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# RECOMMENDATIONS FOR SHOULDER RESTRAINT INSTALLATION IN GENERAL AVIATION AIRCRAFT

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# RECOMMENDATIONS FOR SHOULDER RESTRAINT INSTALLATION IN GENERAL AVIATION AIRCRAFT

## I. Introduction.

There is a critical need for the improvement and use of restraint systems in general aviation aircraft. This need is indicated by the documentation of significant increases of serious and fatal injuries sustained in potentially survivable accidents, and occurring under unstable in-flight conditions. Potentially survivable accidents are classified as those accidents in which (1) the surrounding cabin structure remains intact, without serious deformation, and (2) the level of impact forces is below expected human tolerances.

One of the many contributing factors of these injuries is the direct result of using inadequate or incomplete restraint equipment. This clearly demonstrates that the current practice of using only a seat belt to restrain vulnerable parts of the body cannot provide the necessary protection. In the event of sudden exposure to abrupt impact forces or even extreme conditions of buffeting during flight, the vulnerable portions of the body (e.g. head and neck) are free to move as a pendulum and impact the surrounding structures. In addition, a proper flight control function may be impaired or impossible during a situation of severe buffeting, if the arms and hands are used to aid in restraining excessive body movement.

This study was designed to provide realistic solutions of how and where to install restraint attachments. Specific recommendations for these installations do not require major structural modification.

In addition, a documentary movie was prepared for safety program lectures and discussions to demonstrate and explain the needs and use of restraint equipment.

## II. Discussion and Procedures.

To provide reliable and realistic solutions of installation methods for upper body restraint systems (shoulder harness or belts), it is necessary to understand the functional characteristics of the complete system. Specifically, the belt system should be studied with respect to its basic configuration, relative position over the body surfaces, and the spatial relationships of the attachment end to the shoulder, neck, and head areas. Most restraint systems are designed in such a way that each individual component (belt section) conforms and maintains a certain relationship to a designated body structure or area. In a similar manner, the attachment end of a restraint belt must maintain a certain relative position (angle and spacing) to the head and neck surfaces as it projects posteriorly or laterally over the shoulder and away from the body. This position must provide sufficient freedom to accommodate normal body movements of the seated occupant without head-neck contact or visual interference. This demonstrates that the areas available for restraint attachment are limited by (1) the imposed restrictions of restraint design features, and (2) the actual structures considered acceptable for use.

The basic restraint configurations under consideration in this study consisted of a single diagonal chest belt and a double over-the-shoulder belt system. These specific types were used in the testing procedures since they represent two primary shoulder harness configurations currently in service and available commercially. No attempt was made to evaluate the functional characteristics of either restraint system, except to indicate that certain models of tested aircraft could utilize one type of configuration more effectively due to the limitations of acceptable attachment locations.

A survey of in-service general aviation aircraft was made to determine the number and make of basic cabin structures and variations of each type. This information forms the primary selection criteria to identify and describe certain structural locations that can be considered as potential restraint attachment points.

The survey resulted in a selection of five wrecked aircraft, located within the immediate

Oklahoma City area, that were considered usable and available within the scope of the current program.

Each aircraft selected was inspected to assure a complete and intact basic cabin structure, then mounted on the acceleration track platform. Although mounting details for each individual aircraft varied, all were secured to the platform by a system of adjustable tie-down cables and cradle blocks, when necessary, to stablize the structure.

Concurrently, a seat was installed in a selected position and a seat belt and both shoulder belt configurations were mounted so they could be efficiently interchanged in successive test runs without removing the dummy and seat. A test dummy was then placed in the prepared aircraft and secured by the seat belt in a normal sitting position. Shoulder restraint belts were placed over the appropriate body areas, extended over the shoulders and aligned with structural sites selected for attachment. At this time, all possible combinations of restraint configurations and attachment points were observed and each combination found acceptable was scheduled for dynamic testing.

As each potential attachment location was selected for testing, a detailed examination of the structural site was made to determine the most efficient and reliable method of mounting attachment hardware. A selection of two basic attachment devices, requiring no structural modification, was made. The first, a simple "U" shaped clamp with a ring connector was sized to fit over projecting structure (supporting frames, etc.) and held in place by set screws. This type mounting relies on a friction-torque action requiring the direction of pull by the restraint belt to be at an approximate right angle to the sides of the "U" clamp. The second, a surface type mounting plate with a welded ring connector, was held in place by either a series of sheet metal screws or machine screws with existing threaded holes in the structure, and was sized and shaped to fit the contoured surface. Both methods rely primarily on attachment to the internal structure without external penetration.

Every possible combination of standard seat location, restraint configuration, and attachment site was then subjected to abrupt deceleration forces to determine structural integrity. All tests were conducted under conditions of deceleration levels in excess of 20g's and shoulder belt loads (single and double) greater than 500 pounds.

The facility for these dynamic tests included an indoor acceleration track fitted with a special bearing mounted platform. This platform has a useful surface area 4 feet wide and 10½ feet long to which test structures were secured.

The energy for accelerating this platform was provided by dropping a suspended weight connected to it by cables through a series of pulleys. These pulleys have a mechanical advantage of 4, thus, theoretically, the platform moved at a rate 4 times the velocity of the falling weight. When the platform was pulled to a selected starting position, the weight was raised and suspended (the potential energy). Braking action of the accelerating platform was accomplished by a prepositioned stopping block connected by a cable to a pre-set hydraulic brake system. The stopping (deceleration) distance of the platform after impacting the stopping block, was adjusted by varying the hydraulic pressure in the pre-set brake. This, in effect, controlled the stopping distance to achieve certain peak deceleration loads. An electronic timing device was installed next to the track to record the velocity of the accelerating platform immediately before impact.

## III. Conclusions and Recommendations.

Recommendations of specific structural areas for restraint attachment are given for each of the five tested aircraft. Examinations of in-service aircraft similar to those used in this study, reveal that only small upholstery modifications are necessary to make proper attachment installations. Each recommendation is referenced to a series of photographic figures that illustrate these areas and possible attachment installations. The five aircraft used in this study include (1) Cessna Model 140, (2) Piper Apache, (3) Ercoupe, (4) Beech Model B, and (5) a Luscombe Sedan.

### CESSNA MODEL 140

There are two primary structures in this aircraft that can be considered as reliable tie-down points for upper restraint belts. In Fig. 1, (All figures, 1 through 19, are in the Appendix.) both structures are outlined and an example of attachment hardware is demonstrated. The posterior wing support passing along the overhead from side to side forms a continuous structural projection (area indicated by white arrows) that can accommodate a "U" clamp for restraint attachment. A clamp of this type can be centered behind the seated occupant if a double over-the-shoulder restraint belt system is used and attached to a single tie-down. In addition, dual clamps can be properly spaced to connect each belt separately if desired.

In the event a single diagonal shoulder belt is chosen, excellent side attachments can be made by utilizing the vertical frame posts formed at the aft edge of each door (indicated by the black arrow). These posts with circular cutouts form a reliable attachment location with the use of double plates bolted over the uppermost hole. Rectangular shaped plates extending beyond the edges of the cutout increase the structural strength, and when bolted together through the cutout center by an eyebolt, provide a convenient ring attachment.

## PIPER APACHE

Since this aircraft is basically a 6-place configuration, a selection of three locations for restraint attachments was made, one each for the forward, middle, and rear seats. In this type configuration the number of usable locations is decreased since overhead attachments for a forward seat would possibly interfere with a rear seat occupant. Therefore, all attachment locations selected were upper side structures. In Figs. 2 and 4 the outlined areas marked for reference to Fig. 3 illustrate the intersection of vertical and horizontal frame members which form the frame of a window and door on the right side and the partition between windows on the left side. A triangular plate with attached eyebolt (Fig. 3) secured to the intersecting frame members by a series of sheet metal screws, can provide a usable tie-down for both front row seats. One additional location for the left front seat is indicated by the white arrow in Fig. 4. This structural partition separating the front and rear windows can accommodate a "U" clamp attachment, having the greatest structural strength at the upper end.

Suitable tie-down points for the middle row of seats are located on the rear, vertical portion of the aft window frame as indicated by Fig. 5. The use of a "U" clamp at a point just below the intersection of the window and vertical support frames can provide a satisfactory restraint tie-down.

The welded tube frame that forms the rear cabin boundary can be utilized as an attachment location for the rear row of seats. The intersection of these tubes at the upper rear corners (outlined in Fig. 2 and demonstrated in Fig. 6) can be used to secure restraint connecting devices by loops of steel cable or fitted steel rings.

## ERCOUPE

This two-seated configuration has a number of recommended structural locations for restraint tie-down. In Figs. 7 and 8 a center line location is outlined and one example of a tie-down is illustrated. The use of this location requires that a flat mounting plate be secured by one of two methods to the wide center structure separating the rear windows. The first, using a single eyebolt, would penetrate the internal mounting plate, the skin, and an external plate to distribute the loads over this area. The eyebolt would serve as the attachment device. Although this type of installation would require some modification, it may be advantageous or desirable for use. The other method of mounting, requiring no modification, would use a series of sheet metal screws around the plate edges. An eyebolt or ring welded to the plate surface would provide a convenient attachment point.

Side locations can also be used as indicated in Figs. 9 and 10. They would, however, require pentration of the skin with external backup plates for mounting. The mounting technique is essentially the same as in the center post situation. An example of this tie-down demonstrated in Fig. 9 shows the eyebolt as both the mounting bolt and attachment ring.

The remaining sites of attachment (Figs. 11 and 12) are located on a single horizontal structure to which the forward edge of the rear deck is secured. This structure passes from side to side, providing an infinite number of sites for attachment devices. Since the structure is a single thickness preformed channel, additional stiffening is needed to provide adequate strength. This structure can be strengthened by inserting a rigid aluminum bar to fill the channel. A "U" type clamp can then be fitted over the downward projection for selected attachment positions.

## BEECH MODEL B

This aircraft configuration has two rows of seats and all recommended attachments are located on the frame structure of the rear window.

In Fig. 13 the outlined areas indicate two possible sites of restraint attachment. Each of these areas, shown individually in Figs. 14 and 15, demonstrates an example of a feasible restraint attachment. Observe in Figs. 13 and 14 that a small circular plate is indicated and was used as a point of attachment when a steel ring was welded to its surface. This plate, as standard equipment in the aircraft, is normally held in place by two machine screws and provides a readymade mounting site requiring no modification to the structure. These plates are available for use on both the right and left sides of the cabin and provide reliable attachment points for diagonal type restraint belts.

In Figs. 13 and 15 the outlined area suggests the use of the window partition structure for restraint attachment. The inboard projecting ridge of this partition forms an excellent tie-down location. A metal plate, bent to fit around the back side of the ridge and project forward, was held in place by sheet metal screws. This location is not recommended for the right side, since it would create a hazard to passenger movements through the adjacent door.

The best rear seat attachment locations were found to be on the rear window frame indicated by Figs. 16 and 17. Again, a metal plate bent to conform to the frame contour with a mounted attachment ring is used. This particular plate is held in place by sheet metal screws.

### LUSCOMBE SEDAN

Two structural locations for upper restraint tie-down have been selected for recommendation. Both can utilize the "U" type clamp without any modification. Similar to the wing support structure in the Cessna configuration, this aircraft has a continuous frame member passing along the overhead from side to side which does not form a closed and rigid channel. Selected channel areas should be filled with metal plates to provide a solid base for clamp attachment. The intersection of this structure and the vertical door frame is structurally sound for restraint use (Fig. 18). The other recommended location (Fig. 19) is the cabin frame member that intersects and terminates at the upper surface of the rear window frame. The "U" type clamp when fitted to this projecting structure is a reliable attachment point.

## IV. Summary.

Accident histories reveal that serious and fatal injuries are occurring in general aviation aircraft because of inadequate or incomplete body restraint. Specifically, the use of only a seat belt cannot provide adequate protection to a seated occupant, since the upper body components (e.g. head) are free to move during abrupt decelerations and strike surrounding structures.

Five in-service aircraft were dynamically tested to determine the feasibility of restraint installation and to recommend structural locations and methods for restraint attachment. Specific recommendations for these tested aircraft are considered valid and realistic under conditions of abrupt deceleration peaks in excess of 20g's.

These recommendations have been provided for use by all individuals and organizations seeking realistic solutions for improved personal protection. In the interest of acquiring and maintaining adequate safety standards, additional studies of this type to include all in-service aircraft must be accomplished.

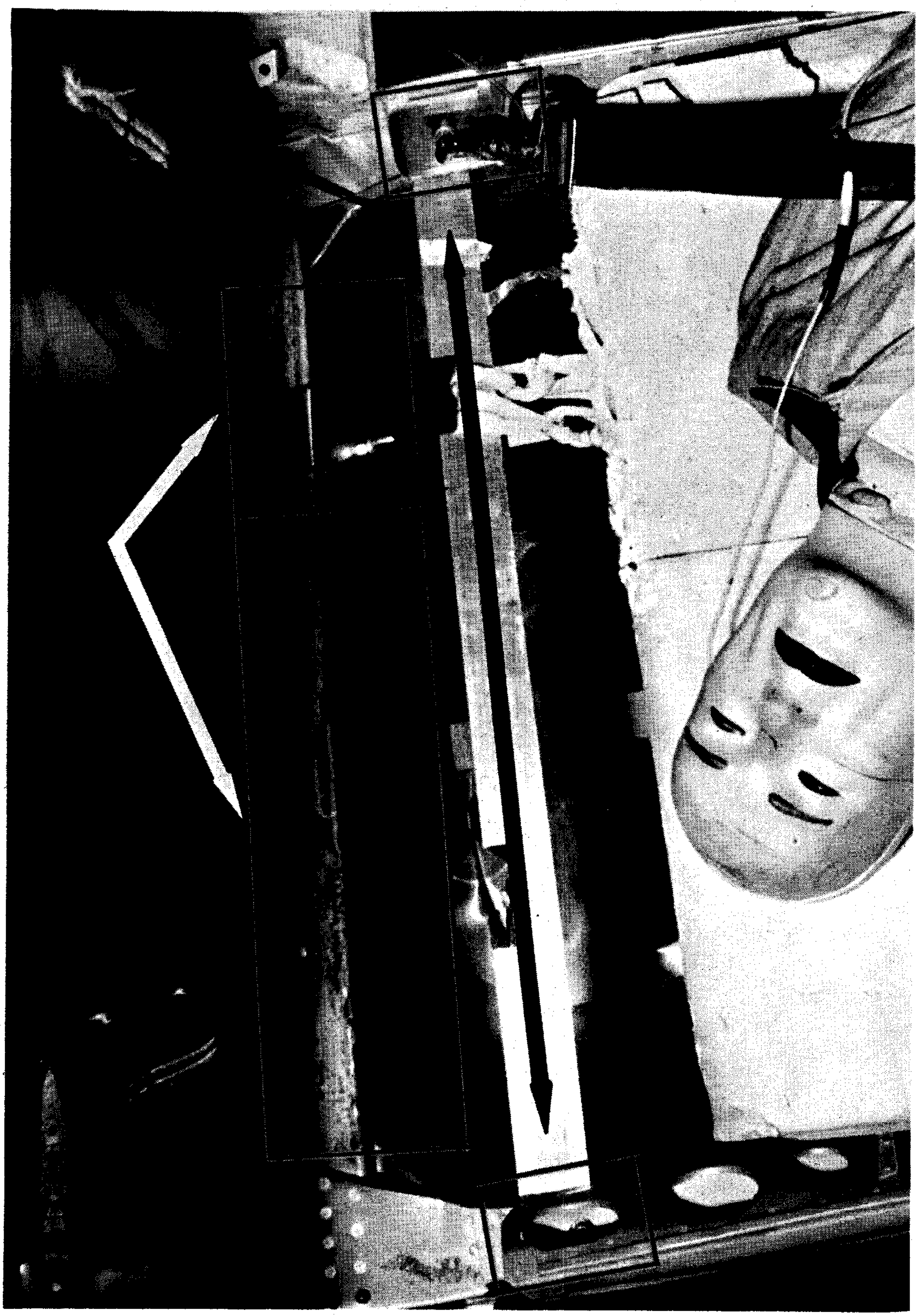

FIGURE 1. Cessna.

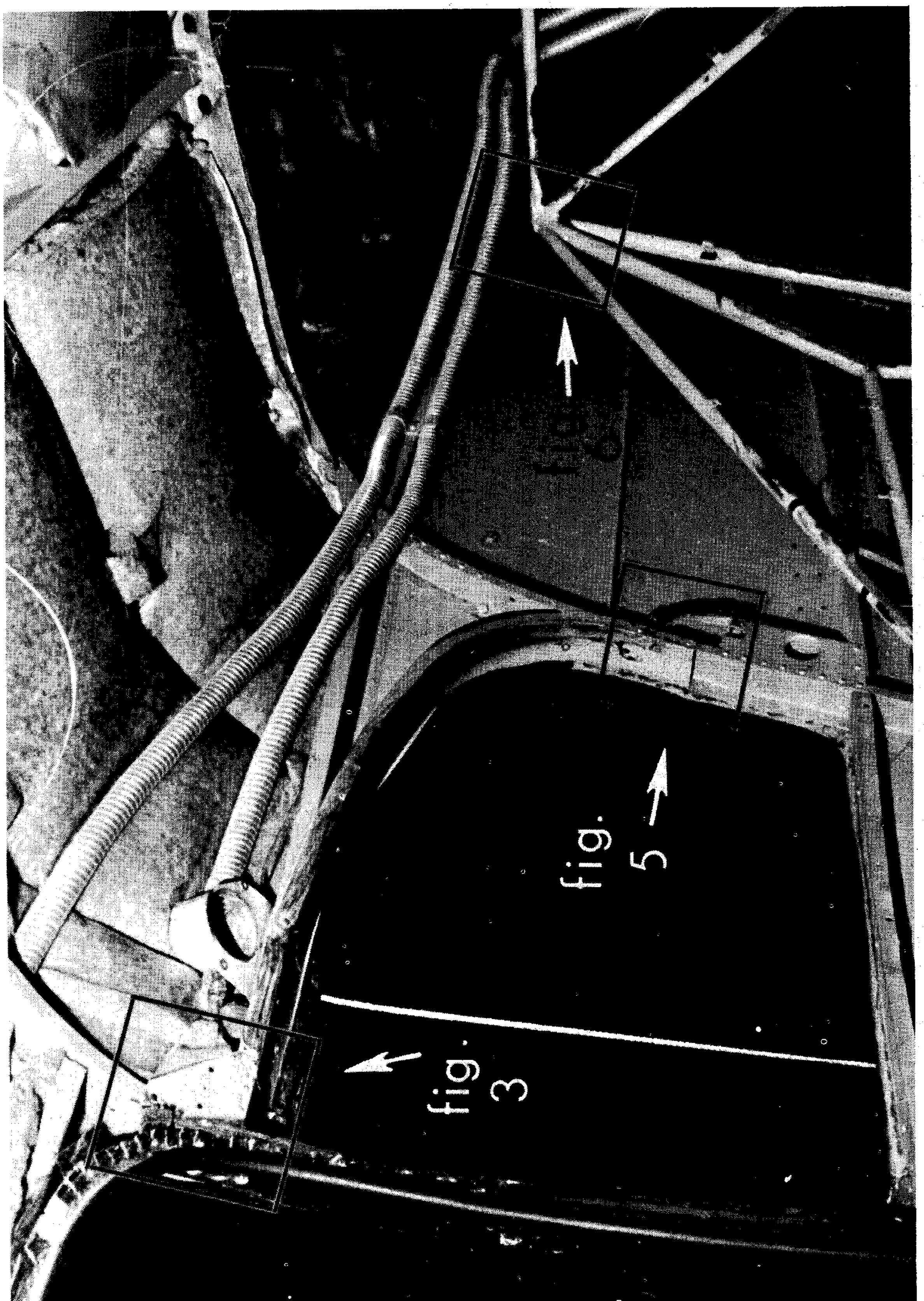


FIGURE 2. Piper: Right side view.

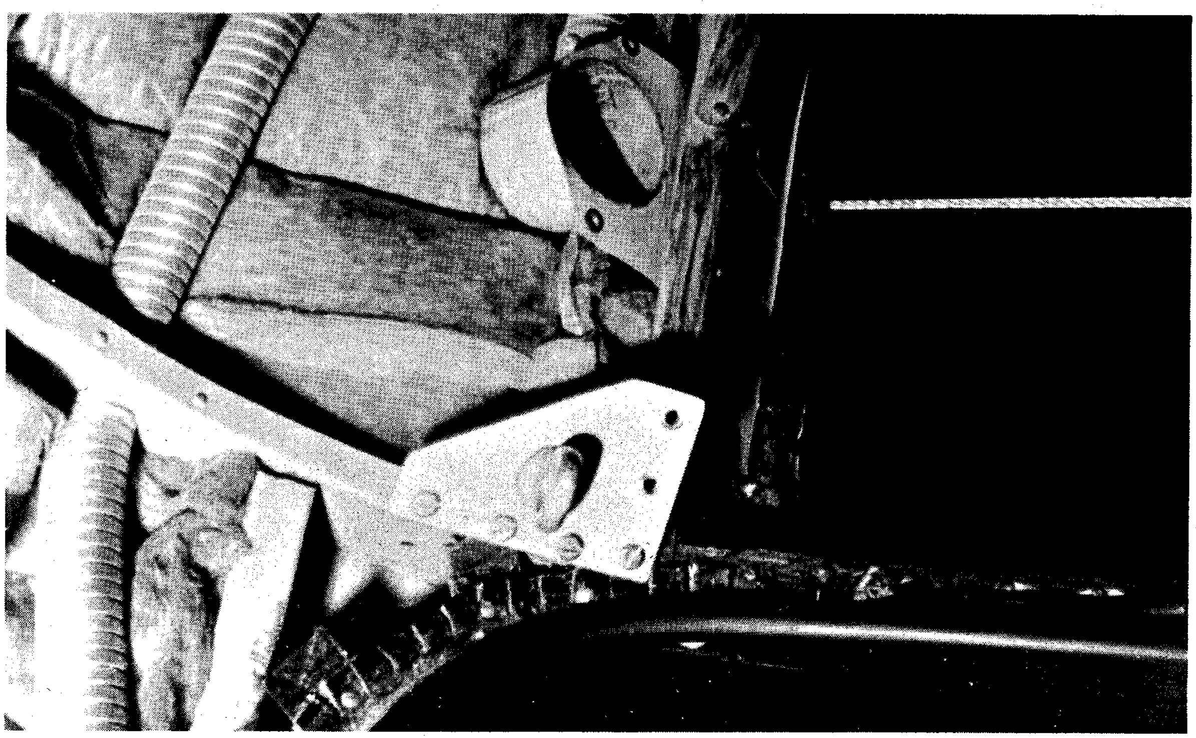

FIGURE 3. Piper: Right side view.

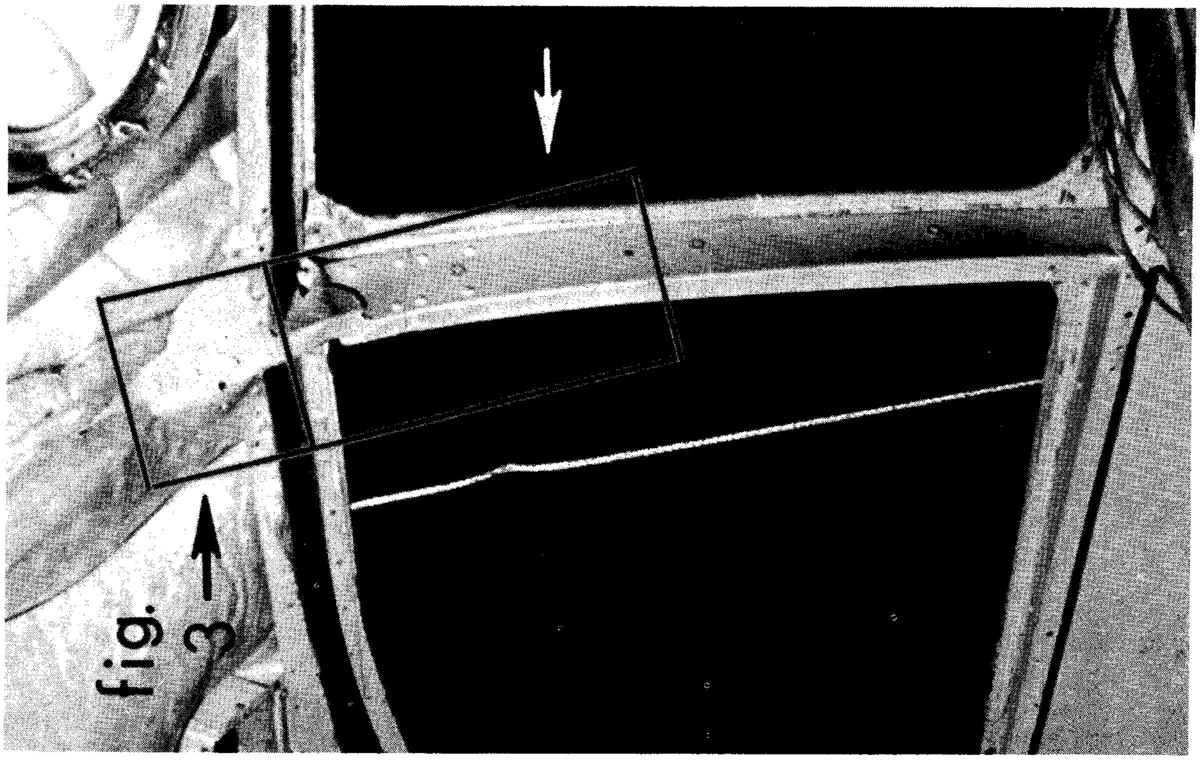


FIGURE 4. Piper: Left side view.

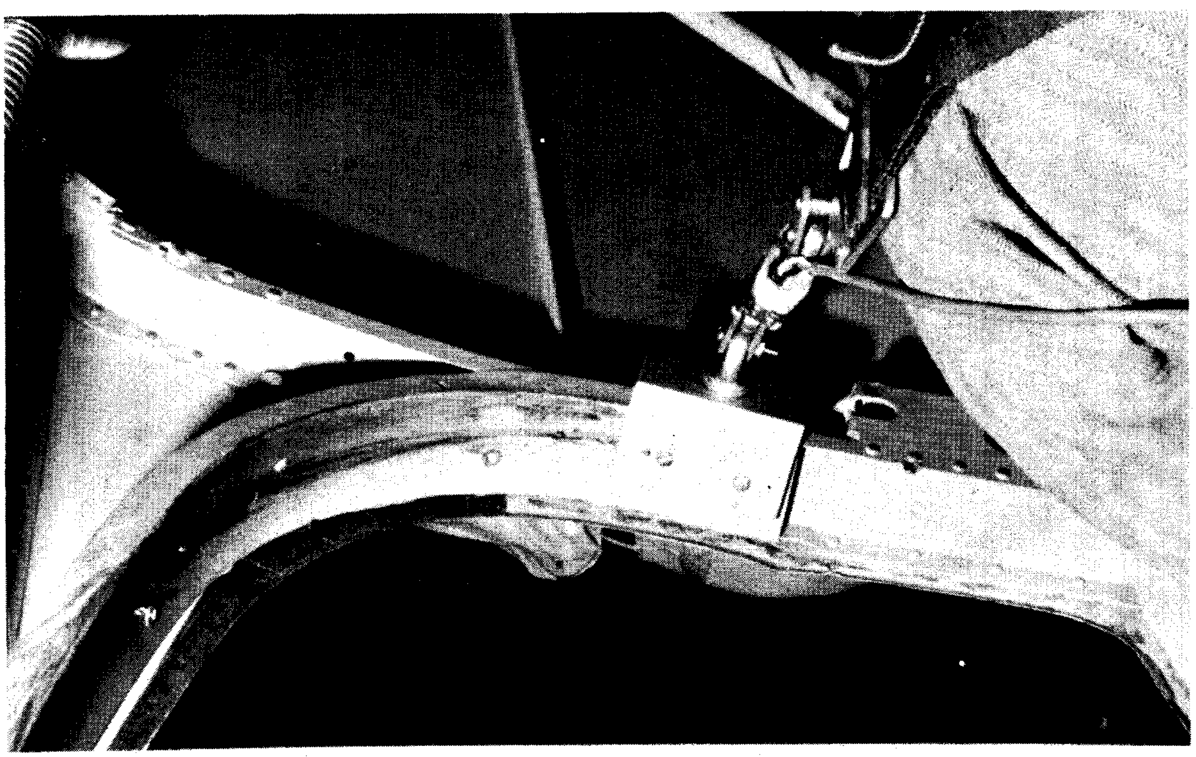

FIGURE 5. Piper; Right side view.

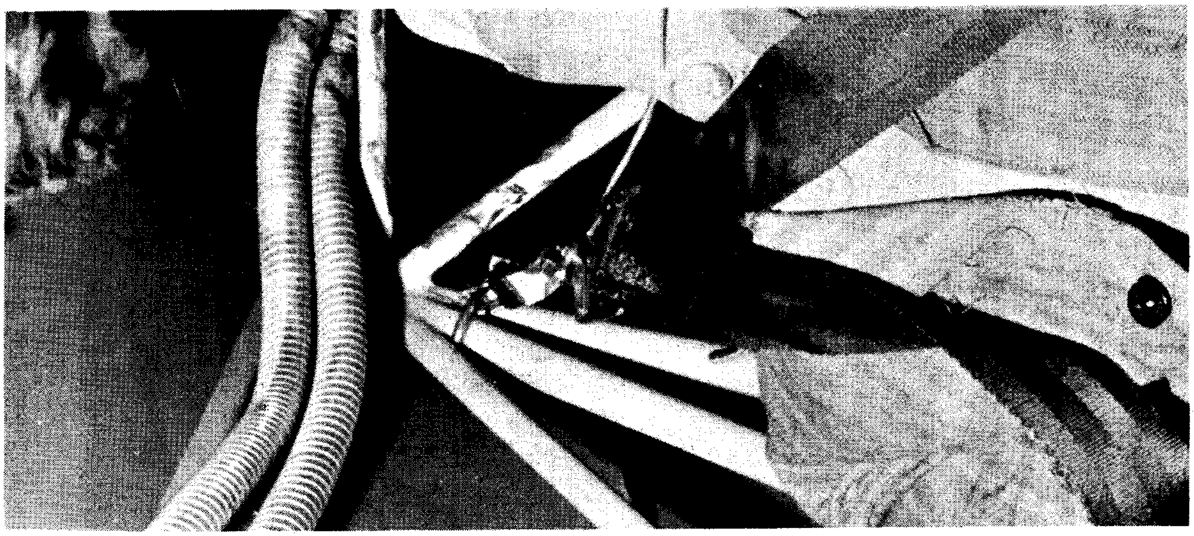

FIGURE 6. Piper: Right side view.

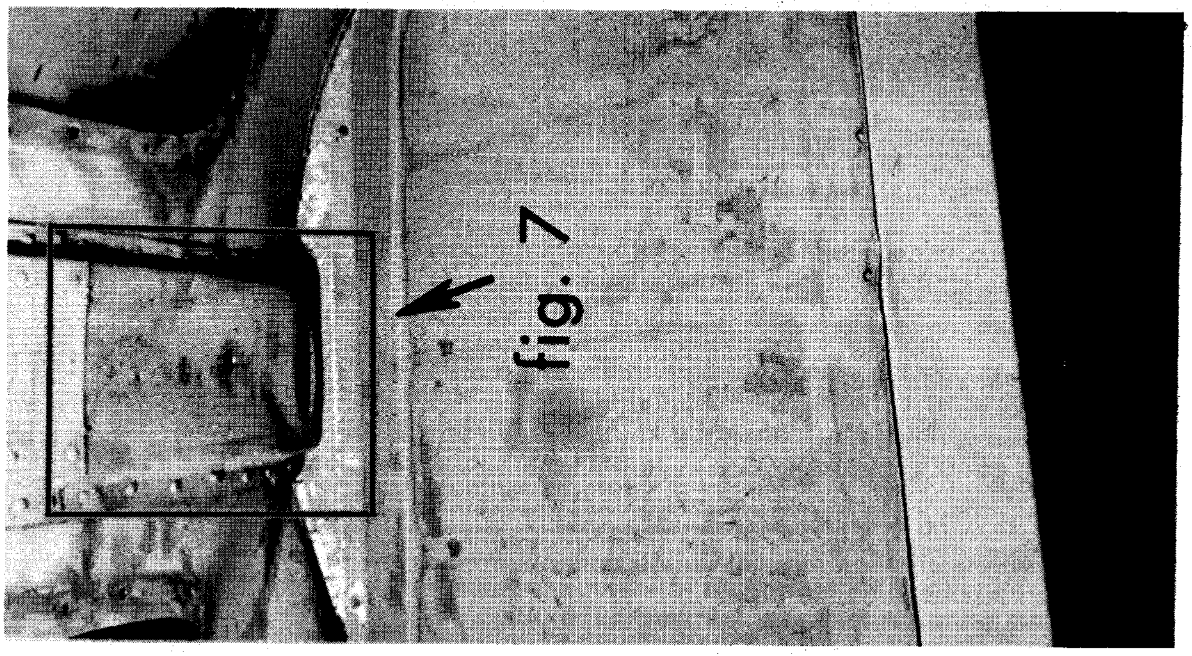


FIGURE 8. Ercoupe.

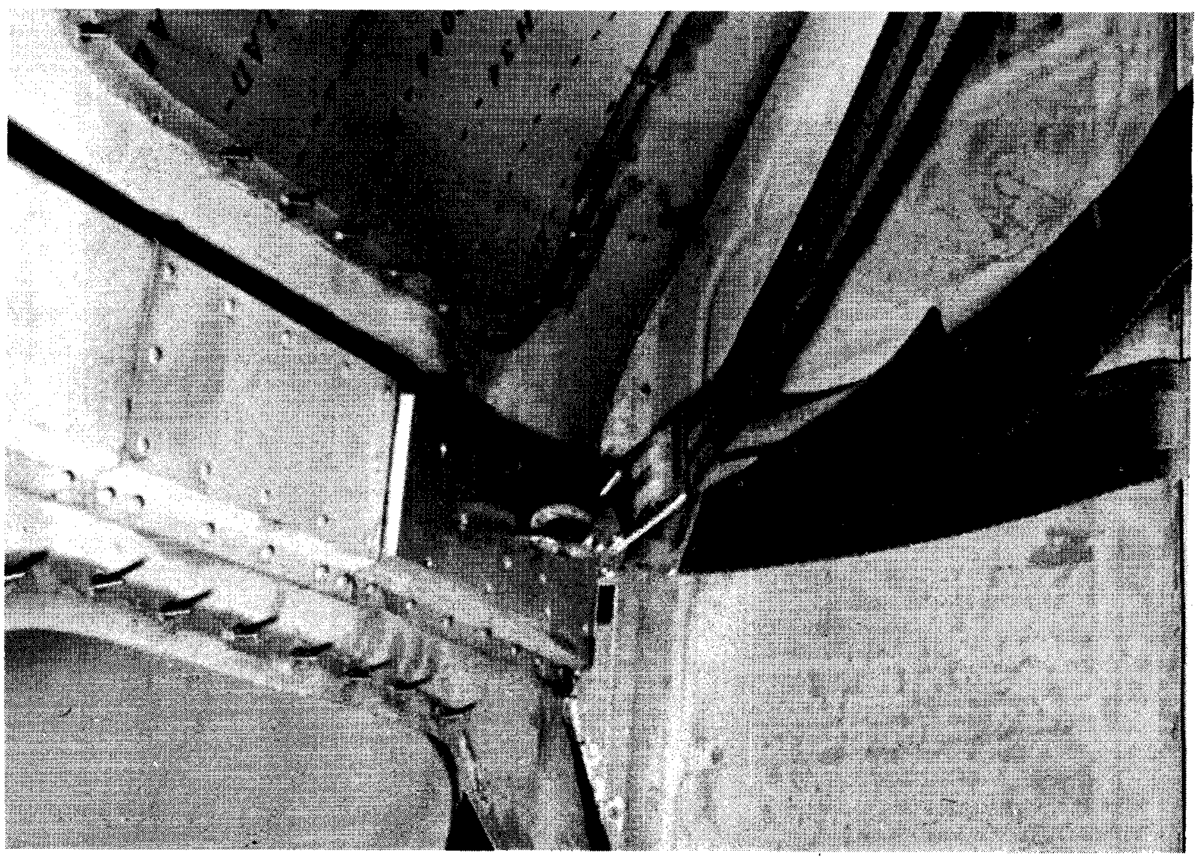

FIGURE 7. Ercoupe.

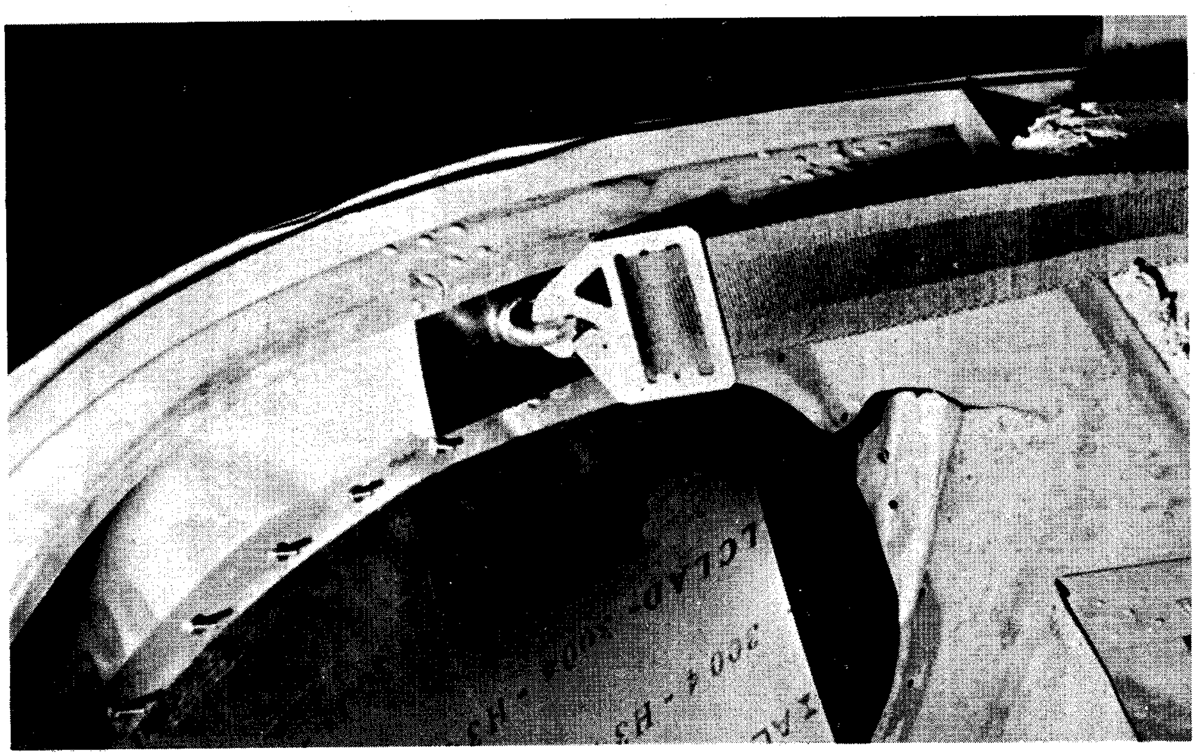

FIGURE 9. Ercoupe: Left side view.

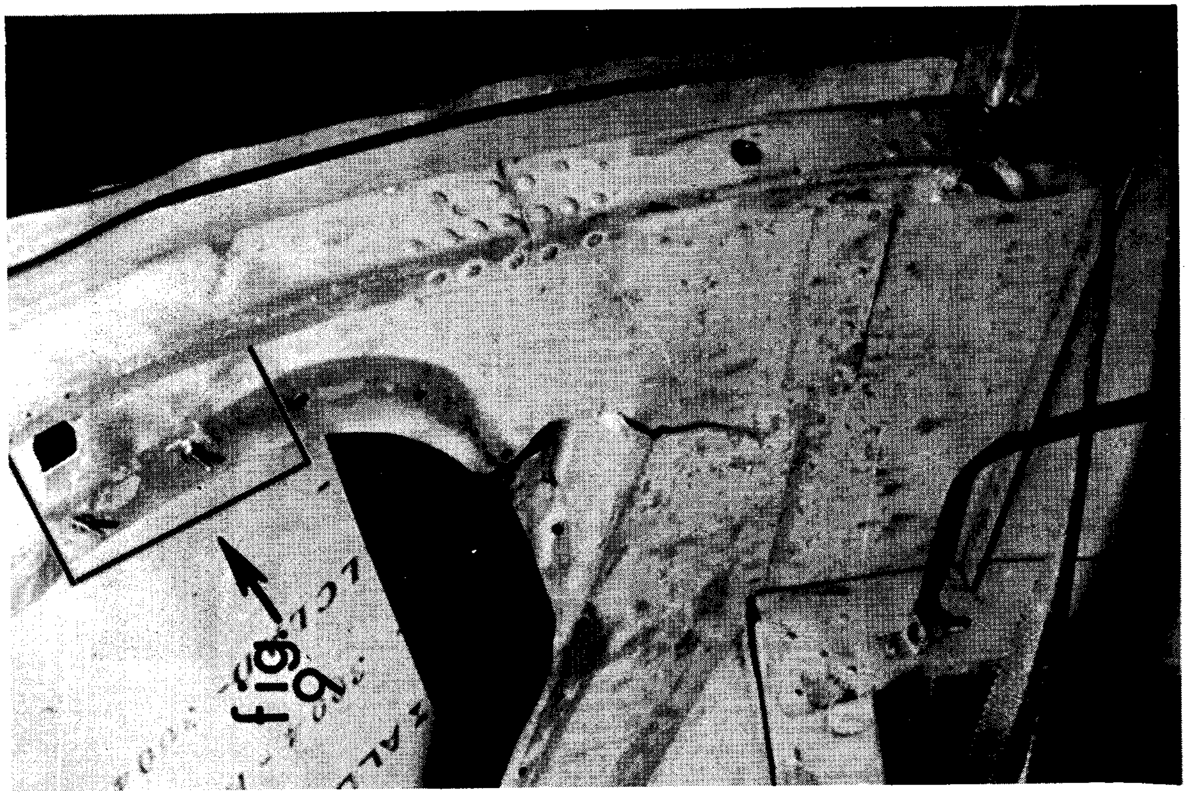


FIGURE 10. Ercoupe: Left side view.

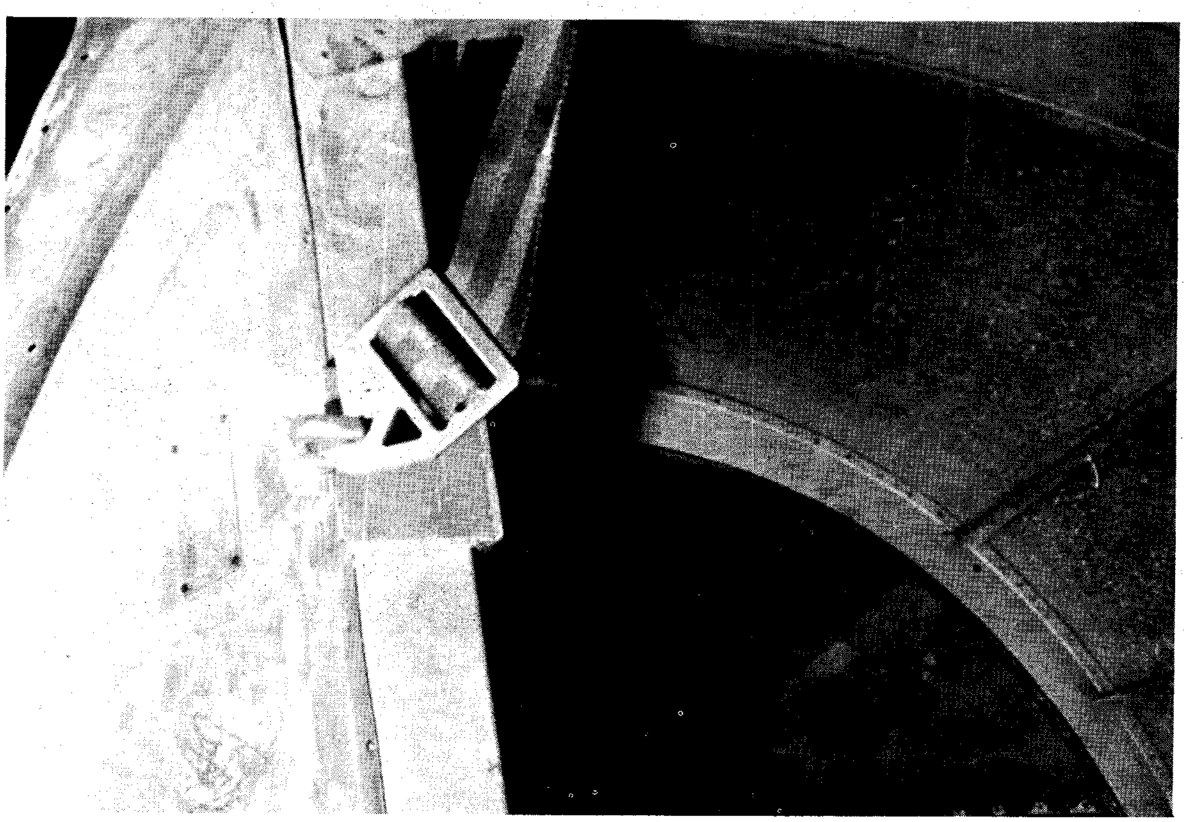

FIGURE 11. Ercoupe.

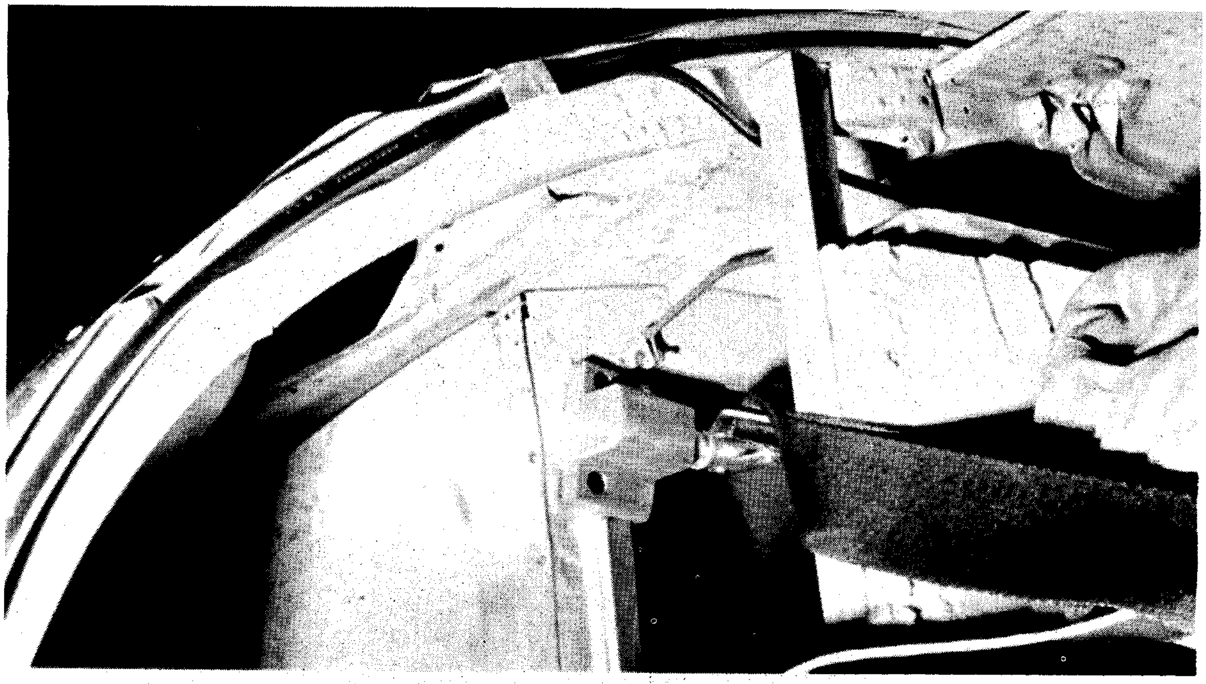

FIGURE 12. Ercoupe.

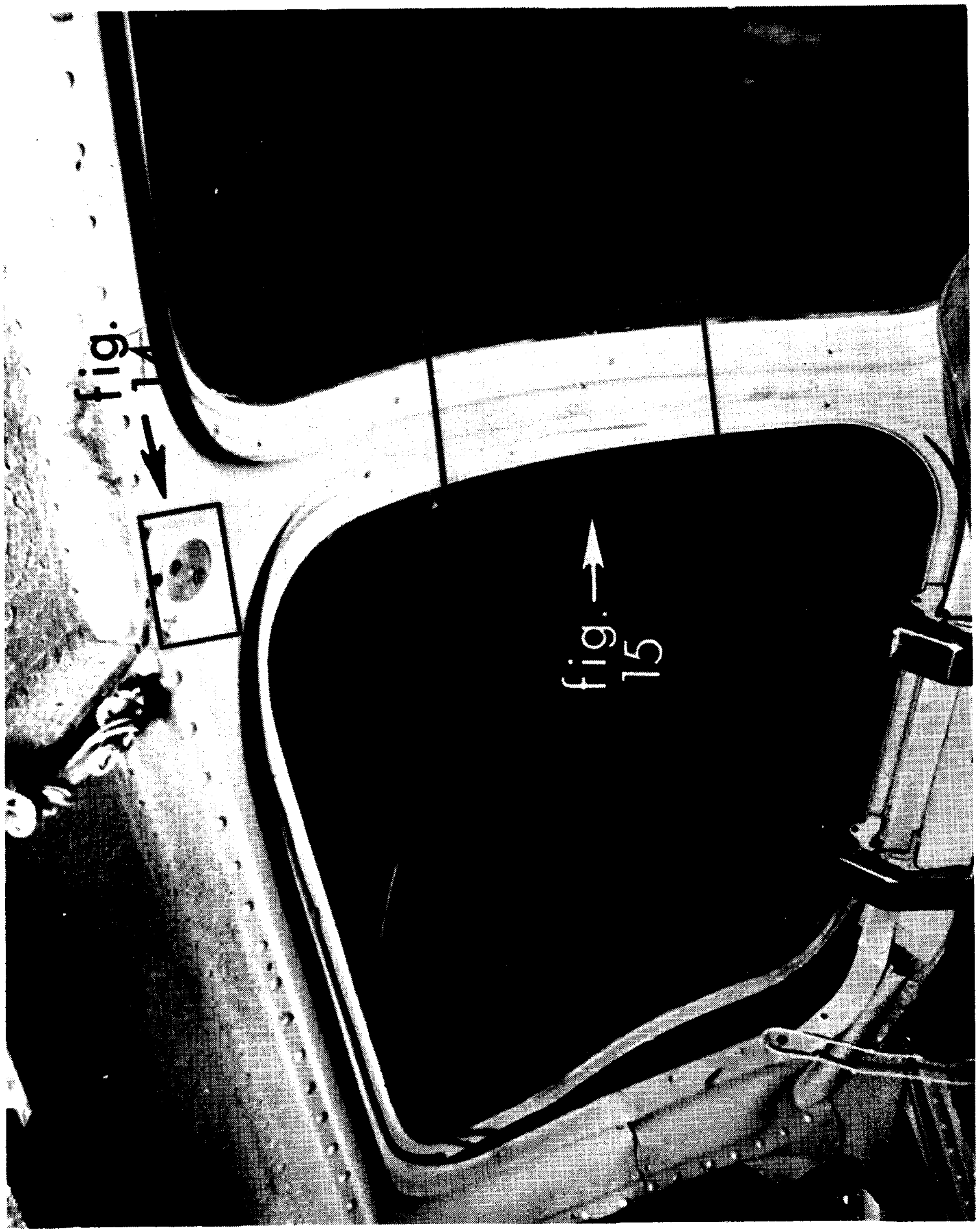


FIGURE 13. Beech: Left side view.

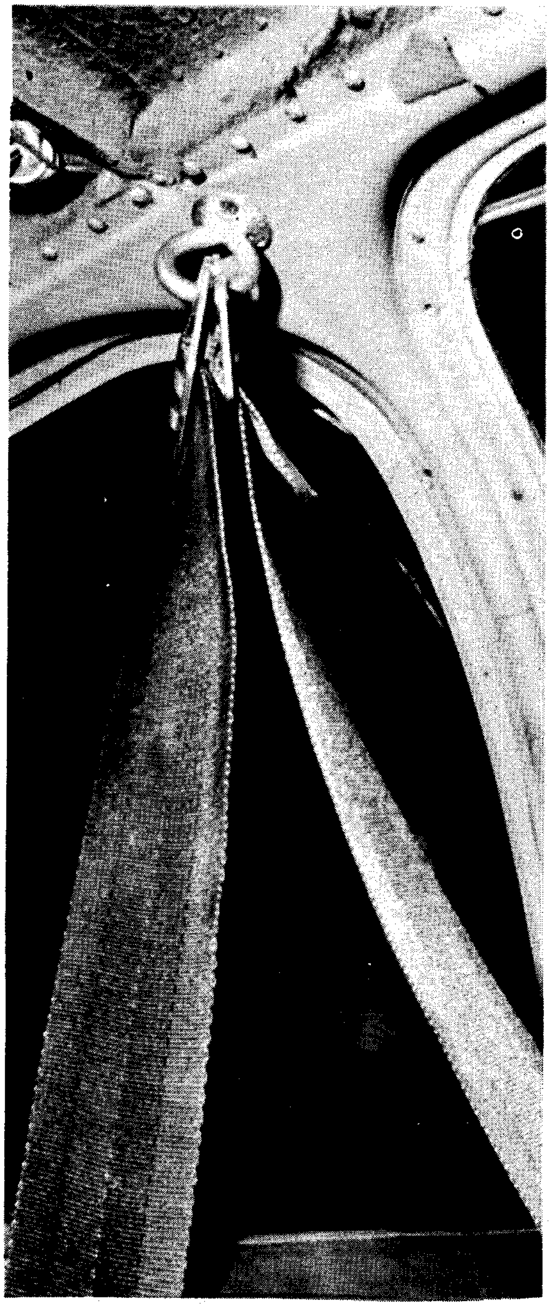

FIGURE 14. Beech: Left side view.

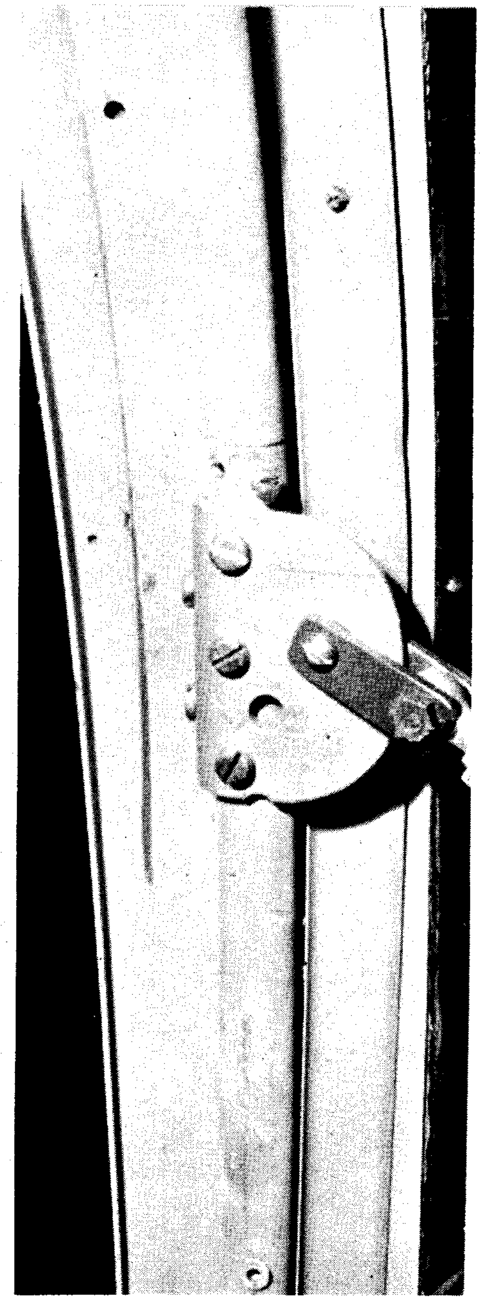

FIGURE 15. Beech: Left side view.

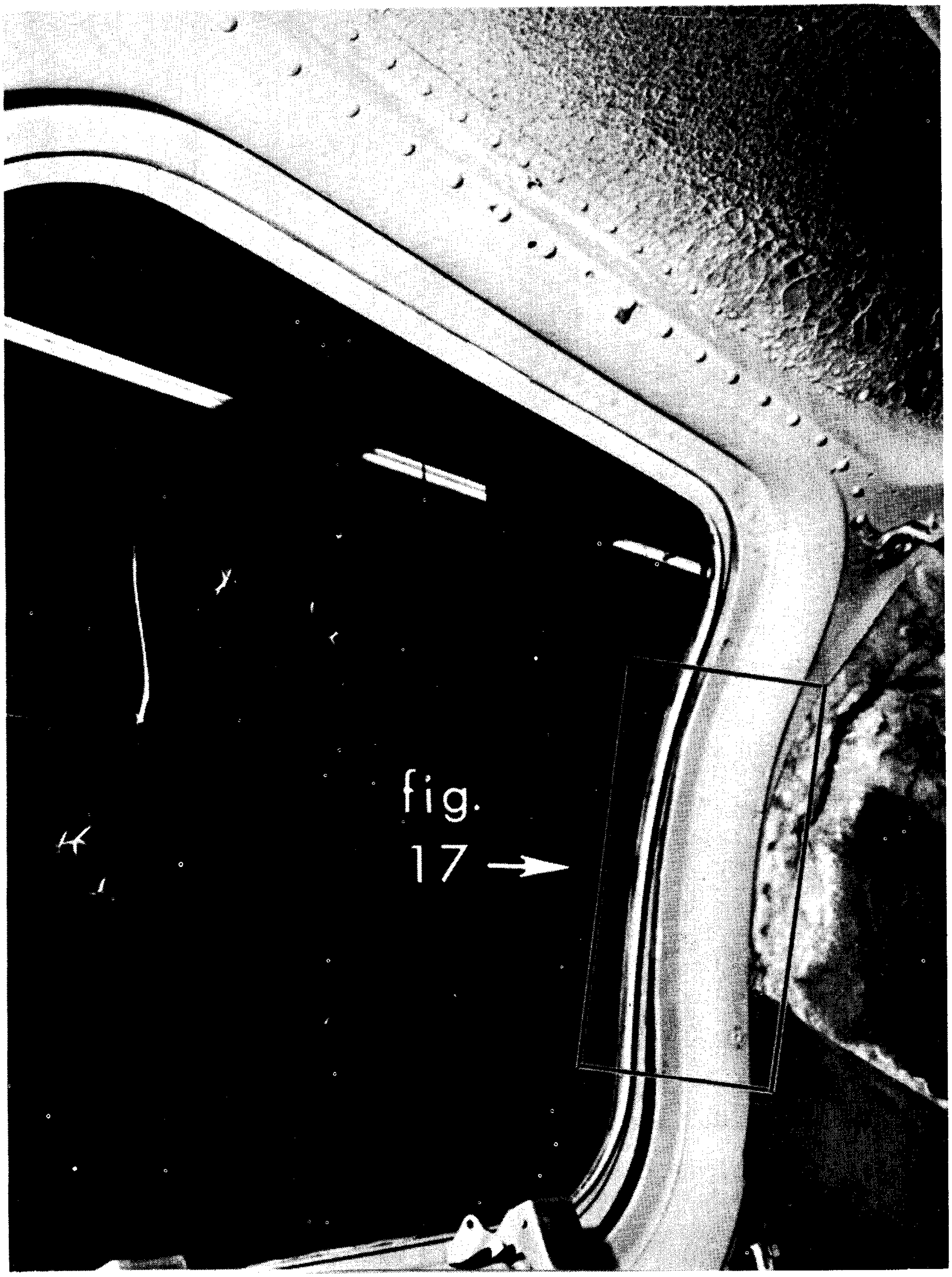


FIGURE 16. Beech: Right rear window.

**FIGURE 17.** Beech: Right rear window.

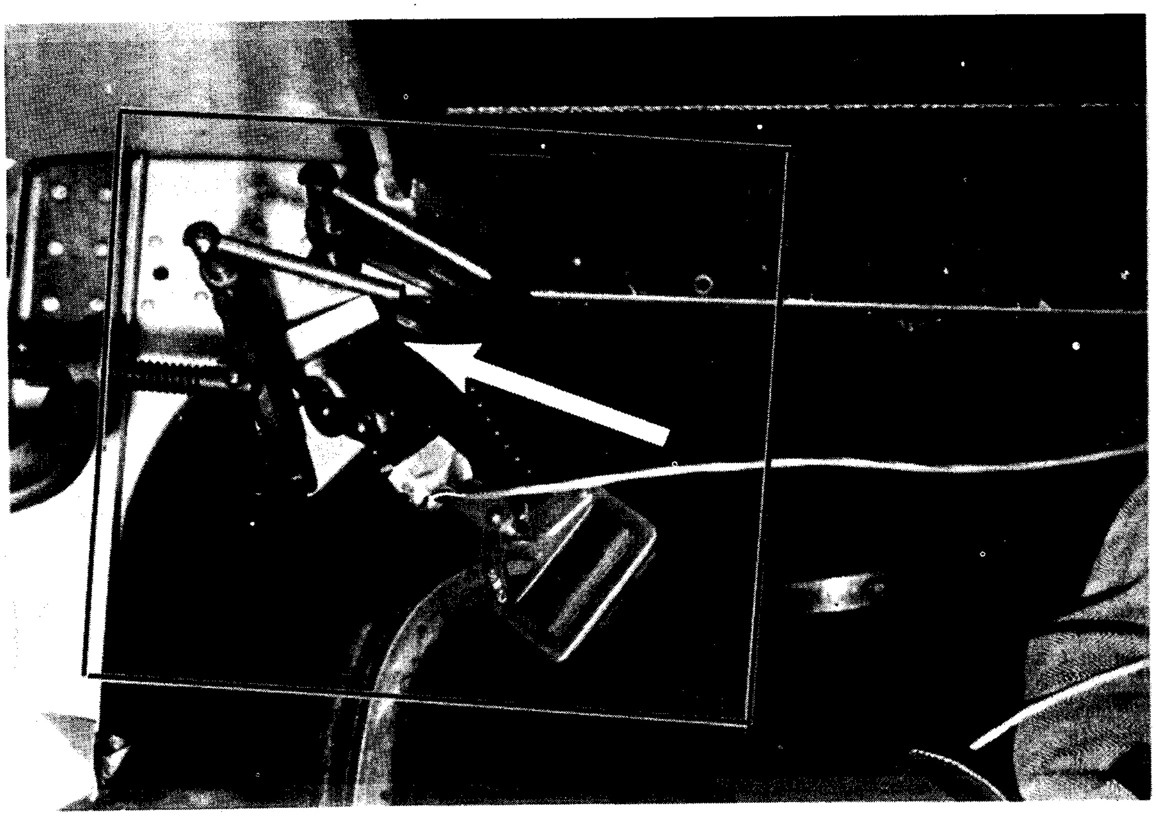

FIGURE 18. Luscombe: Right side view.

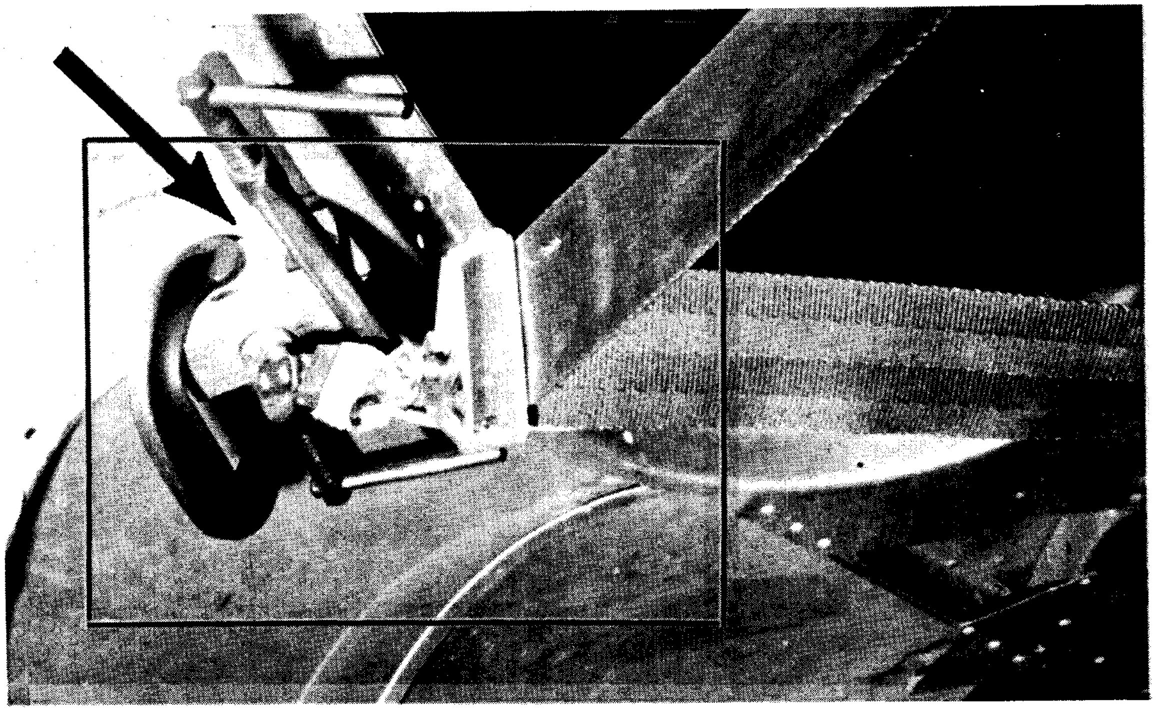

FIGURE 19. Luscombe: Right side view.