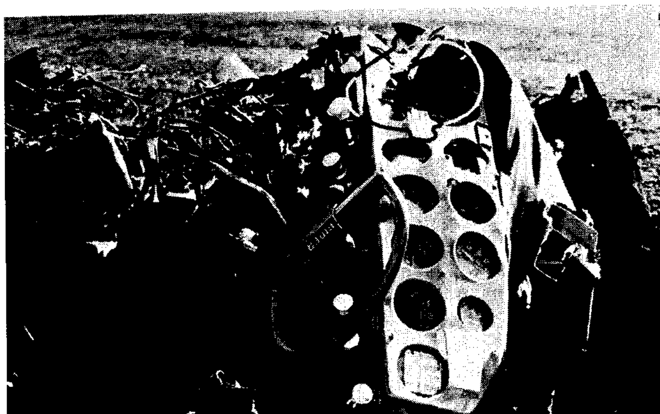
A. Depression made in blacktop road during initial impact.

B. Appearance of aircraft wreckage after skidding 159' down the road.

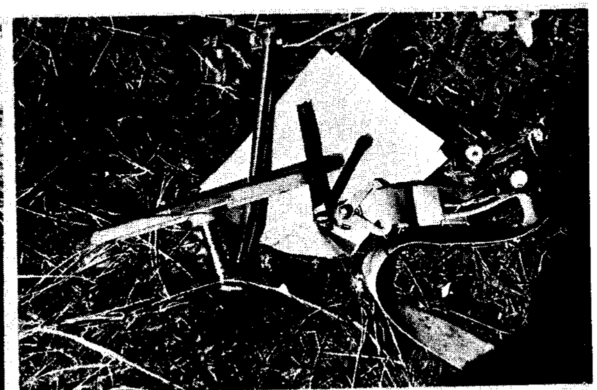


C. Front of aircraft including the instrument panel received extensive destruction. From the extent of cabin disintegration, this crash appears to be nonsurvivable; however, all passengers survived.

CASE 17-2



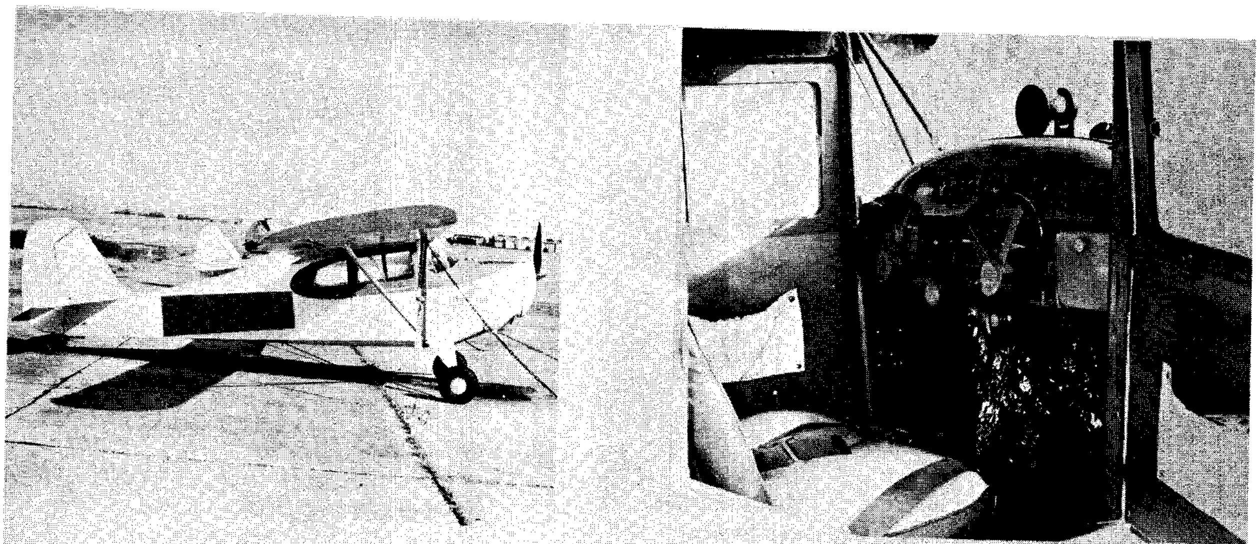
D. The pilot received fatal head injuries when his face impacted the area outlined on the instrument panel. Also note the absence of the pilot's control column & wheel.



E. Pilot received massive puncture of all major body viscera when control column bent to form a spear after seat belt attachment failed.

		INJURIES	STRUCTURES IMPACTED
Pilot: (F)	Head -	Mult. Lac's. & contusions, contusions & hem. of (R) temporal lobe of brain.	Upper left instrument panel.
	Trunk -	Fx. ribs 1 through 10 with massive puncture of all major body viscera.	Control wheel & control column when it bent double to form a spear.
	Extremities -	Mult. Lac's & contusions. Fx. (R) ankle.	Tubes & torn metal under dash.
R. F.: (S)	Head -	Mild facial contusions, Fx. (L) radius.	Probably had (L) arm in front of face, hit upper center of instrument panel.
	Trunk -	Fx. T6.	(R) control wheel.
	Extremities -	Fx. (L) os calcis.	Structure under dash.
L. R.: (S)	Head -	Compound basilar skull Fx. Brain contusion. Compound Fx. maxilla. Blowout Fx. floor (R) orbit. Compound Fx. nose. Lac. through (R) upper lip.	Unknown. Probably (L) door post structure and/or pilot's seat back.
	Trunk -	None.	
	Extremities -	Fx. (R) wrist. Dislocation (R) thumb.	Unknown.
R. R.: (S)	Head -	Mult. contusions face (mild).	
	Trunk -	Contusion (L) chest, Fx. L1, Separation (R) pelvis opening of pubis.	Unknown.
	Extremities -	Sprained (L) ankle.	

CASE 17-3

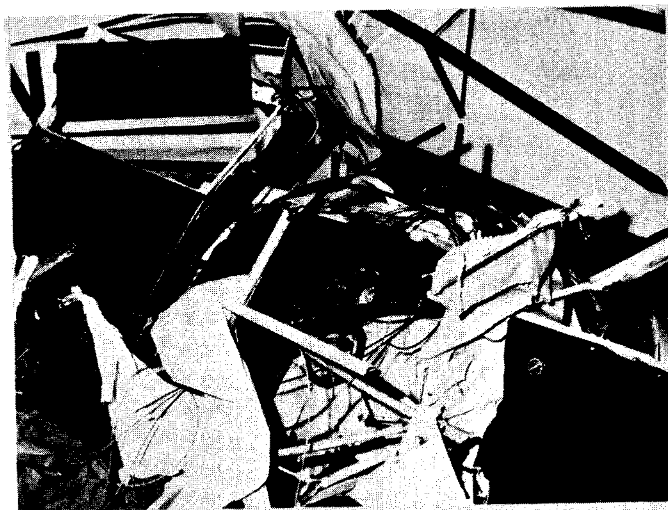


1947 AERONCA CHIEF

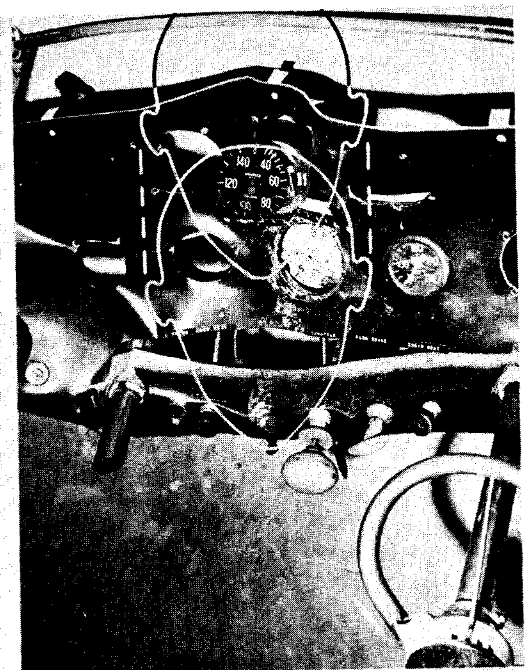
AERONCA CHIEF, a 1940 model aircraft with pilot only, was buzzing friends on the ground. Aircraft pulled up into a stall and crashed into ground in a very steep angle. Seat belt was in use and held. No shoulder harness was in the aircraft. The pilot was thrown forward and slightly to the (R).

ACCIDENT INVESTIGATED BY:
DON ROWLAN AND LEE LOWREY
CAMI

CASE 18-1



A. Close-up of aircraft wreckage looking into the cockpit area.

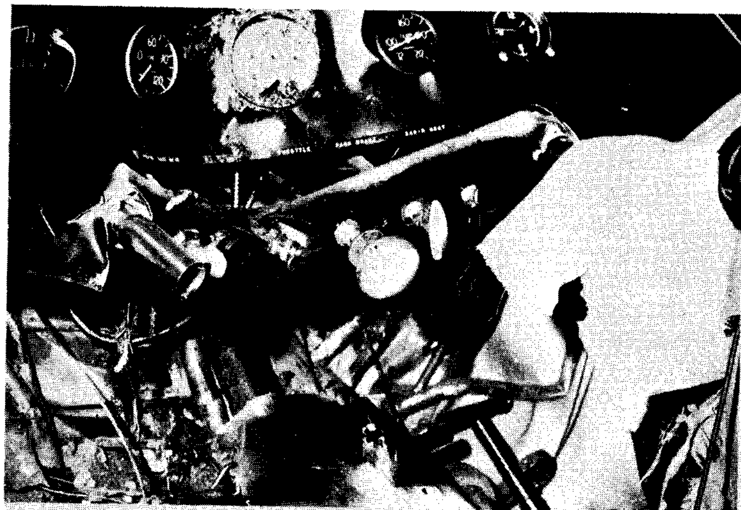


B. Head outlines on instrument panel indicate areas impacted by the pilot's head.

C. Artist sketch of severe lacerations & facial crushing resulting from impact with the instrument panel.

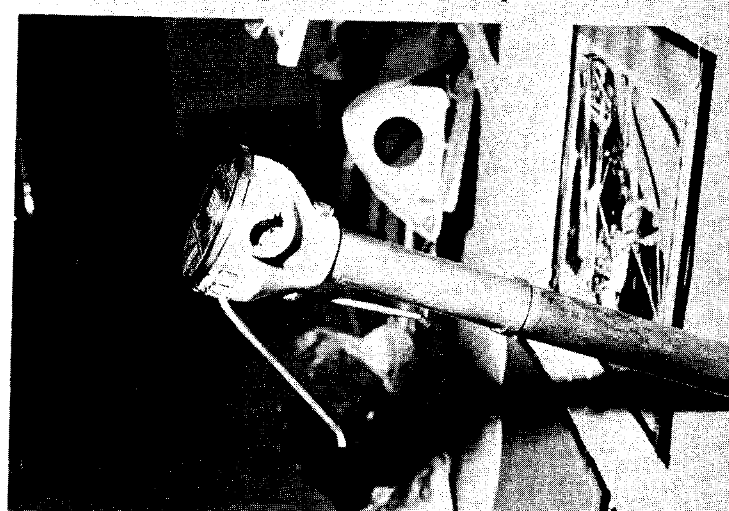
D. Close-up of heavy instruments struck by pilot's head.

CASE 18-2



E. View of lower instrument panel. Knobs & sharp-edged metal produced leg injuries shown in J. Note pilot's control column has been sawed off.

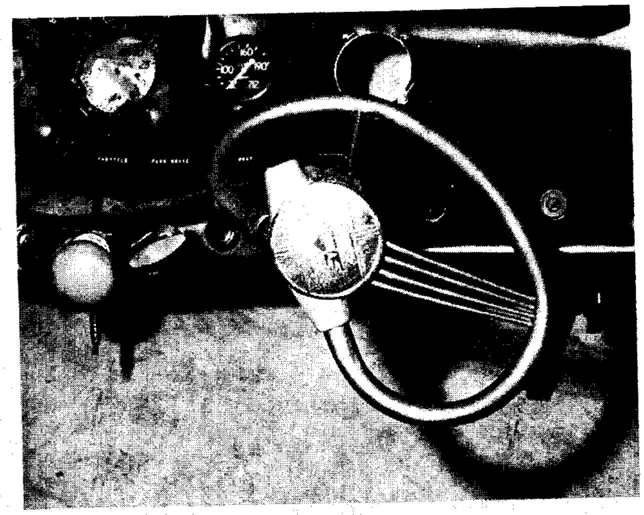
F. Poor design of control wheel allowed chest penetration.



G. Control wheel was removed from chest cavity with difficulty since wire spokes opened up like an unbrella.

CASE 18-3

H. Puncture wounds in the right shoulder from hub & spokes of right control wheel.



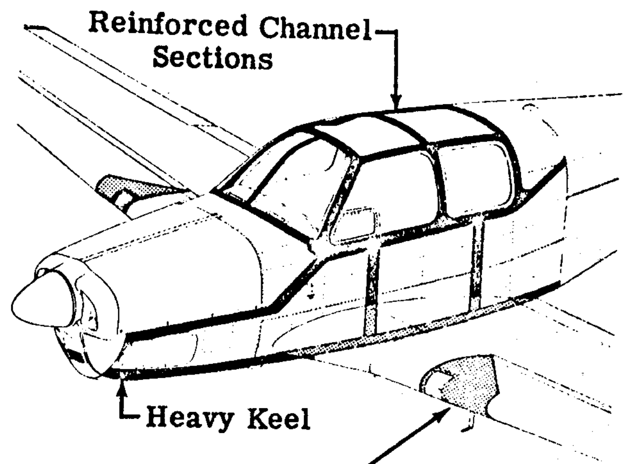
I. Copilot's control wheel.

	INJURIES	STRUCTURES IMPACTED
Pilot:	(F) Head - Crushed facial bones below suborbital ridge. Mult. basal skull Fx's. Brain Hem's.	Upper center instrument panel.
	Severe & mult. facial lac's.	Upper & lower center instrument panel.
	Trunk - Penetrating wound (L) chest, (L) lung, heart, diaphragm, liver & spleen. Mult. rib. fx's.	(L) control wheel rim broke off, hub & spokes penetrated chest like a harpoon. Removed at autopsy.
	Extremities - Small puncture (R) upper anterior shoulder surrounded by 3 smaller punctures.	(R) control wheel & spokes.
	Mangled lower extremities with mult. fx's.	Lower instrument panel.

J. Lower leg injuries.

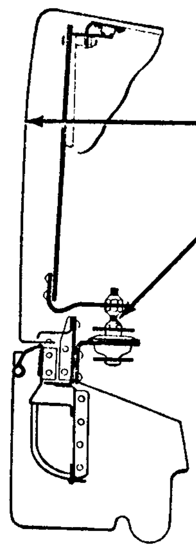
CASE 18-4

These special features are indexed to correspond to the recommendations outlined in the attached article, "Crash Safety Can Be Engineered".



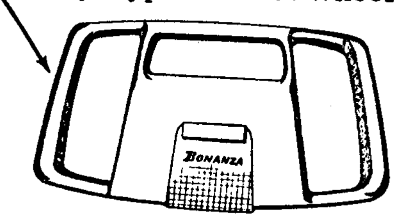
A. The BEECHCRAFT Bonanza's long nose section provides gradual impact deceleration.

B. The BEECHCRAFT Bonanza's wing design provides crash shock absorption in addition to its rugged design which has been tested to over 8.4 G's which is 47 percent above government required safety margins.



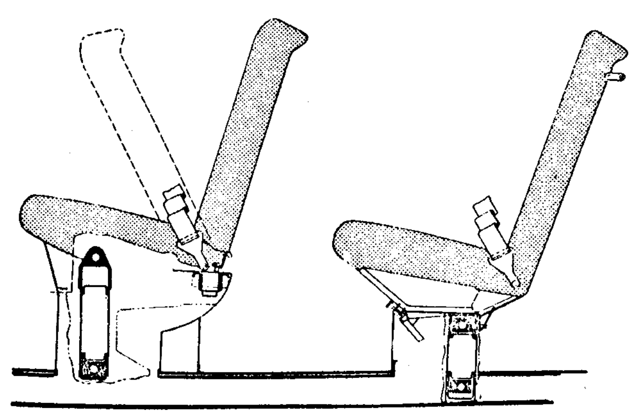
C. The Bonanza's fuselage has reinforced keel section providing occupant protection against crashes and lessening crash damage.

D. The Bonanza's reinforced cockpit provides a strong crash-resistant passenger compartment or structurally-reinforced capsule for maximum occupant protection.



E. The Bonanza instrument panel is installed with shearable shock mounts on basic instrument panel with a thin gauge soft metal head shield to lessen the possibilities of passenger injuries in event of crash landing.

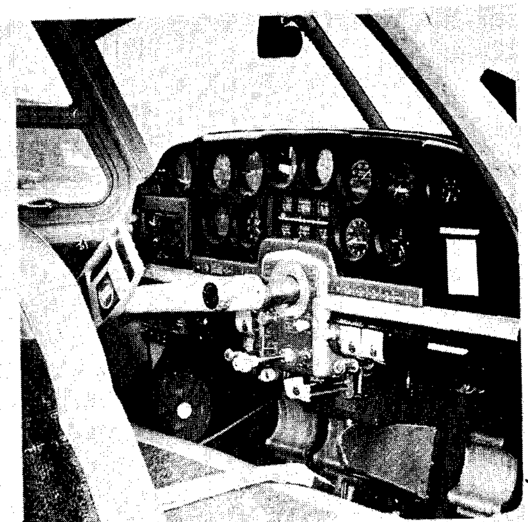
F. The new Bonanza is equipped with body supporting safety-type control wheel to reduce chest and lung injuries in event of crash landing.



G. The Bonanza seats and safety belts are securely mounted to the basic spar truss with the front seat backs hinged to swing forward out of head range of occupants in the rear seat to provide a maximum of passenger protection.

These features which have been outlined above are some of the results of years of private research and testing to enable us to build safer and more practical airplanes.

FIGURE 28. Safety release bulletin—Beech Aircraft Corporation.



1955 BEECH BONANZA

BEECH BONANZA E-35, a 1954 model aircraft with pilot and one passenger (R. F.), was on approach for a landing in poor weather. The aircraft clipped the tops of some small trees and then struck (at 100 m. p. h.) two larger trees, one with each wing, dislodged the trees, and slid to the ground tail-first. The aircraft was equipped with shoulder harnesses and seat belts. The pilot was wearing only his seat belt, while the passenger was utilizing both harness and belt. The pilot was thrown through the windshield; the passenger remained in the aircraft. All restraint equipment, attachments, and seat tie-downs held. The pilot slipped out of his belt. The aircraft cabin remained intact!

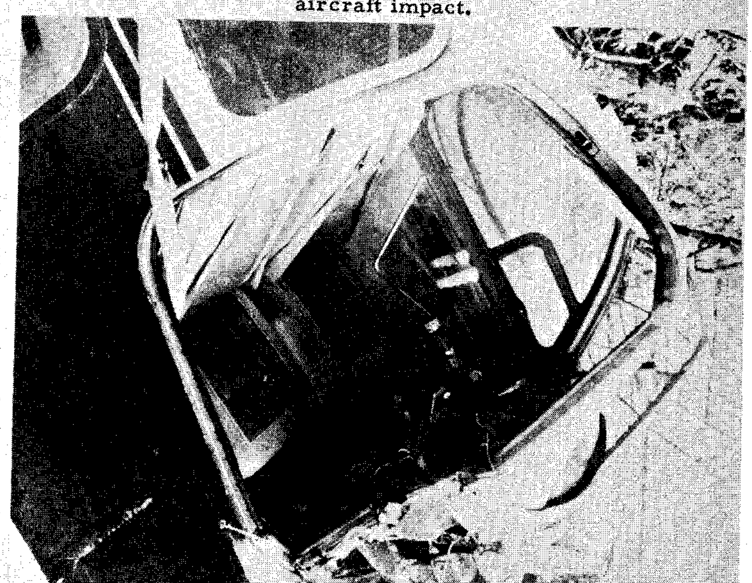
ACCIDENT INVESTIGATED BY:
ERNEST MC FADDEN AND JIM SIMPSON
CAMI

CASE 19-1

A. Wreckage of Beech Bonanza. Note that the tail, wings, & motor are torn away, but the cabin is intact.

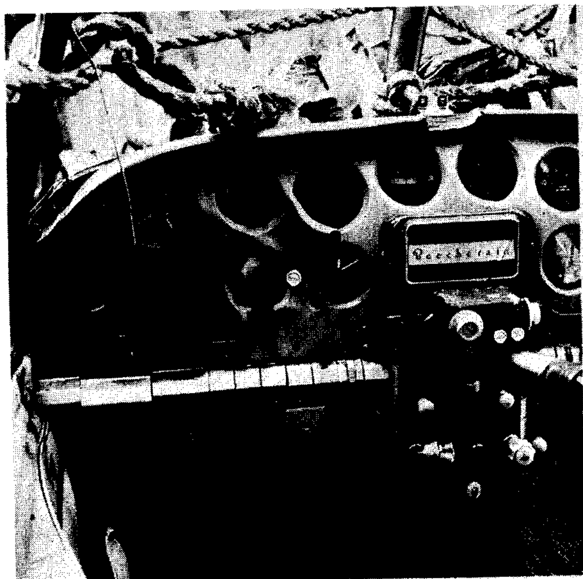
B. Two large trees uprooted by aircraft impact.

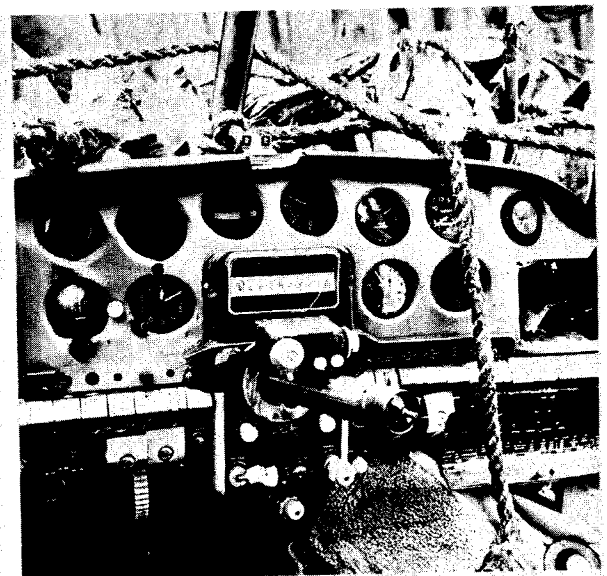
C. Close-up showing cabin integrity.

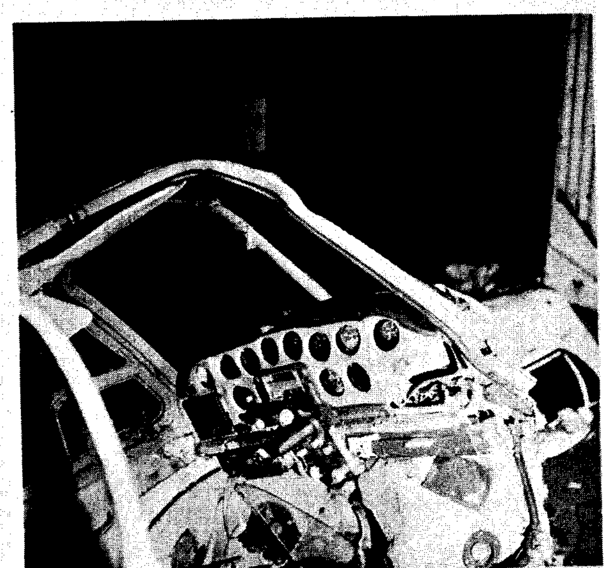


	INJURIES	STRUCTURES IMPACTED
Pilot: (S)	Head - Contusions & abrasions, small lac's.	Windshield.
	Trunk - Fx. (L) ribs 7, 9, 10, 11. Fx. dorsal vertebra #5.	Control wheel.
	Extremities - None.	
R. F.: (S)	Head - Lac. scalp.	Broken windshield entered cabin.
	Trunk - Fx. (L) rib #8 with lung contusions.	Control column post.
	Extremities - Sprain (R) ankle.	Pedals.

CASE 19-2

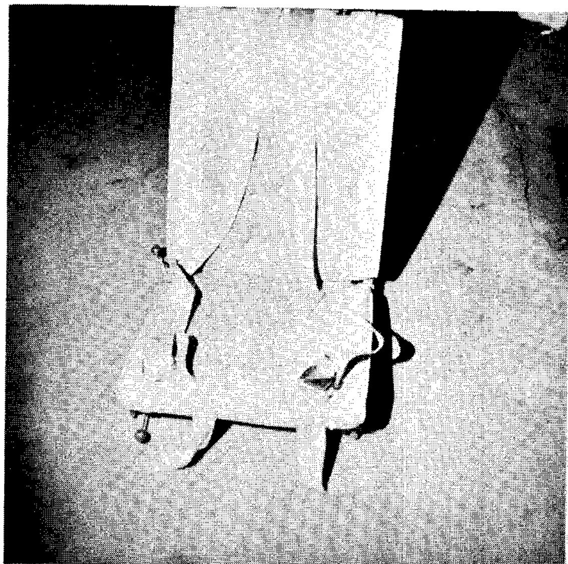


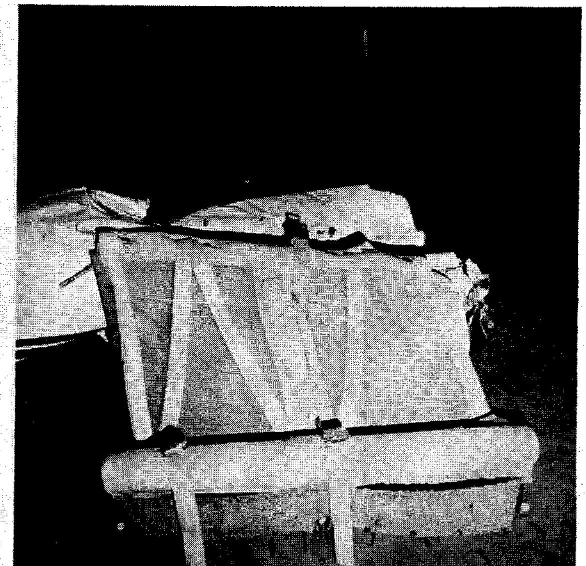




D, E & F Views of instrument panel & cabin interior.

CASE 19-3





G & H Continuous shoulder harness--seat belt combination installed in the Beech Bonanza.

CASE 19-4

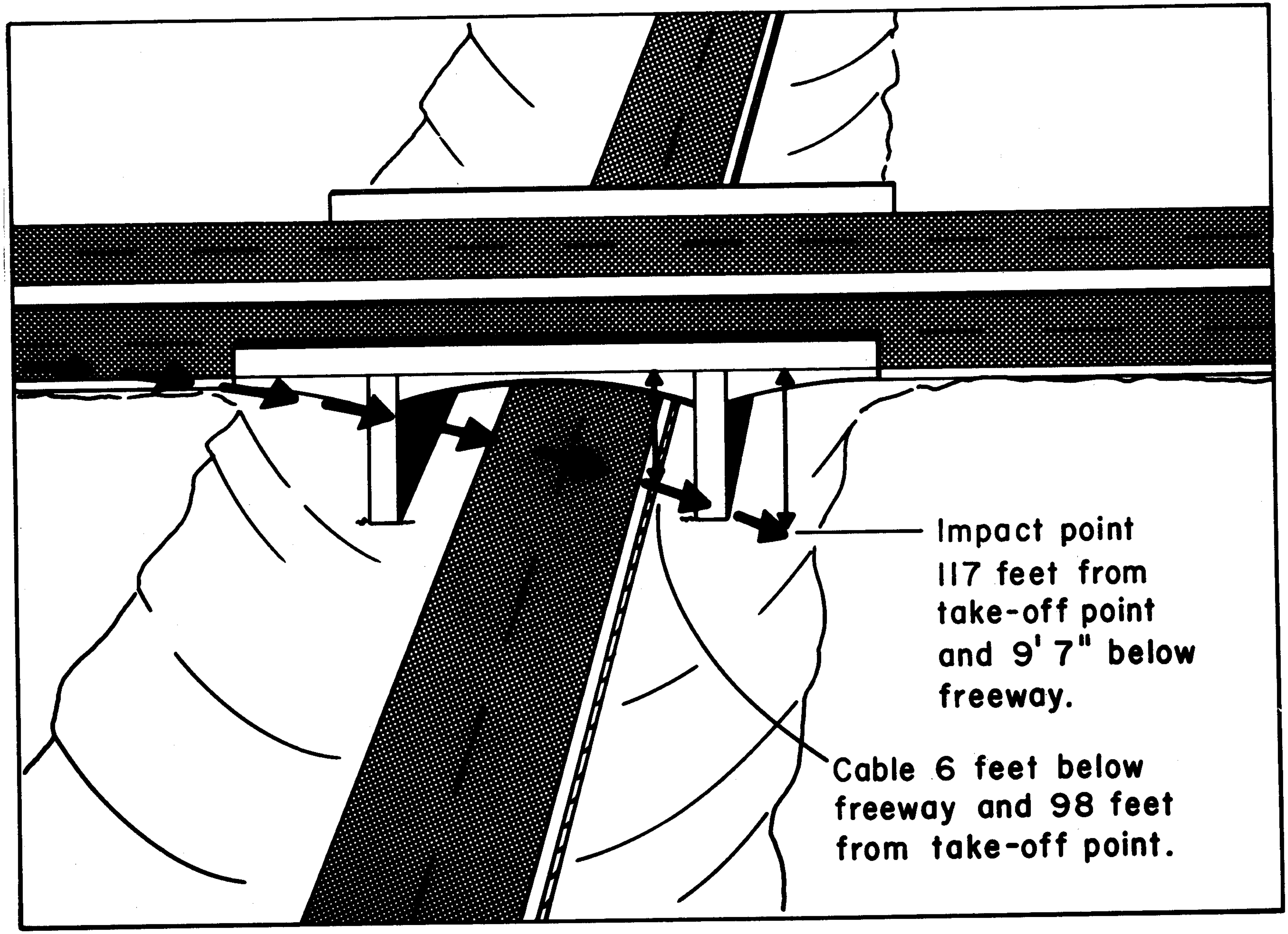


FIGURE 29. Trajectory of an automobile traveling at high velocity after it ran off the freeway.

ing 6 feet below the bridge and about 98 feet from the take-off point. Acceleration due to gravity caused a drop of only 9 feet, 7 inches, during its 117-foot flight. In this instance, one can easily calculate with accuracy that the flight velocity of this vehicle must have been slightly over 100 miles per hour. Crushing of the front of the vehicle was approximately 5 feet (Figure 30) and the depression in the hard earth embankment measured 8 to 12 inches. Hence, it can be calculated that the average deceleration of the car was in excess of 50 "g". Even with these very severe impact forces, the shipping container maintained its integrity and the heavy motor was pushed back under the floor board and not into the cabin. While it is doubtful if light aircraft cabins can be designed to withstand "g" forces of this magnitude, their interior certainly could be modified to incorporate some of the succesful design principles for crash survival illustrated in this accident. Although both shoulder harness and seat belt restraint were available in this automobile, the driver was not utilizing either. As a result, his body slid forward in the seated position until his knees embedded themselves in the lower dash (Figures 31 and 32), a smooth, rounded, ductile metal without knobs or rigid edges. His chest contacted the large diameter steering wheel contoured to fit the body and distribute the load over a large chest area (Figure 33). The chest impact was of sufficient force to crush the collapsible control column mechanism to its maximum distance (8″) (Figure 34). At the same time his head was impacting the padded sunvisor and pushed it through the windshield (Figure 35). The only injuries suffered by the operator of this automobile were a laceration of the face and a small puncture wound on the upper left arm, both resulting from contact with the broken windshield.

FIGURE 30. Side view of vehicle showing crushing of front end during deceleration.

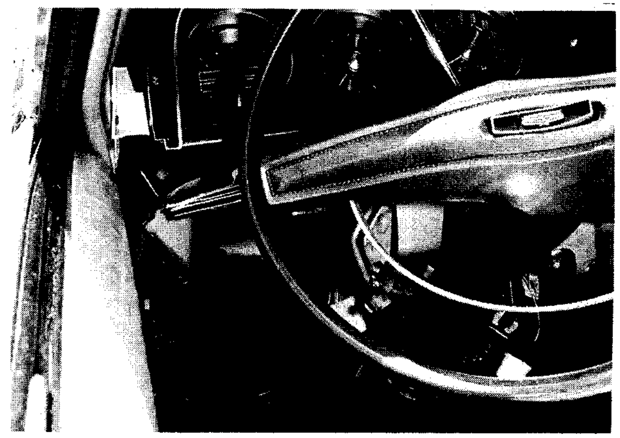


FIGURE 32. Left knee impact.

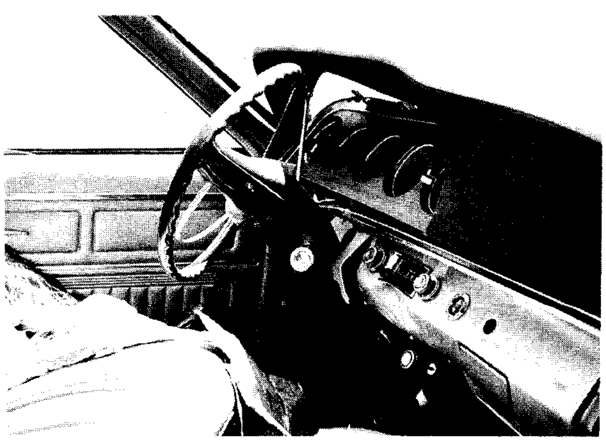


FIGURE 31. Right knee impact area.

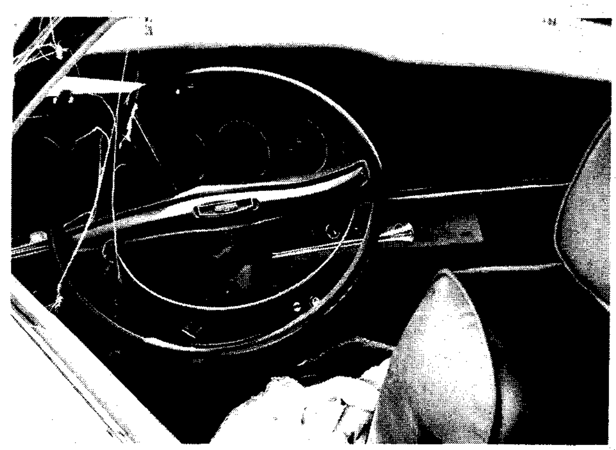


FIGURE 33. Large diameter contoured steering wheel.

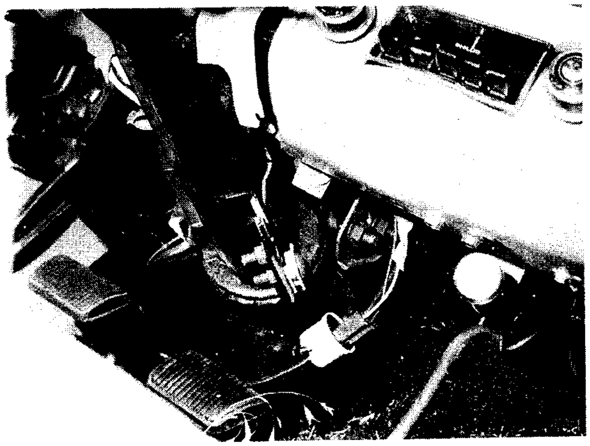


FIGURE 34. Collapsible control column compressed by chest.

FIGURE 35. Padded sunvisor pushed through the windshield by head impact.

The fact that crash safety engineering is sorely lacking in the forward cabin in most current general aviation aircraft is further illustrated by three unusual crash cases presented here. In Case 20 a 1968 Cessna 150–H crashed upside down and the heads of both occupants dragged along the ground, thereby staying away from the lethal instrument panel. Injuries were limited to lacerations of the scalp and abrasions of the face. The deceleration distance for this aircraft as its nose rooted under a large flat rock could not have been more than 4 feet. Assuming a flight velocity before impact of 50 miles per hour, we can calculate a rather impressive 18 to 19 "g" deceleration. The pilot of Case 7 (an identical aircraft) received severe facial injuries when he crashed with an impact of ⅓ this "g" force. Since his aircraft crashed right side up, his head was thrown into the instrument panel. If these two men had crashed into the same rock in an upright position. they would certainly have sustained fatal head injuries.

In two other accidents, occupants were prevented from hitting the instrument panel since one crashed sideways into a telephone pole (Case 21) (1949 Swift GC–1B), and the other hooked one wing root on a tree (Case Number 22) (1961 Piper Colt PA 22–108). In both cases the upper torsos of the occupants were thrown to the side and thereby avoided striking the instrument panel with a much better chance of avoiding serious injury.

Aircraft manufacturers have incorporated some excellent crash safety features in some of their aerial applicator planes. The Piper Pawnee has a steel tubular framework around the cockpit, is equipped with double shoulder harness and seat belt, all anchored to strong fuselage structure, and has a lightweight semicylinder of aluminum (4-inch radius) at the top edge of the instrument panel. In addition, in the knee and lower leg impact area, protruding knobs, sharp edges, and heavy equipment have been reduced and the crushable fiberglass hopper lined with lightweight perforated aluminum helps to attenuate knee impact. In Case 23 a young pre-medical student (while flying a 1960 Piper Pawnee PA–25) crashed from a stall at 140 feet altitude into hard soil at a 45° angle. The actual "g" force is not known, but he impacted hard enough to break both his double strap harness and a 3-inch seat belt. In Case Number 24, the pilot of another Pawnee PA 25–235 (1964) crashed with sufficient force to break his double strap shoulder harness, but his seat belt held. In laboratory testing of 2-inch wide double shoulder harness restraint, the breaking point was found to be over 35 "g" and since both pilots still had sufficient body momentum left to impact their heads at velocities of over 30 ft./sec. on the instrument panel protected by the aluminum roll, the author estimates that these two aircraft crashed with impact forces of at least 40 "g". It is amazing that even with these crash forces the shipping container (aircraft cockpit) retained its integrity and did not collapse on its occupant. Tests were conducted in this laboratory to evaluate the energy attenuating characteristics of the aluminum roll for head impact protection. The results of the test impacts with an instrumented dummy head at 15 and 30 ft./sec., along with