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BIRD IMPACT TESTS OF THE DOUGLAS MODEL DC-8 AIRPLANE WINDSHIELD

FOR LIMITED DISTRIBUTION

by

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MODEL DC-8 AIRPLANE WINDSHIELD

INTRODUCTION

Tests of the impact of freshly killed bird carcasses on the windshield panels of the Douglas Model DC-8 airplane were conducted at the Technical Development Center of the Civil Aeronautics Administration, Indianapolis, Indiana, from March 26, 1957, to April 21, 1957, and also on June 19 and 20, 1957. The purpose of these tests was to determine the ability of the windshields and supporting structure to resist penetration when struck by a four-pound bird carcass. Tests also were conducted to evaluate the possible hazard to the pilot and copilot resulting from flying windshield fragments. A complete resume of the tests is presented in Table I. The tests were conducted in accordance with the Douglas Aircraft Company test proposal of February 25, 1957, entitled "Outline of CAA Windshield Bird Test Program for DC-8."

The tests were conducted with the assistance of Messrs. Nick Napavance, Arthur S. Lundgren, and Hal Linderfelt of the Douglas Aircraft Company, Inc.

WINDSHIELD INSTALLATION

General.

The cockpit structure and windshield panels tested were in accordance with the Douglas Aircraft Co. drawings listed in Table II. Insofar as the windows and supporting structure are concerned, the test article was verified as conforming to these drawings by CAA-designated inspectors, Messrs. B. Robinson and B. B. Farnham of the Douglas Aircraft Co., in their letter of January 6, 1958, File No. C8G30-58-144, to Mr. G. T. Castle, Douglas Aircraft Co., CAA Liaison Engineer.

The windshield panels tested consisted of the center window, the side window, and the clear-view window. An eyebrow window which is to be included in the production version of the Model DC-8 airplane was not provided for in the test structure and consequently, could not be tested. The windows tested are identified in Table I.

The center- and side-window installations consisted of flat panels of the double-panel type. The center-window panels were rectangular in shape, each having a height of approximately 21 1/2 inches and a width of approximately 20 1/4 inches. As installed, the center window sloped back 45° from the vertical plane. The side-window panels were trapezoidal in shape, having a height of approximately 17 3/4 inches, a top edge length of approximately 21 inches, and a bottom edge length of approximately 28 3/4 inches. As installed, the side windows sloped back 53° from the vertical plane.

Two center- and side-window designs were tested, one incorporating in each of its two panels a 0.300-inch-thick interlayer of 21 parts plasticized polyvinyl butyral, and the other incorporating in each of its two panels a 0.360-inch-thick interlayer of 21 parts plasticized vinyl. Construction of these windows is shown in Figs. 1 and 2.

The exterior and interior panels for the center- and side-window installations were mounted rigidly to the window frame as shown in Figs. 3, 4, and 5, with an air gap of 0.50-inch or slightly less, depending upon vinyl thickness, separating the two panels.

The clear-view window arrangements tested also were of the double-panel type, consisting basically of two panels of compound curvature approximately 18 3/4 inches wide by 20 1/2 inches high mounted rigidly in the window frame. A typical cross-sectional view of this window as mounted in its closed position is shown in Fig. 6. The windows consisted of interior and exterior panels separated by an air gap. The clear-view window can be opened, in which case it is guided by an upper and lower track which allows forward and aft movement. When locked in the closed position, this window was retained, as originally submitted for tests, at the center of the upper frame edge, along the full length of the forward frame edge and at one point located at the aft end of the lower frame edge. One hand-operated lever controls locking, unlocking, and opening of the window. When in the closed and locked position, this window slopes back 64° from the vertical plane.

Three clear-view window designs were submitted for test. The construction of the three designs referenced to appropriate Douglas Aircraft drawings are shown in Fig. 7.

The side- and center-window designs, as submitted for test, incorporated the Electropane heating unit developed by the Libbey-Owens-Ford Glass Co. This heating unit was incorporated in the exterior panels of each window only. Heating of the interior panels was dependent upon conduction of heat from the outer panel through the intervening airspace and upon maintaining cockpit heat at 70° F. The clear-view window was dependent entirely upon cockpit temperature for heat.

Changes Made During Tests

No changes were made in the windshield canopy during the first five tests.

The center and side windows incorporating the 0.360-inch-thick vinyl interlayers were used exclusively in Test No. 6 and in all subsequent tests because it was found that the windows incorporating 0.300-inch vinyl interlayers were being penetrated at velocities at or near 425 mph.

The retaining arrangement for the clear-view window failed in Test No. 7, allowing the window to rotate inward about its forward upper and lower track attachment points. To prevent this, a retaining bar was added to fix the aft edge of the window frame in the closed position as shown in Fig. 6. During the next test on the clear-view window, with the retaining bar mounted by utilizing existing doubler plate retaining bolts through the post located between the clear-view and aft windows, it was found that, upon impact, the outside doubler plate peeled back, snapping off the bolt heads. This forced the retaining bar to depart from its fixed position, thereby permitting the aft edge of the window to open inwardly. To correct this condition, the number of bolts through the retainer was doubled, with every other bolt extending only through the aft post bolting flange and retainer bolting edge as shown in Fig. 6.

TEST PROCEDURE

Freshly killed chicken carcasses were propelled at the test structure by means of a compressed air gun. To assure the greatest degree of accuracy of carcass velocity and point of impact on the respective windows, the chicken carcass was backed by a 6-inch-long Styrofoam plug 6 inches in diameter with a thin plastic disc 5 1/2 inches in diameter bonded to the aft end. This plug and chicken carcass were placed in a light cloth bag which then was sewn shut. This arrangement gives the appearance of a projectile approximately 6 inches in diameter and 14 inches long. The combined weight of the chicken carcass, plug, plastic disc, and cloth bag was 4 pounds plus or minus 2 ounces. The weight of the plug, disc, and bag was approximately 5 ounces.

The cockpit structure was positioned so as to line up the desired impact position with the line of flight of the projectile. The projectile flight path was determined by sighting through "peep" sights mounted at both ends of the gun barrel. The cockpit base was bolted securely to the test cell bed, and 4-by-4-inch wood members were positioned between the principal longitudinal members of the cockpit and the test cell backstop to prevent excessive rearward movement of the cockpit structure. This mounting arrangement is shown in Figs. 8A and 8B.

Two life-sized clay figures were positioned in the test article so as to represent actual pilot and copilot body positions. These clay figures were used to evaluate possible hazards due to flying window fragments. The clay figures were fitted with either sun glasses or goggles during each test and were clothed in lightweight shirts after the first test. Damage to the clay figures was repaired as required following each test. In addition, during each test a high-speed camera was focused on the inside face of the test window to aid in evaluating window material fragmentation and the progression of structural failures. Hereafter in this report the two clay figures will be referred to as "pilot" and "copilot."

The center window was impact tested at a point corresponding to the geometric center of the window and at a point six inches below the top sill and six inches inboard of the left centerpost sill measured in the plane of the window. The side window was impact tested at a point corresponding to the pilot's eye position as projected forward to the plane of the outside face of the window and at a point six inches below the top sill and six inches inboard of the cornerpost sill measured in the plane of the window.

Velocity measurements were determined by the bird carcass projectile breaking two pairs of fine steel wires positioned a distance of four feet apart between the end of the gun barrel and the target. One pair of wires was connected to a recording oscillograph while the second pair of wires was connected to a direct-reading electronic chronograph. A third method for determining the velocity of the projectile, using a high-speed camera, was employed as a check on the oscillograph and chronograph. In determining velocity from the timing-device measurements, credence normally was given to those measurements which represented best gun-calibration velocities, when one or more measurements appeared to be in error. The velocities so selected then were averaged to determine one velocity for each test. Both the oscillograph and the chronograph failed to operate properly during Test No. 9, and full weight was placed on the time measurement obtained from the high-speed camera.

Heating of the center and side windows was accomplished by applying the proper voltage to the Electropane heating unit contained in the outer panels through a 400-cps 1.5KVA inverter and heat control unit. This power supply arrangement is similar to that which will be installed in the DC-8 airplane and is designed to keep the heated windows at an average temperature of 110° F. In the actual DC-8 airplane, heat from the outer window Electropane unit is expected to produce vinyl temperatures of 85° F. to 100° F. in the interior center- and side-window panels. The cockpit was heated to desired temperatures by electrical heating units.

Window temperatures were obtained prior to each test from thermocouples attached to the glass faces of the test panels by means of masking tape. Normally, temperatures were determined for the center and side windows at a position opposite the sensing element, at one or two random positions on the outside face of the exterior panel, and at the expected impact point on each of the four glass faces. Temperatures for the clear-view window design incorporating an interior glass-vinyl-glass panel were obtained at the geometric center of the inner glass face and in the airspace separating the two panels. Cockpit temperatures normally were obtained from a thermometer located adjacent to the inner face of the interior panel being tested. Cockpit temperatures only were recorded during tests of the clear-view window incorporating two panels of stretched Plex-55. Outside air temperatures were recorded for each test.

TEST RESULTS

Basic data pertaining to the individual impact tests are presented in Table III. The results of the tests are as follows.

Test No. 3-1.*

The carcass hit the window about one inch below the target point. Both the outer and inner window panels were penetrated by a major portion of the carcass. No failure of the sill or retaining structure occurred. Most of the carcass which penetrated the window passed to the right of the pilot, although a few particles impinged upon the pilot's face, chest, and right shoulder area. Three particles of full-tempered glass about 1/4-inch on edge penetrated into the right shoulder of the pilot. The outer corner of the right glass lens in the goggles worn by the pilot was broken by flying windshield fragments, and glass particles from this lens impinged upon the pilot's eye socket area. There was no left lens in the goggles. Small particles and slivers of semitempered glass impinged lightly upon the pilot's face, chest, and shoulder area. The copilot was struck by numerous small particles of semitempered glass, but none were imbedded deeply in the clay and could be removed by gentle brushing. Upon examination of the vinyl failure which occurred, it was determined that the window was not properly heated when tested. The control box for the Electropane heating units then was examined, and it

*The numeral "3" is a test series number pertaining to all the tests reported herein The numeral "1" is the test number.

was found that it was not operating properly. In final analysis, this was not considered to be a valid test of the impact strength of the side window and supporting structure because of the low vinyl temperature. Results of this test are shown in Figs. 9, 10, and 11.

Test No. 3-2.

The carcass hit about one inch below the target point. None of the carcass penetrated into the cockpit area. The vinyl in the exterior window panel sheared for a length of 11 inches along the inboard edge, for a length of 11 inches along the top edge, and for a length of 8 inches along the cornerpost edge. There was no failure of the vinyl in the interior window panel. No failure of sill and retaining structure occurred. The upper center doubler plate for the outer panel warped outward about 1/8-inch. Fine sharp-edged particles of semitempered glass from the aft face of the interior window panel impinged upon the pilot's face below eye level and upon his clothing in the chest area. None of the glass imbedded in the exposed clay parts of the pilot's body; that is, the face and neck, and no penetration or tearing of the cloth shirt occurred. The sun glasses worn by the pilot remained intact and undamaged. Results of this test are shown in Figs. 12 and 13.

Test No. 3-3.

The projectile hit about two inches below the target point. None of the chicken carcass penetrated into the cockpit area. The exterior window panel vinyl tore for a length of four inches along the top sill metal insert toward the upper left corner and downward about four inches along the cornerpost sill metal insert, as shown in Fig. 14. The vinyl in the interior window panel failed primarily along the cornerpost edge, as shown in Fig. 15. The relative positions of the two vinyl breaks were such that penetration by the bird carcass was prevented. The interior panel vinyl temperature was lower than optimum for maximum impact strength, which apparently resulted in the failure of this interlayer. The pilot's face was pelted slightly by flying glass. At the level of the pilot's upper lip, small slivers of glass imbedded about 1/64-inch in the clay. One 3/8-inch-long sliver of glass imbedded itself about 1/64-inch along the left side of the bridge of the pilot's nose. The sun glasses worn by the pilot remained intact and were not damaged in any manner. The pilot is shown in Fig. 16. Numerous small particles of semitempered glass impinged upon the clothing of both the pilot and copilot. None of these penetrated the cloth.

Test No. 3-4.

Penetration of a slight amount of chicken-carcass entrails was experienced as the vinyl tore for a length of 14 inches along the top sill metal insert of the exterior window panel, as shown in Fig. 17. A piece of the interior window panel about 13 inches wide and 13 1/2 inches long tore out, as shown in Fig. 18. Apparently, this panel was too low in temperature for maximum impact strength. The location of the breaks in the exterior and interior panels was such that the small amount of carcass which penetrated the exterior panel was almost entirely contained by the interior panel. The piece of the interior window which tore out was propelled aft between the pilot and copilot to a location near the aft bulkhead of the cockpit structure. Small particles of glass impinged upon the pilot's and copilot's clothing, but none penetrated. The semitempered glass from the aft face of the interior window and full-tempered glass sandwiched between the panels was propelled predominantly in a plane normal to the window and downward into the aisle between the pilot and copilot. No glass was propelled at either pilot or copilot at eye level, and the glasses worn by the two clay figures were undamaged. No apparent damage to the window sills was noted, although the top center doubler plate retaining the outer window was warped outward slightly.

Test No. 3-5.

The chicken carcass struck about two inches below the target point. The vinyl in both the exterior and interior panels tore for a length of nine inches along the upper metal insert parallel to the top sill, as shown in Figs. 19 and 20. This failure was located predominantly at the left center portion of the window. Part of the bird carcass extruded through the tear in the vinyl interlayers. The right shoulder area of the pilot was struck by particles of semitempered glass and bird carcass as shown in Fig. 21, but none penetrated the clothing of the pilot. The small amount of glass which departed from the aft face of the interior panel was propelled predominantly downward between the pilot and copilot. The upper doubler retaining plate for the exterior window panel was bent upward and inward as four top sill bolts failed. Failure of the interior panel during this test apparently was due to a low vinyl interlayer temperature.

Test No. 3-6.

The chicken carcass hit about 1/2-inch below the target point. None of the carcass penetrated into the cockpit area as the interior window panel remained intact. See Fig. 22. The vinyl pulled away from the metal insert of the exterior window panel for a length of nine inches along the top edge, as shown in Fig. 23. The metal insert cracked for a length of seven inches along the top edge of the exterior window panel. The small amount of glass which departed from the aft face of the interior window panel was directed predominantly downward and normal to the plane of the window. A few particles of glass impinged upon the lower faces of the pilot and copilot, but did not penetrate the clay. Figure 24 shows the pilot after this test. One-half of the upper doubler plate tore free as four retaining bolts failed. After this test, it was noticed that the upper sill edge was bent inward about 1/4-inch.

Test No. 3-7.

Upon impact, the window opened as the latching mechanism failed and the window swung inward about the upper and lower forward track retaining points, allowing a considerable portion of the bird carcass to enter the cockpit aft of the copilot. The copilot was hit a severe blow in the back of the head as the window frame swung inward. Neither the exterior nor interior stretched Plex-55 window panels ruptured. The window frame cracked just forward of the upper aft corner at a location which had been weakened by machining a clearance recess for a latching mechanism nut. High-speed pictures of the test indicated that the window frame was forced open by hydraulic action of the carcass at the upper aft corner, and subsequent warping of the window frame allowed the upper and lower window latches to slip from their normally closed positions. Results of this test are shown in Figs. 25, 26, and 27.

Test No. 3-8.

The carcass hit about two inches below the target point. A considerable amount of bird carcass entered the cockpit area. The vinyl in the exterior window separated from the metal edge attachment, then tore for a length of six inches near the upper sill, continuing around the corner and downward along the cornerpost sill for a length of five inches, as shown in Fig. 28. The penetration of the bird then tore the vinyl interlayer of the interior window for a length of five inches along the upper sill and continued around the corner and downward along the cornerpost sill for a length of six inches, as shown in Fig. 29. A second tear in the interior panel vinyl five inches in length and slightly outboard of the first tear contributed further to the failure. The copilot was struck directly in the face and upper chest area by bird entrails and particles of semitempered and full-tempered glass, as shown in Figs. 30 and 31. The glass particles had sufficient energy to imbed themselves in the clay face of the copilot and penetrate through the cloth shirt and imbed themselves in the left shoulder area. The sun glasses worn by the copilot were severely damaged as the glass lenses were broken and particles of the lenses were driven into the eye socket area. It appeared that most of the damage to the copilot was caused by the full-tempered glass nuggets which were released by failure of the interior window. Inspection of the break in the vinyl interlayers indicated that the vinyl in the area of the failure was at a lower temperature than that required for best results.

Test No. 3-9.

The chicken carcass hit two inches inboard of the target point. None of the bird carcass entered the cockpit area. The vinyl interlayer in the exterior window tore for a length of five inches from the upper outboard corner downward parallel to the cornerpost sill. There was no vinyl failure of the interior window panel. Relatively few particles of semitempered glass departed from the aft face of the interior window panel. The glass which was accelerated rearward struck the pilot in the face from the neck level up to the point of the nose. The right lens of the pilot's goggles was scarred slightly by flying glass but remained undamaged otherwise. The lens material was cut from 0.020-inch-thick cellulose acetate sheet. The edge of the upper outer doubler retainer for the exterior panel was warped outward slightly. Results of this test are shown in Figs. 32, 33, and 34.

Test No. 3-10.

Prior to this test the aft edge of the window frame was held rigidly in place by incorporating a retaining bar mounted as shown in Fig. 6. Upon impact, both the interior and exterior outer stretched Plex-55 panels shattered, allowing partial penetration of the carcass. As the carcass traveled rearward, it forced the aft doubler plate outward and the aft window frame inward. As the doubler plate bent outward, bearing failure of the doubler plate in combination with tension failure of the bolts fastening the aft window frame retaining bar allowed the retaining bar to fly inward behind the pilot. None of the pieces of Plex panels which were shattered struck the pilot, because the pieces that entered the cockpit area were directed aft and outward toward the aisle passing behind the pilot. That part of the carcass which impinged upon the left side and back of the pilot extruded into the cockpit between the aft post and the window frame. The force of the impact moved the window frame slightly rearward, disengaging the lower forward hook and forward retaining bar. Results of the test are shown in Figs. 35, 36, and 37.

Test No. 3-11.

The carcass struck about three inches below the target point. A slight amount of the bird carcass entered the cockpit area and passed between the pilot and copilot positions. The exterior window failed as the vinyl interlayer pulled away from the metal insert for a length of 13 inches from right center into the upper left corner of the window. This failure continued around the upper left corner and downward a length of five inches parallel to the left centerpost sill, as shown in Fig. 38. The vinyl in the inner window failed in such a manner that a large circular-shaped glass-vinyl-glass flap, approximately 12 inches in diameter, and hinged parallel to the right centerpost sill, was formed. See Fig. 39. The failures of the two vinyl interlayers were so positioned with respect to each other that the bird carcass which entered the cockpit was turned 90° downward from its line of flight. Small particles of glass impinged upon the pilot and copilot, but did not imbed themselves in the clay. Most of the glass which departed from the window was directed downward between the pilot and copilot positions. Failure of the exterior window appeared to be due to faulty fabrication. Apparently, failure of the interior window was caused partly by its inability to absorb the added amount of energy imparted to it when the exterior window failed excessively, and partly by its below-minimum vinyl temperature.

Test No. 3-12.

None of the bird carcass entered the cockpit area. The vinyl interlayer of the exterior window failed in the upper outboard corner as the vinyl delaminated from the metal insert for a length of five inches along the top sill and the metal insert sheared for a length of four inches downward along the cornerpost sill, as shown in Fig. 40. There was no failure of the interior window interlayer. See Figs. 41 and 42. Most of the semitempered glass of the aft face of the interior window remained laminated to the vinyl. A portion of this glass which was accelerated rearward by the impact struck the pilot's face from chin level to eye level. The goggles worn by the pilot remained intact, although both of the 0.020-inch-thick cellulose acetate lenses were scarred somewhat by flying glass particles. One or two slivers of glass were imbedded about 1/4-inch in the exposed clay at the pilot's eye level. See Fig. 43. Most of the glass particles which impinged on the pilot's face hit in a flat position and were imbedded approximately their own thickness, about 1/32-inch. There was no apparent damage to the sill structure, except for an outward warping of the upper outboard doubler plate for the exterior window.

Test No. 3-13.

The carcass hit two inches inboard of the target point. None of the bird carcass entered the cockpit. The exterior window panel failed as the metal insert sheared along the top edge for a length of five inches toward the upper outboard corner, and the vinyl sheared along the cornerpost edge downward a length of eight inches from a point two inches inboard of the upper outboard corner, as shown in Fig. 44. No vinyl failure of the interior window panel occurred. See Figs. 45 and 46. Numerous particles of semitempered glass which departed from the aft face of the interior window were directed toward the pilot's face from chin to eyebrow level. The glass particles, which were sliver-like with sharp edges, penetrated into the clay about 1/32-inch. The pilot's goggles remained intact except for numerous scratches on both of the 0.020-inch-thick cellulose acetate lenses caused by flying glass particles. See Fig. 47 for the glass-impingement pattern on the pilot's face.

Test No. 3-14.

Part of the bird carcass entered the cockpit area as the vinyl interlayer metal insert laminates in both the interior and exterior window panels failed. The exterior window metal insert failed in bending and sheared for a length of eight inches along the top edge toward the left corner of the window and downward along the left cornerpost edge a length of eight inches. In addition, the vinyl tore and delaminated from the metal insert for a length of 12 inches along the top edge of the window into the upper left corner. This failure is shown in Fig. 48. The vinyl interlayer of the interior window delaminated from the metal insert for a length of ten inches along the upper edge into the left-hand corner and downward from the corner a length of eight inches, as shown in Fig. 49. The predominant cause of this failure was due to delamination of the vinyl from the metal insert of the interior window which is considered to be a defect in this window. The part of the carcass which penetrated the windshield continued aft between the pilot and copilot positions as did the flying glass departing from the windshield. A few particles of bird entrails and glass impinged upon the pilot's face as shown in Fig. 50, but the energy of these particles was low and caused no damage. Three-fourths of the external window panel doubler retaining plate departed from its fixed position as eight retaining bolt heads failed in tension, snapping off the heads. The upper sill lip for the exterior window panel was deformed inward slightly.

Test No. 3-15.

There was no penetration of the window. The exterior window panel metal insert failed in bending for a length of eight inches along the upper edge into the upper left corner and then downward for a length of five inches, and the vinyl sheared for a length of four inches parallel to the top sill of the window at the edge of the upper metal insert, as shown in Fig. 51. The vinyl of the interior window panel resisted penetration, as shown in Fig. 52. A few flakes of glass impinged on the pilot and copilot but no penetration in the clay was observed. Only a relatively small amount of semitempered glass departed from the aft face of the interior window panel. One-third of the external window top center retaining plate tore loose as the four retaining bolts failed in tension. This test produced a 3/16-inch permanent set in the upper sill lip for the external window.

Test No. 3-16.

Prior to this test the method for retaining this window was revised to incorporate twice the number of bolts, every other bolt fastening the retaining bar directly to the aft post flange only, as shown in Fig. 53. In addition, heat was applied to the interior glass-vinyl-glass window panel by heating the cockpit area to a temperature of 100° F. Upon impact, the external stretched Plex-55 window panel failed, as shown in Fig. 54. The interior glass-vinyl-glass window panel resisted penetration, as shown in Fig. 55. A small amount of bird-carcass entrails extruded through, between the window sill and the window frame near the upper aft corner. Hydraulic action of the bird carcass forced the aft doubler plate outward, snapping off one bolt head. A few small particles of semitempered glass from the aft face of the interior window panel impinged upon the left side of the copilot's face, as shown in Fig. 56, but only two small particles imbedded themselves in the clay to any degree. The copilot's goggles were undamaged There was no indication that any glass had been propelled at the copilot at eye level.

Test No. 3-17.

The bird carcass struck slightly below the target point. The fuselage was dented inward about one inch forward of frame station 123. The 0.051-inch-thick aluminum skin tore horizontally 5 1/2 inches along the forward frame edge and longitudinally 1 1/2 inches forward of the frame. Nine rivets attaching the skin to the frame failed. The deck of the airplane was deformed quite noticeably from the point of impact aft to the window sill. The frame sustained a tear through its flanged radius downward 2 1/2 inches. Three lower sill window retaining 1/4-inch bolt heads failed. Both the forward semitempered glass face of the external side window and the aft semitempered glass face of the interior side window were cracked severely by the impact. The forward face of the external side-window panel was cracked prior to the test, but sustained additional damage during the test. No glass departed from the aft face of the interior window. A very small amount of carcass extruded through the tear in the skin and impinged upon the copilot at waist height. Results of this test are shown in Figs. 57 and 58.

Test No. 3-18.

The bird carcass hit near the forward edge of the window frame, which would be considered the critical strike area as far as flying glass is concerned. The external Plex-55 window panel failed as shown in Fig. 59. The vinyl of the interior window did not fail, preventing penetration. See Fig. 60. A small portion of the bird carcass extruded through the structure between the window frame and aft post into the cockpit. The window frame cracked near the upper aft hinge point as in Test No. 7. The aft frame fixed retainer remained intact. The center section of the aft outer doubler facing plate bowed outward as in previous tests of this window, and two retaining bolt heads failed in tension. Numerous semitempered glass particles from the aft face of the interior window impinged upon the left side of the pilot's head from neck level to above the left ear, as shown in Fig. 61. Only two of these particles were imbedded to any degree in the clay. The pilot's eye area was untouched as the goggles with 0.020-inch-thick plastic lenses remained undamaged. The glass spatter pattern indicated that very few glass particles were directed toward the pilot's eye area.

Test No. 3-19.

For this test, the interior glass-vinyl-glass panel for the clear-view window was reduced in temperature to nearly 45° F to determine whether a lower temperature limit extrapolation relative to penetration velocity could be applied to the window. Upon impact, part of the carcass entered the cockpit as the external stretched Plex-55 panel shattered, as shown in Fig. 62, and the interior panel vinyl interlayer failed, as shown in Fig. 63. About one-quarter of the interior window panel tore loose and was forced inward and to the rear of the cockpit, missing the pilot. The window frame cracked just forward of the upper aft corner as in two previous tests of this window (Tests Nos. 7 and 18). The upper hinged window frame retainer failed partially, and the aft fixed retaining bar failed in bending and direct tension. The copilot was struck on the right side of the face and neck area by small semitempered glass particles and bird-carcass entrails, as shown in Fig. 64. Most of the glass merely impinged upon the clay with little or no penetration.

Test No. 3-20.

The clear-view window used in this test incorporated a flat, 1/4-inch-thick Plex shield mounted approximately 1 inch inboard of the interior stretched Plex-55 panel Upon impact, all three Plex panels shattered, allowing part of the bird carcass to enter the cockpit area. The aft window frame fixed retaining bar failed completely in bending and tension as the aft window edge was forced inward. None of the remaining window-frame retainers failed. The left side of the pilot's face was marked in one or two places where pieces of Plexiglas had struck. In addition, the left side of the pilot's face was struck by numerous particles of bird-carcass entrails. The pilot's goggles were untouched by flying window fragments. There was one gash about 1 1/2 inches long and 1/2-inch deep in the back of the pilot's head on the left side, indicating that one large piece of Plexiglas had been hurled in that direction. The Plex shield was totally destroyed by the impact. Results of this test are shown in Figs. 65, 66, and 67.

CONCLUSIONS

Center Window (vinyl interlayer 0.30-inch thick in both exterior and interior panels).

1. This window, consisting of two panels, Douglas Aircraft Co. Drawings Nos. 5616219, Revision A, and 5616240, Revision A, will prevent the penetration of a 4-pound bird at a maximum impact velocity of 425 mph provided both the exterior and interior panels are maintained at a minimum temperature of 110° F. This window design will prevent penetration at 400 mph provided a minimum temperature of 100° F. is maintained in both panels. As noted in Tests Nos. 4 and 5, slight penetration did occur due primarily to failure of the interior panel, which in both cases was below minimum temperature for best results. The penetration velocities indicated above are for a strike near the upper outboard corner, the critical strike location for this window.

2. For a bird strike at any position on this window at a velocity of 425 mph, no appreciable hazard from flying glass particles is presented pilot personnel. The relatively few fine particles of semitempered glass which were propelled from the aft face of the interior panel were directed predominantly downward normal to the plane of the panel and between the pilot and copilot. This window is located in such a position, relative to the pilot and copilot, that in the event of penetration of part of the bird carcass resulting from failure of the interior panel, as occurred during Test No 5, no appreciable hazard to the pilot or copilot exists.

Center Window (vinyl interlayer 0.36-inch thick in both exterior and interior panels).

1. This window, consisting of two panels, constructed as shown in Douglas Aircraft Co. Drawings Nos. 5593529, Revision B, and 5593546, Revision B, will prevent the penetration of a 4-pound bird carcass at an impact velocity slightly greater than 460 mph for a strike near an upper outboard corner provided that both the exterior and interior window panels are maintained at a minimum temperature of 110° F. The results of Tests Nos. 14 and 15 form a basis for this conclusion. Based on the results of Test No. 6, it is further concluded that this window design will prevent penetration in the event of an upper outboard corner bird strike at 400 mph provided that the exterior and interior window panels are maintained at a minimum temperature of 100° F. The upper outboard strike position is critical for this window.

2. For a bird strike at any position on this window at an impact velocity as high as 460 mph, no appreciable hazard from flying glass fragments is presented to pilot personnel. The relatively few fine particles of semitempered glass which are propelled from the aft face of the interior panel are directed predominantly downward normal to the plane of the panel and between the pilot and copilot, as shown in the results of Test No. 15. Test No. 15 involved an upper outboard strike location which is the critical impact position on this window from a glass-fragmentation viewpoint. Furthermore, it is significant to note, as evidenced from the results of Test No. 14, that penetration of the window at a critical strike location by a part of the bird carcass at a velocity of 466 mph, produced no serious fragmentation hazard to either the pilot or copilot.

Side Window (vinyl interlayer 0.30-inch thick in both the interior and exterior panels).

1. This window, consisting of two panels, constructed as shown in Douglas Aircraft Co. Drawings Nos. 5616275, Revision B, and 5616353, Revision A, is considered to be capable of preventing the penetration of a 4-pound bird carcass at an impact velocity of at least 425 mph for an upper outboard corner strike position, provided that a minimum temperature of 110° F. is maintained in both panels. This is based upon analysis of the results of Tests Nos. 1 through 5. Upper outboard corner impact tests were not conducted on this window beyond a velocity of 394 mph. Based on the results of Test No. 3, this window will prevent penetration at a velocity of 394 mph provided both exterior and interior panels are maintained at a minimum temperature of 100° F.

2. For a bird-strike velocity of 425 mph with the strike occurring at an upper outboard corner, fine glass particles from the aft face of the interior panel of this window are directed toward pilot personnel below eye-level position. This is based upon the results of tests conducted on side windows containing 0.36-inch-thick vinyl interlayers.

Side Window (vinyl interlayer 0.36-inch thick in both the interior and exterior panels).

1. This window, consisting of two panels, constructed as shown in Douglas Aircraft Co. Drawings Nos. 5593704, Revision B, and 5593703, Revision B, will resist the penetration of a 4-pound bird carcass at an impact velocity slightly greater than 482 mph for a bird strike near the upper outboard corner provided a minimum temperature of 110° F. is maintained in both the exterior and interior panels. The upper outboard corner is a critical strike location for this window. This window will resist penetration at

425 mph for an upper outboard strike position, provided that a minimum temperature of 100° F. is maintained in both the exterior and interior panels. These conclusions are based upon the results of Tests Nos. 9 and 13.

2. For a bird strike near the upper outboard corner at a velocity as low as 425 mph, glass fragments are propelled toward the facial areas of the pilot personnel. This does not appear to constitute an appreciable danger to them, however, until a velocity of 448 mph is reached. At this velocity, the glass-impingement pattern on the pilot extended from eye level to neck level. At a velocity of 482 mph, the flying glass impingement is similar to that experienced at 448 mph, but both the velocity and amount of glass particles impinging upon the pilot increased noticeably. As noted from the results of Tests Nos. 9, 12, and 13, the goggles worn by the pilot protected his eye area at all test velocities where no penetration occurred. These three tests involved upper outboard corner impacts, which is the critical strike position on this window relative to windshield fragmentation.

Clear-View Window.

1. The window design incorporating two stretched Plex-55 panels as shown in Douglas Aircraft Co. Drawing No. 5616457, Revision A, failed in Test No. 7 at a bird-strike velocity of 400 mph. The window frame cracked, allowing the window to unlatch and swing inward into the back of the co-pilot's head. This design was revised by adding a fixed bar which rigidly retained the aft window edge, as shown in Fig. 6. The design, as revised, failed during Test No. 10 at 386 mph as both acrylic panels shattered. The penetration velocity of this window is considered to be well below 386 mph.

2. Flying window material from the stretched Plex-55 double-panel window did not strike the pilot during Tests Nos. 7 and 10. The Plex fragments, which were propelled inward, passed behind the pilot's head position toward the center aisle of the cockpit.

3. The window design incorporating an exterior stretched Plex-55 panel and an interior glass-vinyl-glass panel, as shown in Douglas Aircraft Co. Drawings Nos. 5615112, Revision A, and 5613987, Revision C, respectively, will resist penetration at 448 mph provided the vinyl interlayer of the interior panel is maintained at a temperature equal to or greater than 105° F. and an aft window-frame latch equal in strength to the fixed retainer shown in Fig. 6 is installed. This is based upon the results of Tests Nos. 16 and 18.

4. At 448 mph, flying glass from the design incorporating a glass-vinyl-glass interior panel struck the side of the pilot's face when a bird strike occurred near the upper forward edge of the window. This is a critical strike location for this window relative to glass fragmentation. The pilot's eye area was forward of the glass-impingement pattern on the pilot's head, and the velocity of the glass particles was quite low, as shown in the results of Test No. 18.

5. The window design incorporating two stretched Plex-55 panels and a 1/4-inch-thick Plex protective shield mounted inboard of and parallel to the interior panel, as shown in Douglas Aircraft Co. Drawings Nos. 5616457, Revision A, and EO 5654977, proved to be more hazardous to pilot personnel than did the same window with no shield. Upon impact at 386 mph during Test No. 19, the Plex shield shattered completely and one or more Plex-55 fragments struck the back of the pilot's head with sufficient energy to indent the clay with a gash 1 1/2 inches long, 1/2-inch deep, and 1/4-inch in width.

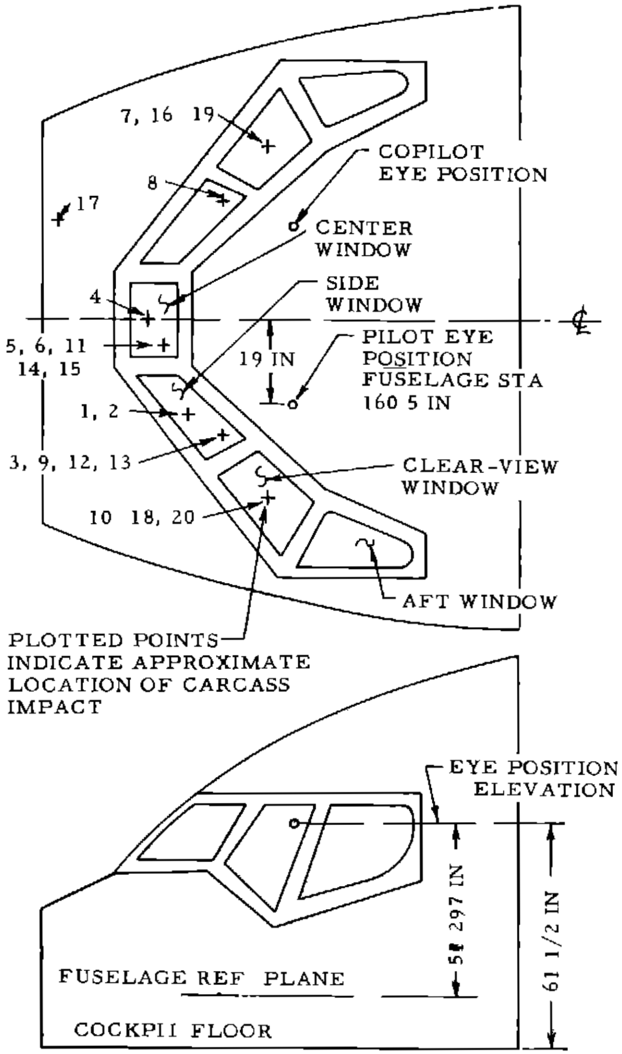


TABLE I

Position of Impact

Test No	Window (See 4)	Velocity (mph)		Results
1	S-	408		Penetration
2	S	401		No penetration
3	S-	394	(1)	No penetration
4	C	426		Slight penetration
5	C	393		Penetration
6	C	405		No penetration
7	CV	400	(2)	Penetration
8	S	424		Penetration
9	S	425		No penetration
10	CV	395		Penetration
11	C	444		Slight penetration
12	S	448		No penetration
13	S	482		No penetration
14	C	466		Penetration
15	C	460		No penetration
16	CV	404	(3)	No penetration
17	Forward Deck	490		No penetration
18	CV	448	(3)	No penetration
19	CV	435		Penetration
20	CV	386		Penetration

(1) Vinyl in both inner and outer windows was torn, but none of bird carcass entered cockpit area

(2) Window latches failed allowing penetration

(3) Small part of bird carcass entered cockpit by extruding between window frame and aft sill

(4) S = side window, C = center window, CV = clear-view window

TABLE II

DOUGLAS DRAWINGS

Drawing	Title	Sheet	Rev.
5612643	Enclosure Assembly Fuselage - Windshield Test		C
5613067	Enclosure Installation - Cockpit Upper Sills	1	B
5614224	Enclosure Installation - Cockpit Lower Sills	1	E
5641261	Test Installation - Windshield Panel and Sills	1	A
5616219	Panel Assembly - Center Windshield - Outer	1	A
5616240	Panel Assembly - Center Windshield - Inner	1	A
5593529	Panel Assembly - Center Windshield - Outer	1	B
5593546	Panel Assembly - Center Windshield - Inner	1	B
5616275	Panel Assembly - Side Windshield - Outer	1	A
5616353	Panel Assembly - Side Windshield - Inner	1	A
5593704	Panel Assembly - Side Windshield - Outer	1	B
5593703	Panel Assembly - Side Windshield - Inner	1	B
5613217	Window Assembly - Pilot's Clear-View	1	-
5613987	Panel Assembly - Clear-View Window Glass	1	C
5613216	Window Assembly - Pilot's Clear-View	1	-
5615112	Panel - Clear-View Window - Acrylic Outer	1	A
5616457	Panel - Clear-View Window - Acrylic	1	A

TABLE III
TEST CONDITIONS AND WINDOW DATA

Test No (1)	Date	Window Tested	DAC Drawing Number Exterior Panel	DAC Drawing Number Interior Panel	Aiming Point (2)	Projectile Velocity (mph)	Outside Air Temp (F)	Cockpit Temp (F)
3-1	3/26/57	Pilot's side window	5616275 Revision A	5616353 Revision A	Pilot's eye position	408	31	65
3-2	3/28/57	Pilot's side window	5616275 Revision A	5616353 Revision A	Pilot's eye position	401	50	80
3-3	3/29/57	Pilot's side window	5616275 Revision A	5616353 Revision A	Upper left corner	394	55	81
3-4	4/1/57	Center window	5616219 Revision A	5616240 Revision A	Center	4[illegible]6	52	82
3-5	4/2/57	Center window	5616219 Revision A	5616240 Revision A	Upper left corner	393	43	80
3-6	4/4/57	Center window	5593529 Revision B	5593546 Revision B	Upper left corner	405	70	8[illegible]
3-7	4/5/57	Copilot's clear-view window	5616457 Revision A	5616457 Revision A	Center	100	18	80
3-8	4/6/57	Copilot's side window	5593704 Revision B	5593703 Revision B	Upper right corner	424	53	[illegible]
3-9	4/9/57	Pilot's side window	5593704 Revision B	5593703 Revision B	Upper left corner	425	54	8
3-10	4/10/57	Pilot's clear-view window	5616457 Revision A	5616457 Revision A	Center	395	59	--
3-11	4/13/57	Center window	5593529 Revision B	5593546 Revision B	Upper left corner	444	4	58
3-12	4/14/57	Pilot's side window	5593704 Revision B	5593703 Revision B	Upper left corner	448	6	1[illegible]8
3-13	4/15/57	Pilot's side window	5593704 Revision B	5593703 Revision B	Upper left corner	482	59	[illegible]
3-14	4/16/57	Center window	5593529 Revision B	5593546 Revision B	Upper left corner	466	53	92
3-15	4/18/57	Center window	5593529 Revision B	5593546 Revision B	Upper left corner	460	67	89
3-16	4/18/57	Copilot's clear-view window	5615112 Revision A	5613987 Revision C	Center	404	76	100
3-17	4/19/57	Fuselage below copilot's side window	---	---	---	490--	84	8[illegible]
3-18	4/21/57	Pilot's clear-view window	5615112 Revision A	5613987 Revision C	Center	448	80	86
3-19	6/19/57	Copilot's clear-view window	5615112 Revision A	5613987 Revision C	Center	435	--	--
3-20 (4)	6/20/57	Pilot's clear-view window	5616457 Revision A	5616457 Revision A	Center	386	70	110

(1) The numeral '3' is a test series number pertaining to all the tests reported herein. The numeral '1', '2', '3', '4', and so forth is the test number.

(2) As viewed from inside the cockpit.

(3) For center and side windows vinyl temperature, as given, is an average of the temperatures of the two glass panes bonded to the vinyl. For clear-view windows vinyl temperatures, as given, are an average of the temperature of the dead airspace of the window and the glass pane on the pilot's side of the panel.

(4) Incorporated integral 0.25-inch-thick Plex-55 shield as shown in Fig. 7 - Design No. 3.

TABLE III (Continued)

TEST CONDITIONS AND WINDOW DATA

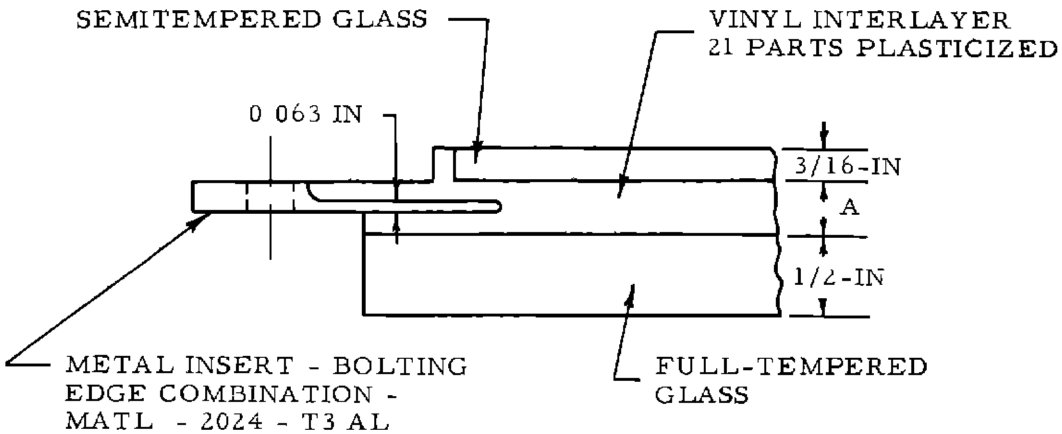
Test No (1)	Vinyl Temperature Data(3) Exterior Panel Temp (°F)	Vinyl Temperature Data(3) Interior Panel Temp (°F)	Window Panel Material and Thickness Data: Exterior Panel (thickness in inches)	Window Panel Material and Thickness Data: Interior Panel (thickness in inches)
3-1	---	---	Outer Face - 0.1875 Semitempered Glass Interlayer - 0.30 PVB (21 parts plasticized) Inner Face - 0.50 Full-tempered Glass	Outer Face - 0.375 Full-tempered Glass Interlayer - 0.30 PVB (21 parts plasticized) Inner Face - 0.125 Semitempered Glass
3-2	102	85		
3-3	106	91		
3-4	98	82	"	
3-5	100	93		
3-6	105	111	Outer Face - 0.1875 Semitempered Glass Interlayer - 0.360 PVB (21 parts plasticized) Inner Face - 0.50 Full-tempered Glass	Outer Face - 0.375 Full-tempered Glass Interlayer - 0.360 PVB (21 parts plasticized) Inner Face - 0.125 Semitempered Glass
3-7	---	---	0.675 Stretched Plex-55	0.525 Stretched Plex-55
3-8	106	103	Outer Face - 0.1875 Semitempered Glass Interlayer - 0.360 PVB (21 parts plasticized) Inner Face - 0.50 Full-tempered Glass	Outer Face - 0.375 Full-tempered Glass Interlayer - 0.360 PVB (21 parts plasticized) Inner Face - 0.125 Semitempered Glass
3-9	104	102		"
3-10	---	---	0.675 Stretched Plex-55	0.520 Stretched Plex-55
3-11	108	84	Outer Face - 0.1875 Semitempered Glass Interlayer - 0.360 PVB (21 parts plasticized) Inner Face - 0.50 Full-tempered Glass	Outer Face - 0.375 Full-tempered Glass Interlayer - 0.360 PVB (21 parts plasticized) Inner Face - 0.50 Semitempered Glass
3-12	111	118	"	
3-13	114	117	Outer Face - 0.1875 Semitempered Glass Interlayer - 0.360 PVB (21 parts plasticized) Inner Face - 0.50 Full-tempered Glass	Outer Face - 0.375 Full-tempered Glass Interlayer - 0.30 PVB (21 parts plasticized) Inner Face - 0.125 Semitempered Glass
3-14	110	107	"	"
3-15	115	107	"	"
3-16	---	105	0.675 Stretched Plex-55	Outer Face - 0.375 Full-tempered Glass Interlayer - 0.375 PVB (26 parts plasticized) Inner Face - 0.125 Semitempered Glass
3-17	101	101	---	---
3-18	---	108	0.675 Stretched Plex-55	Outer Face - 0.375 Full-tempered Glass Interlayer - 0.375 PVB (26 parts plasticized) Inner Face - 0.125 Semitempered Glass
3-19	---	44		"
3-20 (4)	---	---		0.520 Stretched Plex-55

(1) The numeral "3" is a test series number pertaining to all the tests reported herein. The numeral "1," "2," "3," "4," and so forth, is the test number.

(2) As viewed from inside the cockpit.

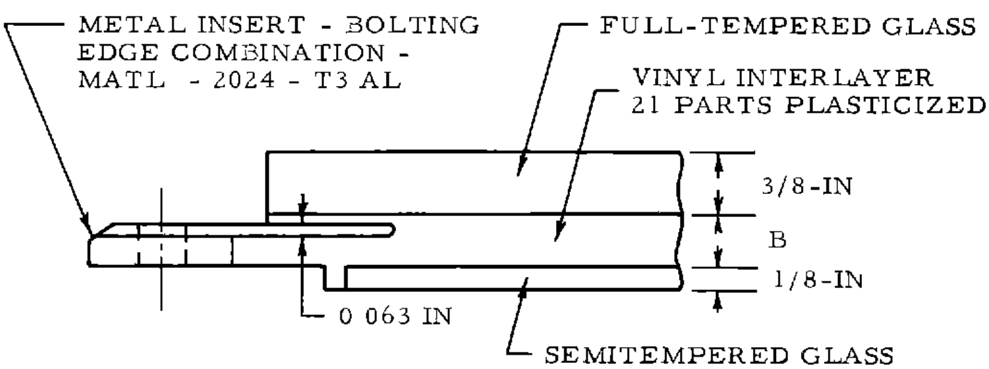
(3) For center and side windows vinyl temperature, as given, is an average of the temperatures of the two glass panes bonded to the vinyl. For clear-view windows vinyl temperatures, as given, are an average of the temperature of the dead airspace of the window and the glass pane on the pilot's side of the panel.

(4) Incorporated integral 0.25-inch-thick Plex-55 shield as shown in Fig. 7 - Design No. 3.



CONSTRUCTION OF CENTER
WINDOW EXTERIOR PANEL

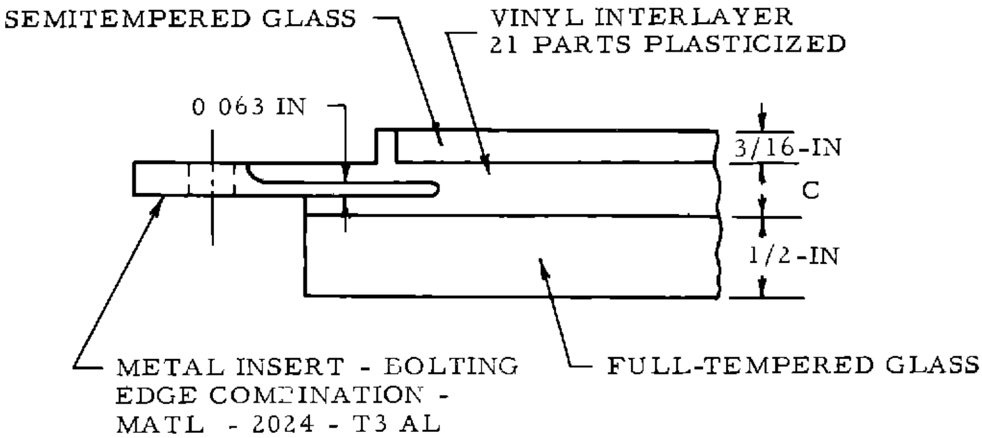
A = 0 300 IN - REF DAC DWG NO 5616219 REV A
A = 0 300 IN - REF DAC DWG NO 5593529 REV B



CONSTRUCTION OF CENTER
WINDOW INTERIOR PANEL

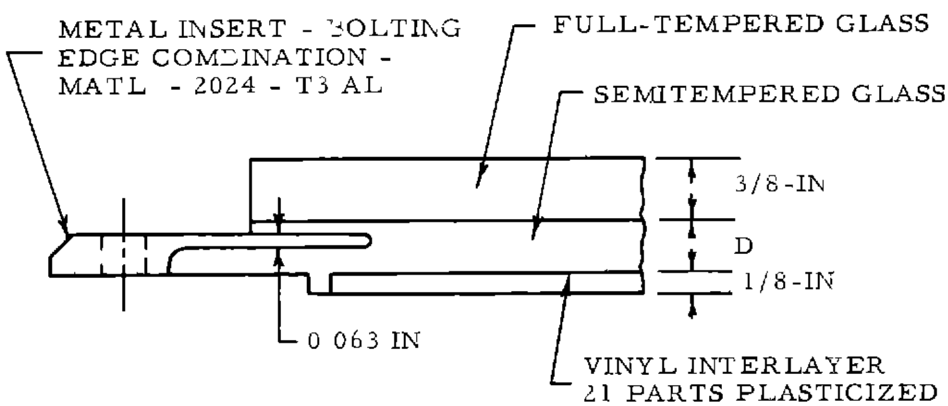
B = 0 300 IN - REF DAC DWG NO 5616240 REV A
B = 0 360 IN - REF DAC DWG NO 5593546 REV B

FIG 1 CENTER WINDOW CONSTRUCTION



CONSTRUCTION OF SIDE
WINDOW INTERIOR PANEL

C = 0 300 IN - REF DAC DWG NO 5616275 REV A
C = 0 360 IN - REF DAC DWG NO 5593704 REV [illegible]



CONSTRUCTION OF SIDE
WINDOW EXTERIOR PANEL

D = 0 300 IN REF DAC DWG NO 5616353 REV A
D = 0 360 IN REF DAC DWG NO 5593703 REV B

FIG 2 SIDE WINDOW CONSTRUCTION

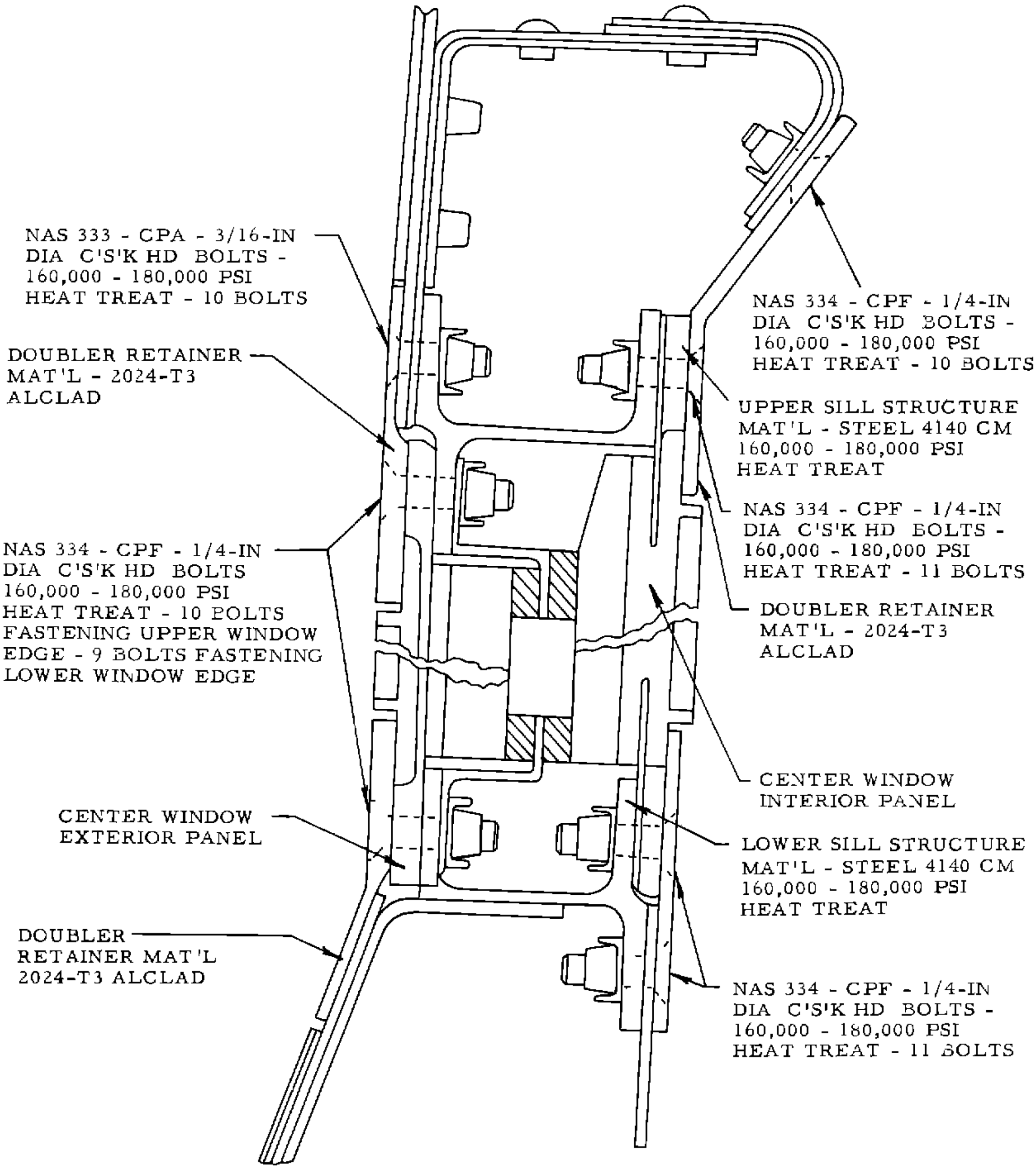


FIG 3 CENTER WINDSHIELD UPPER AND LOWER SILL RETAINING ARRANGEMENTS

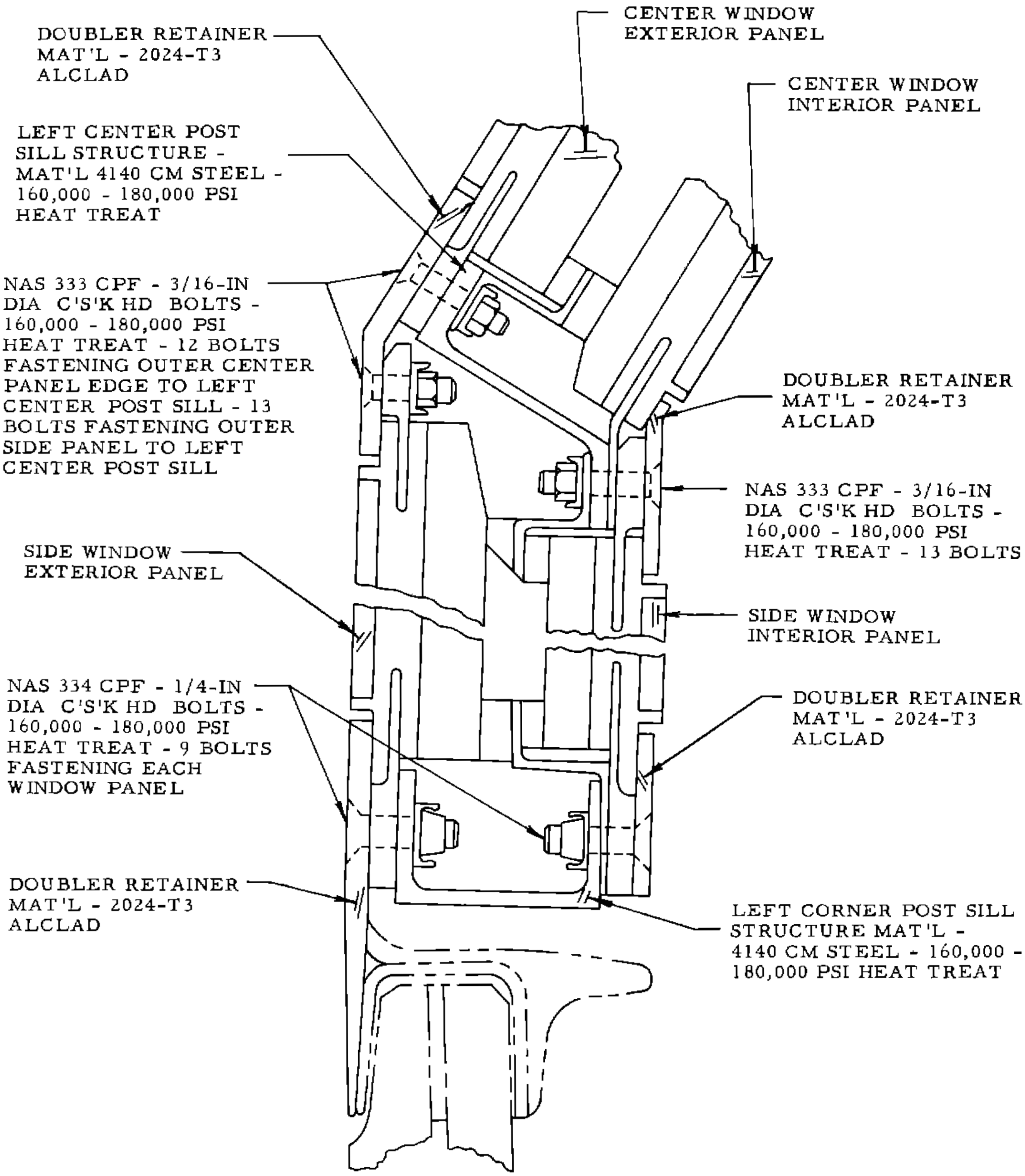


FIG 4 CENTER AND SIDE WINDSHIELDS LEFT CENTER POST AND CORNER POST SILL RETAINING ARRANGEMENTS

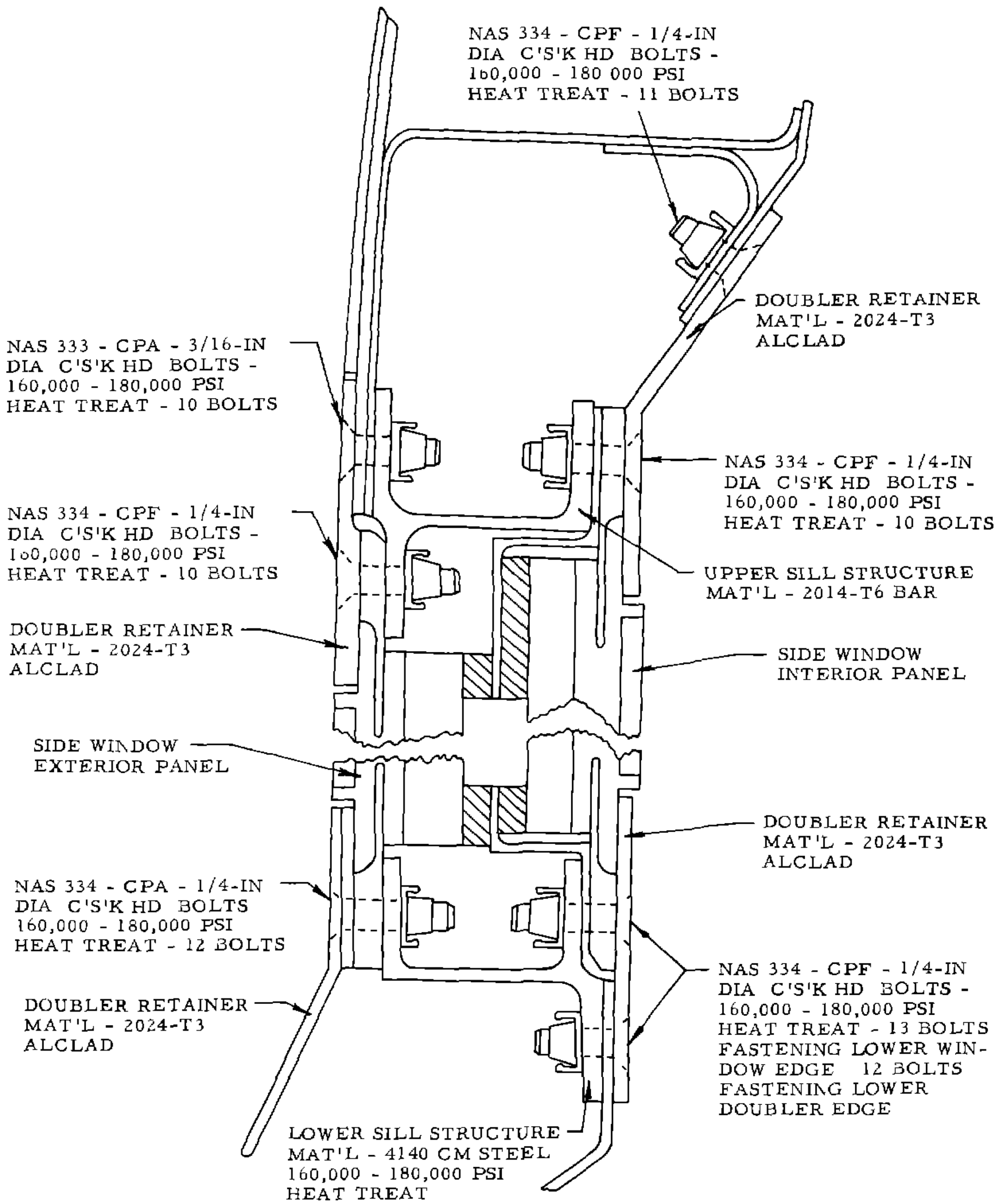


FIG 5 SIDE WINDSHIELD UPPER AND LOWER SILL RETAINING ARRANGEMENTS

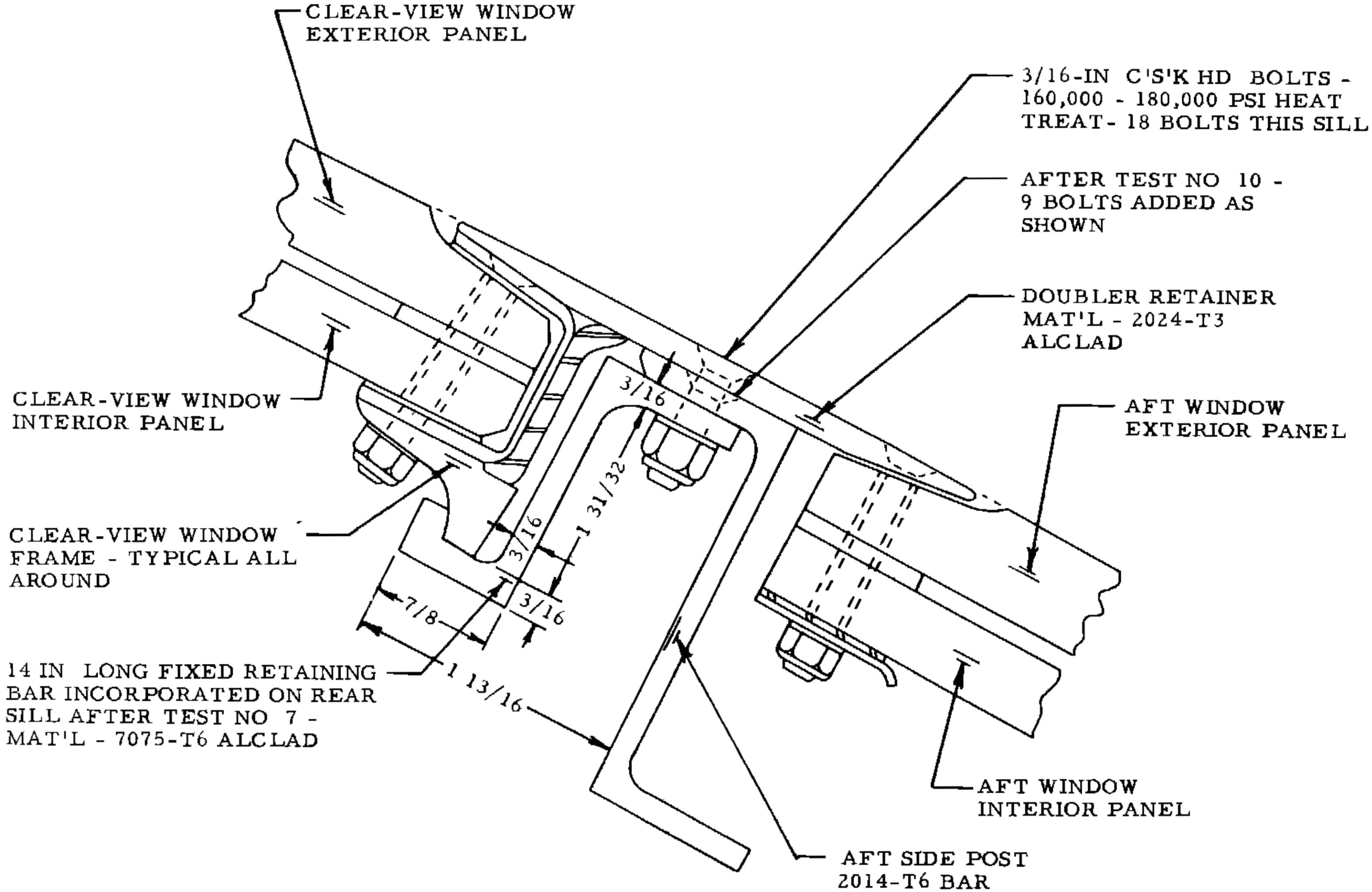


FIG 6 CLEAR-VIEW WINDOW AFT SILL ARRANGEMENT

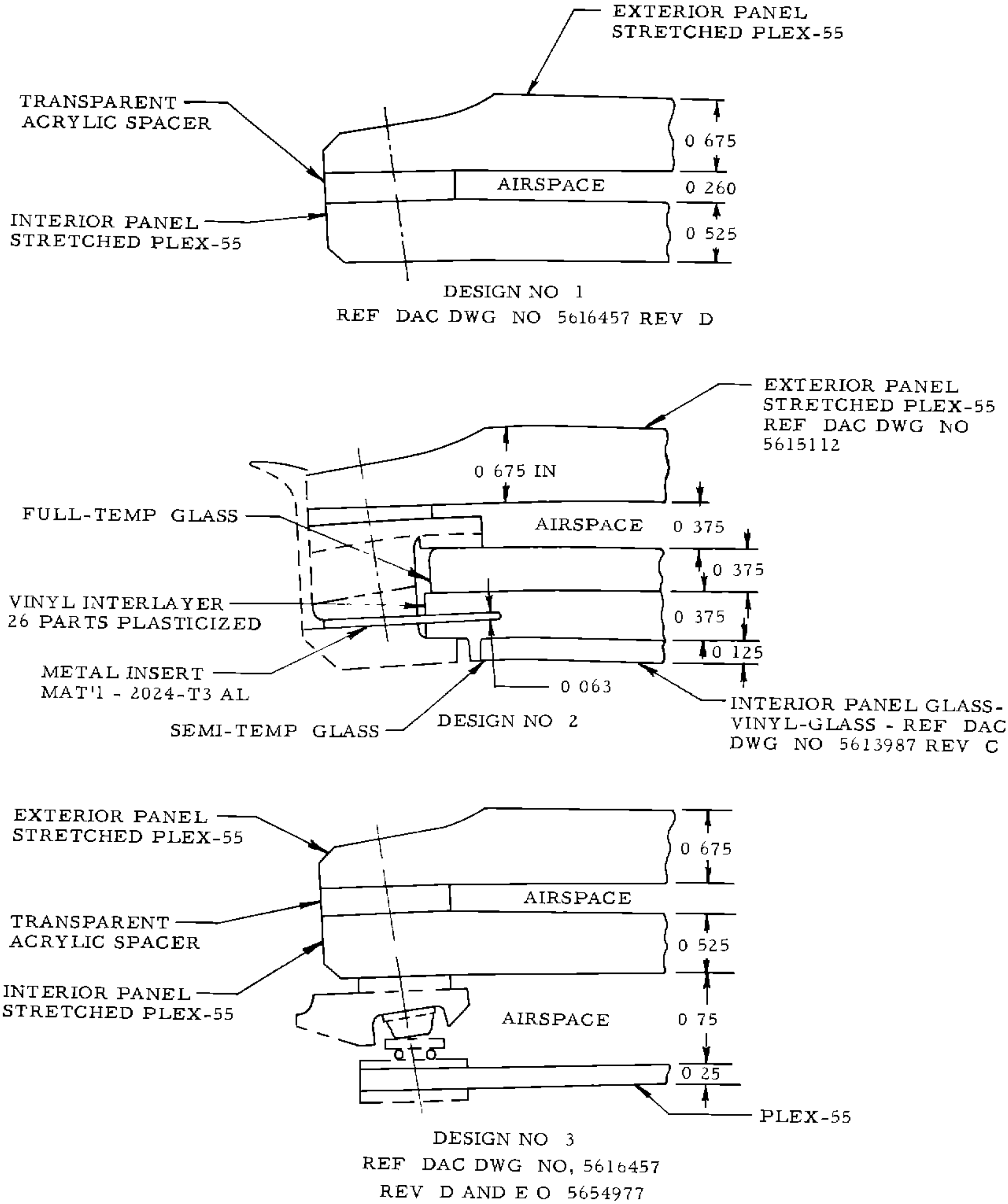


FIG 7 CLEAR-VIEW WINDOW CONSTRUCTION

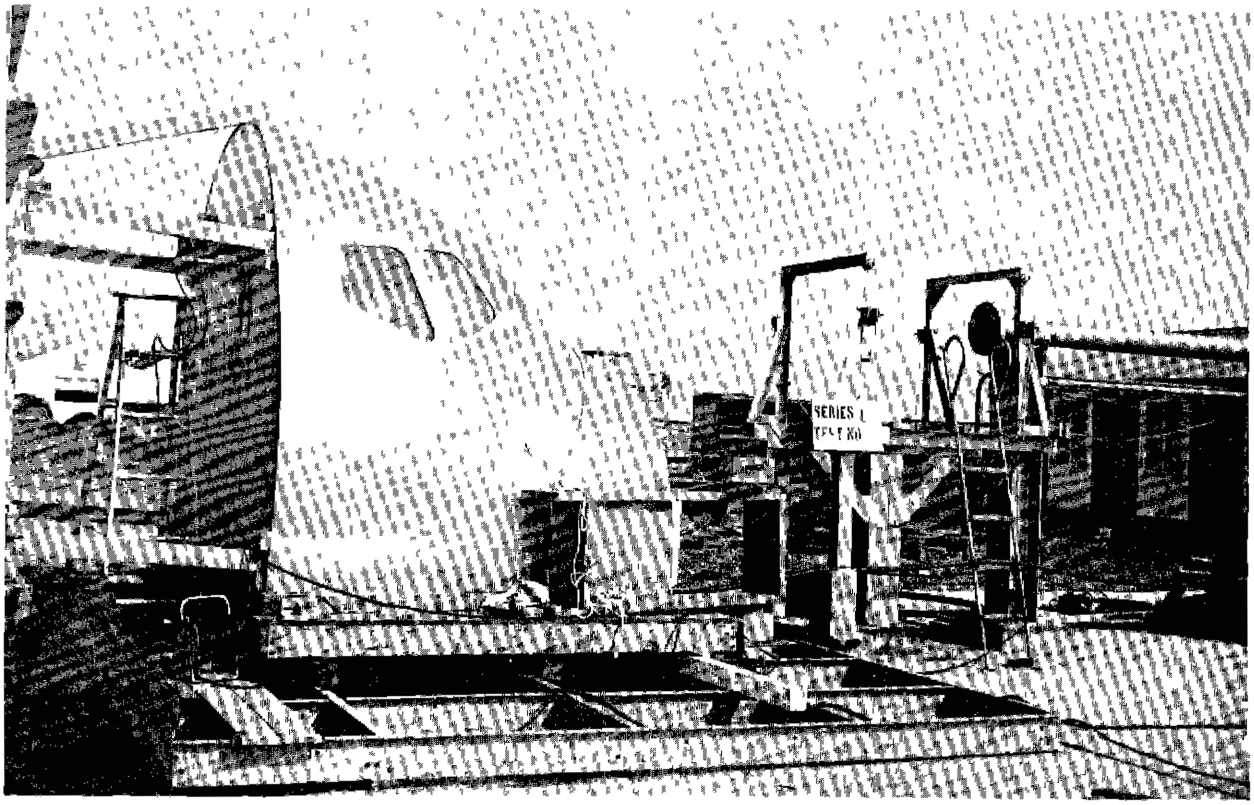


FIG 8A WINDSHIELD TEST COCKPIT MOUNTING ARRANGEMENT

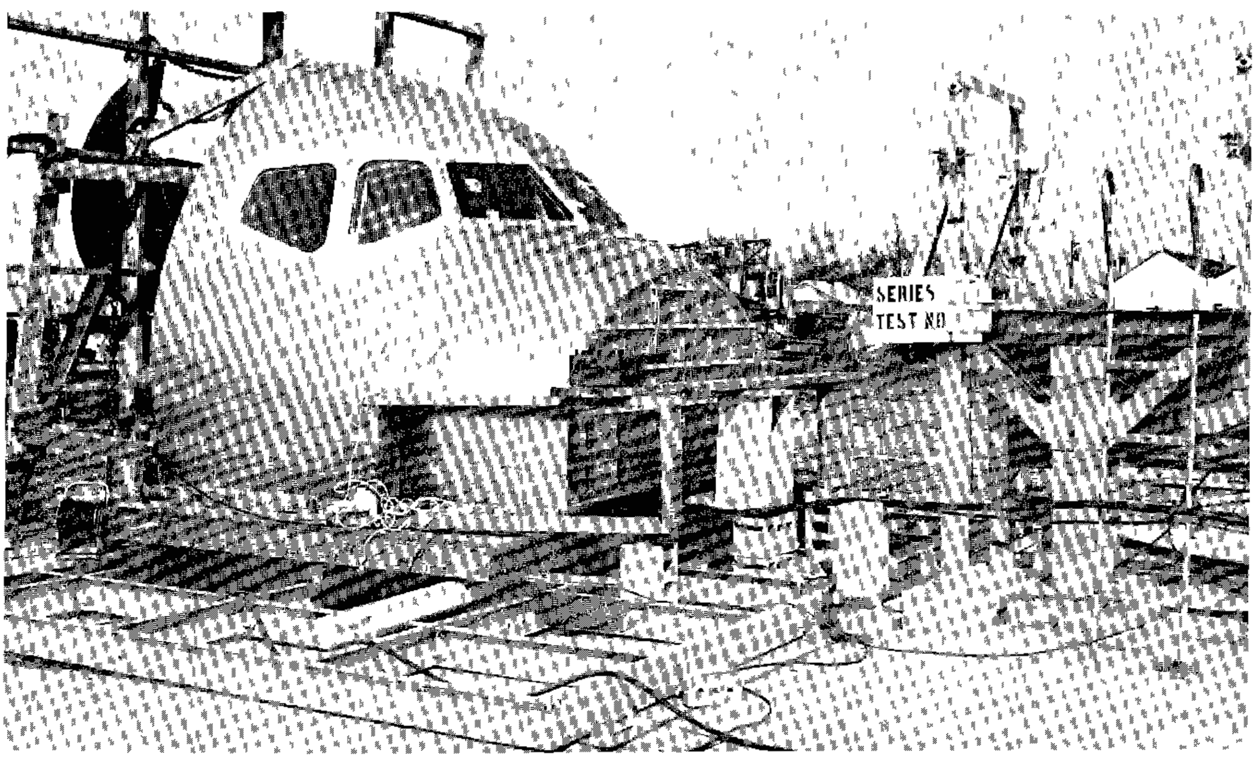


FIG 8B WINDSHIELD TEST COCKPIT MOUNTING ARRANGEMENT

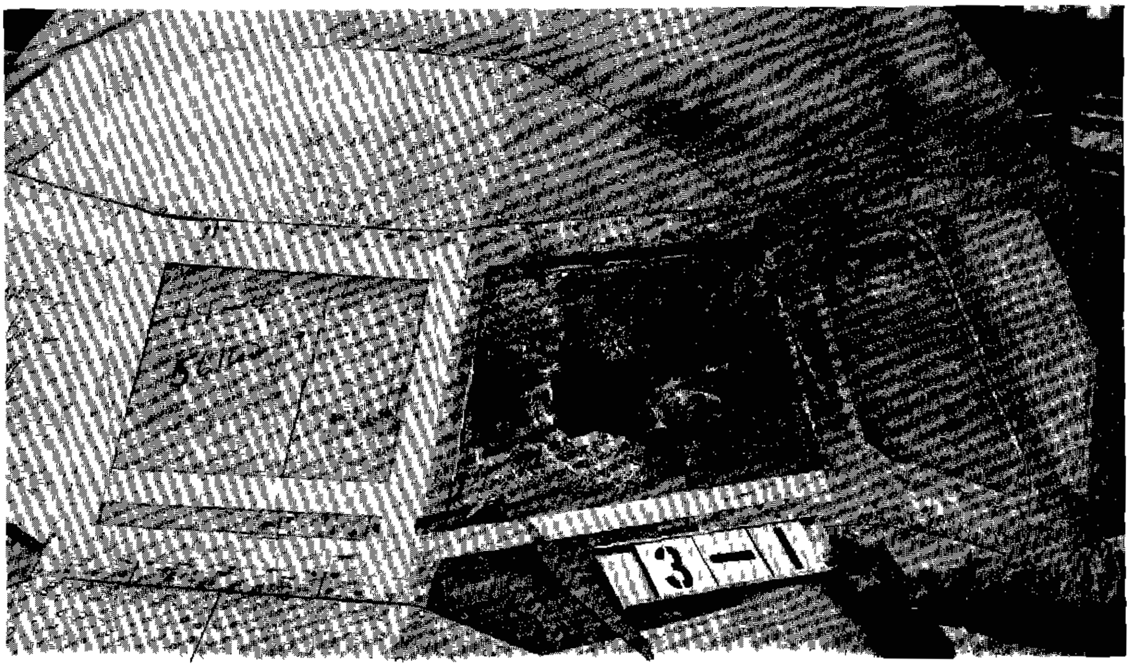


FIG 9 TEST NO. 1 - EXTERIOR PANEL, PROTECTILE VELOCITY - 408 MPH

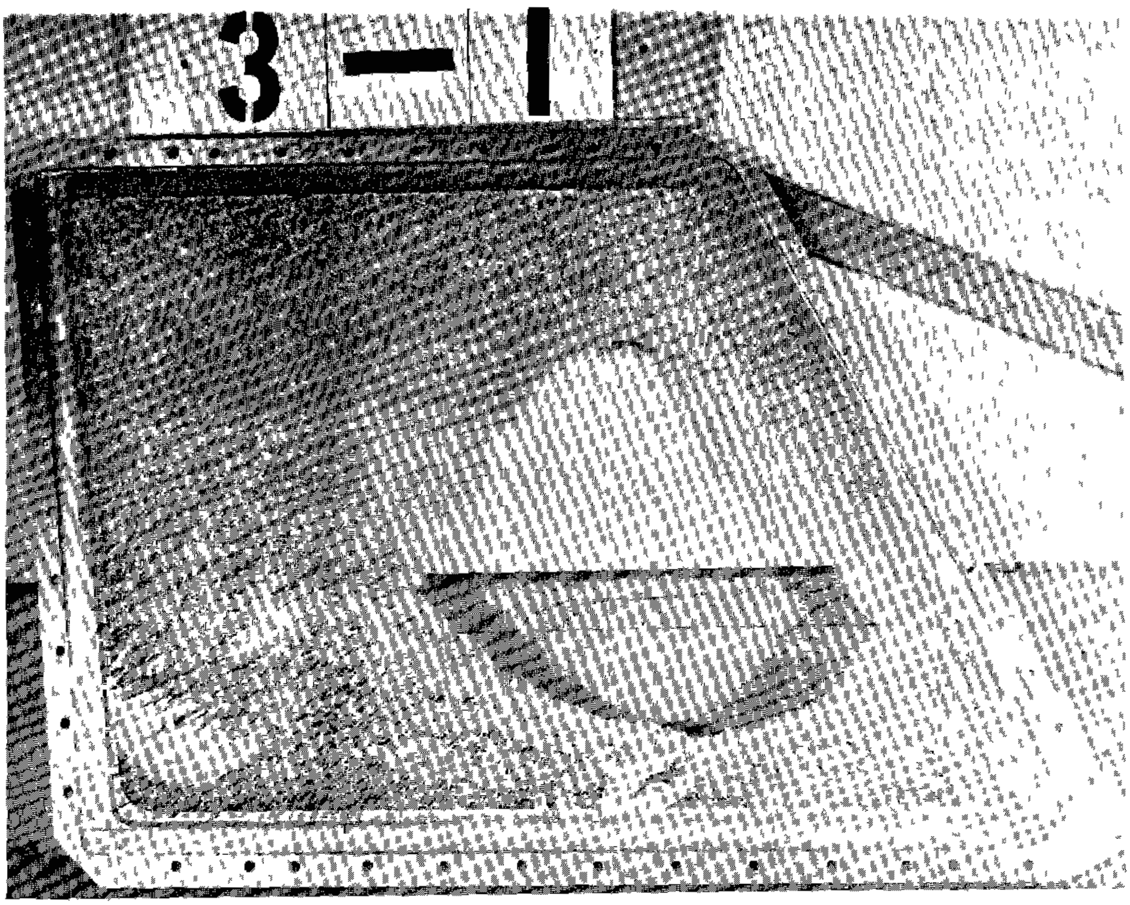


FIG 10 TEST NO 1 - INTERIOR PANEL, PROJECTILE VELOCITY - 408 MPH

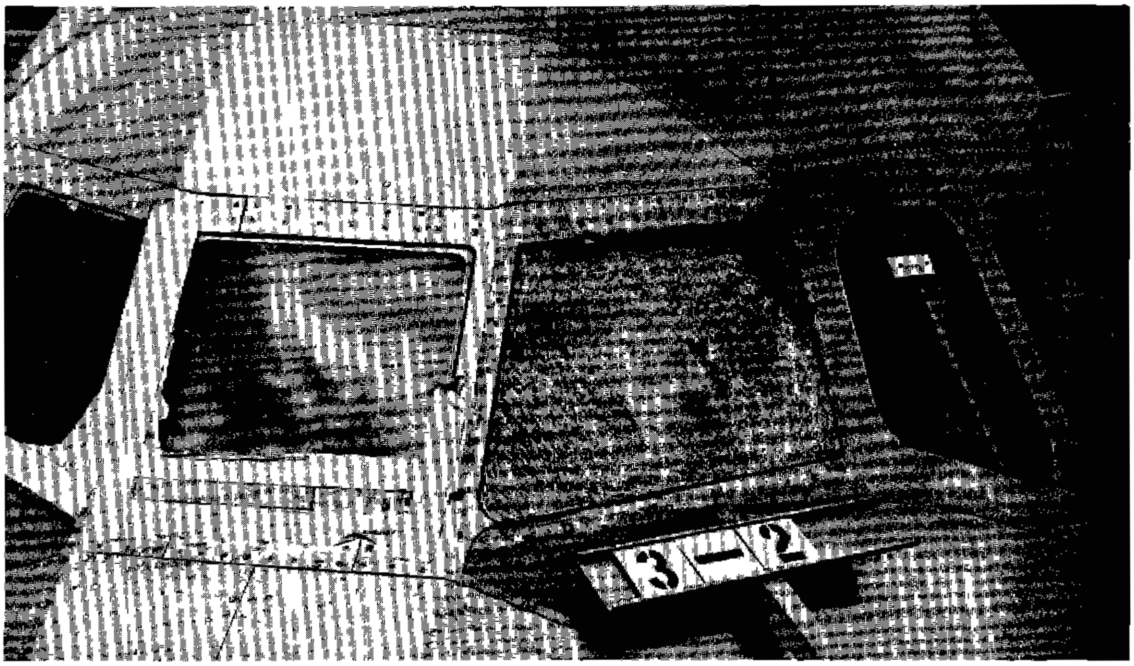


FIG 11 TEST NO. 1 - PILOT, PROJECTILE VELOCITY - 408 MPH

FIG 12 TEST NO 2 - EXTERIOR PANEL, PROJECTILE VELOCITY - 401 MPH

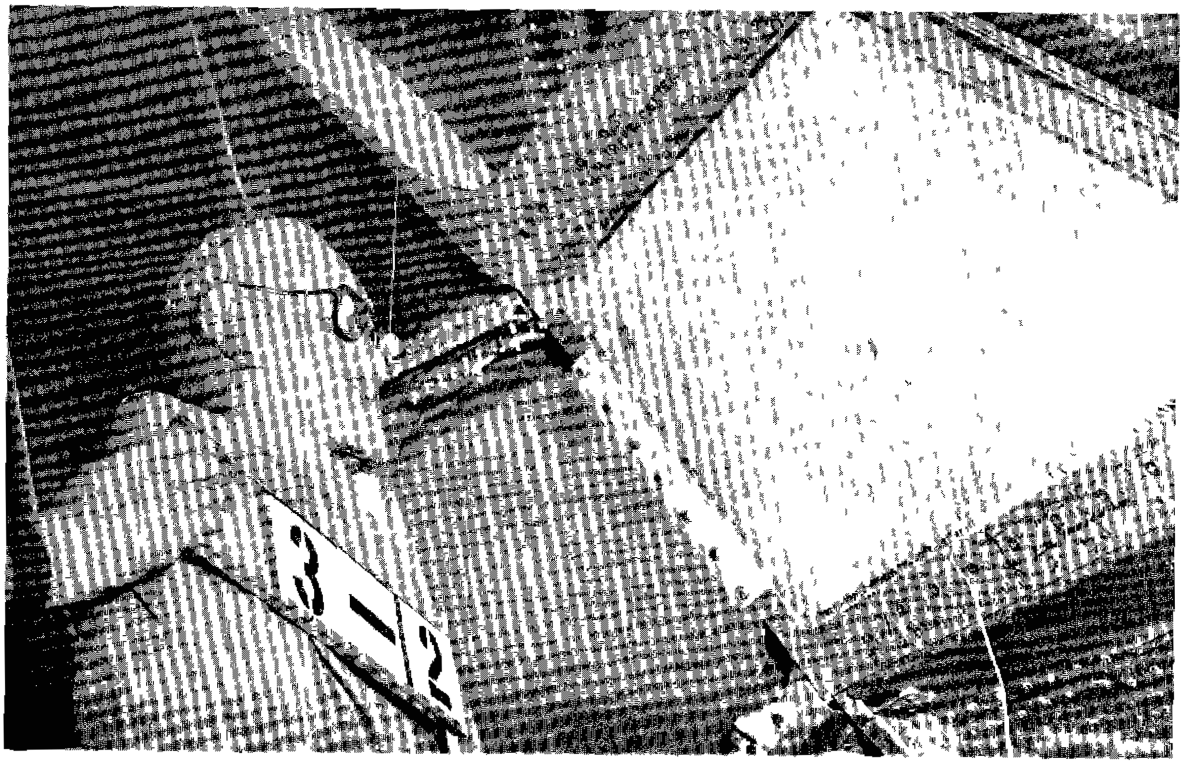


FIG 13 TEST NO 2 - INTERIOR PANEL AND PILOT, PROJECTILE VELOCITY - 401 MPH

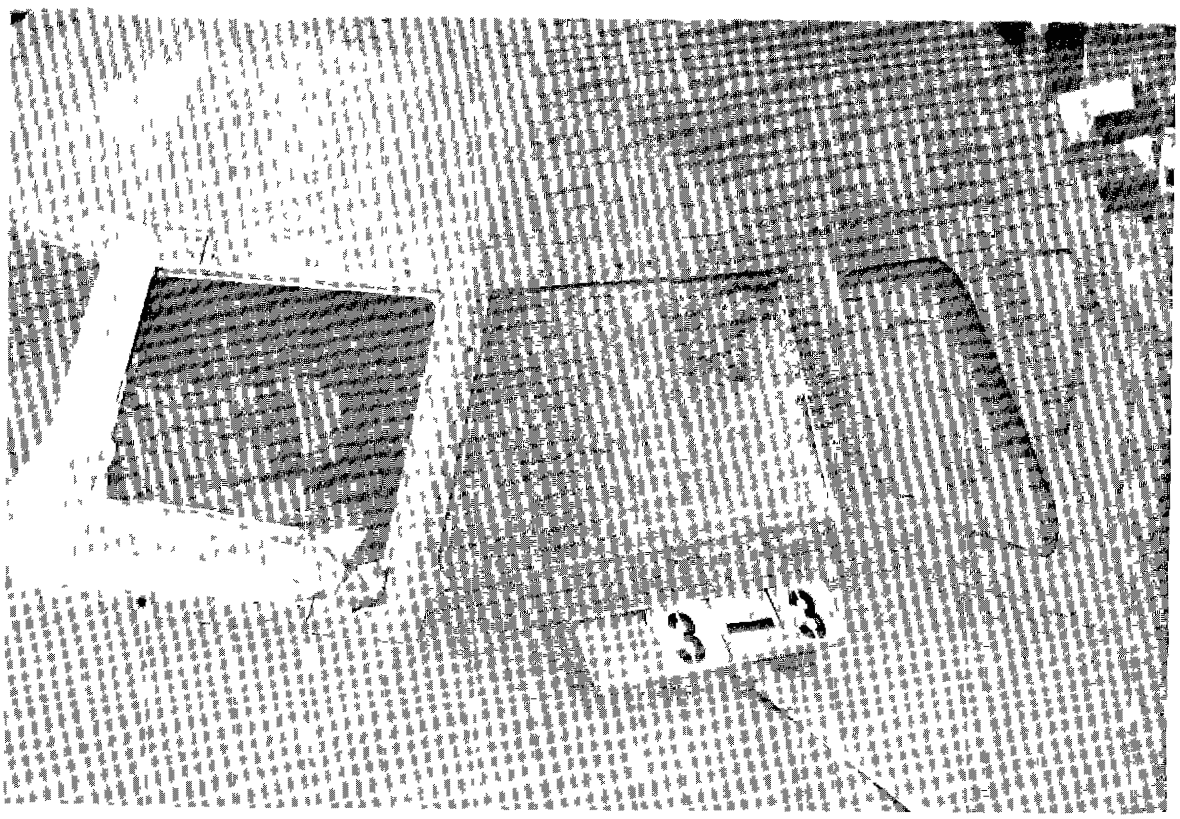


FIG 14 TEST NO 3 - EXTERIOR PANEL, PROJECTILE VELOCITY - 394 MPH

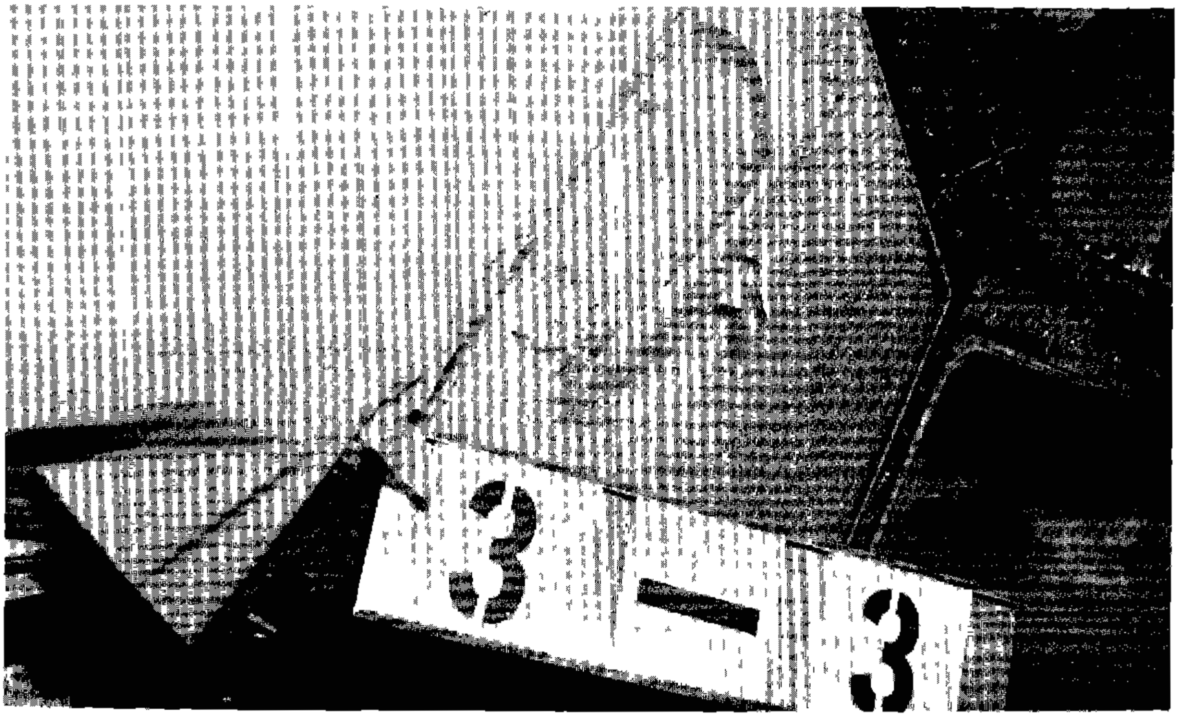


FIG. 15 TEST NO 3 - INTERIOR PANEL, PROJECTILE VELOCITY - 394 MPH

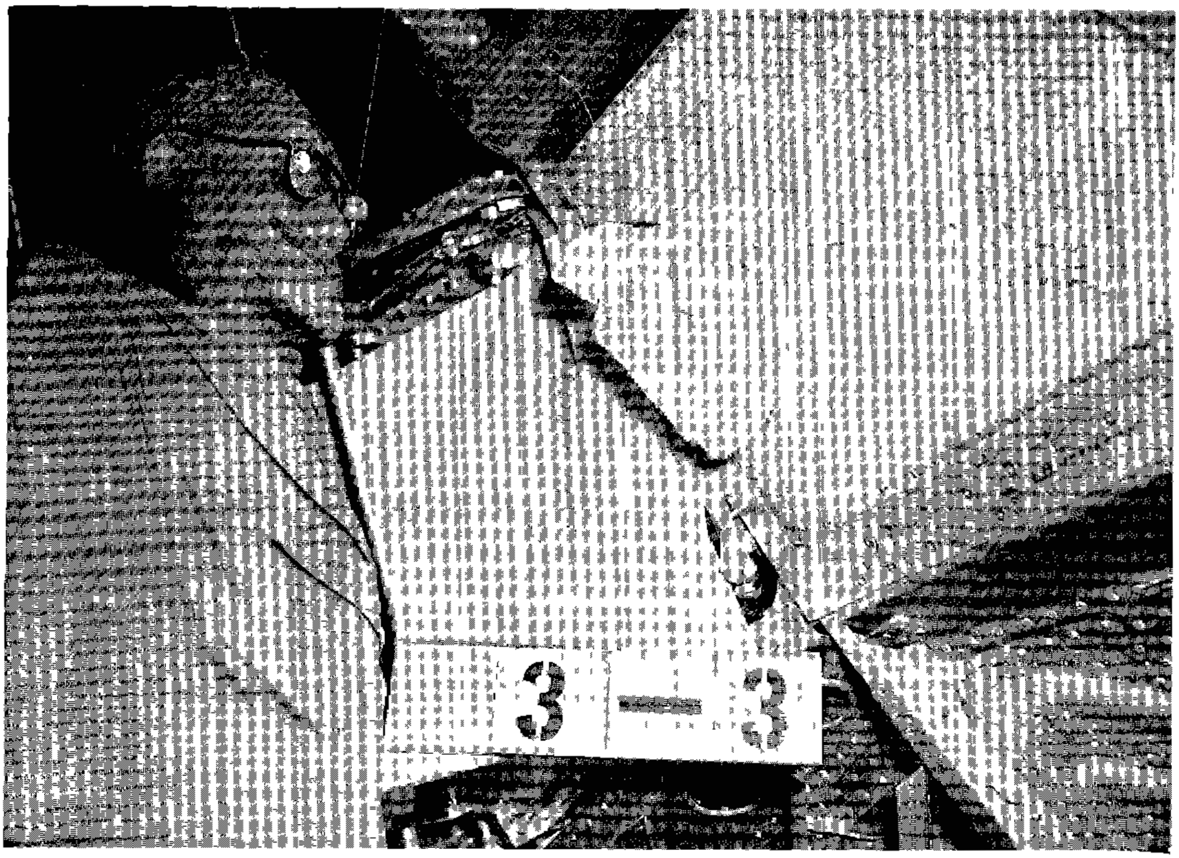


FIG 16 TEST NO 3 - PILOT, PROJECTILE VELOCITY - 394 MPH

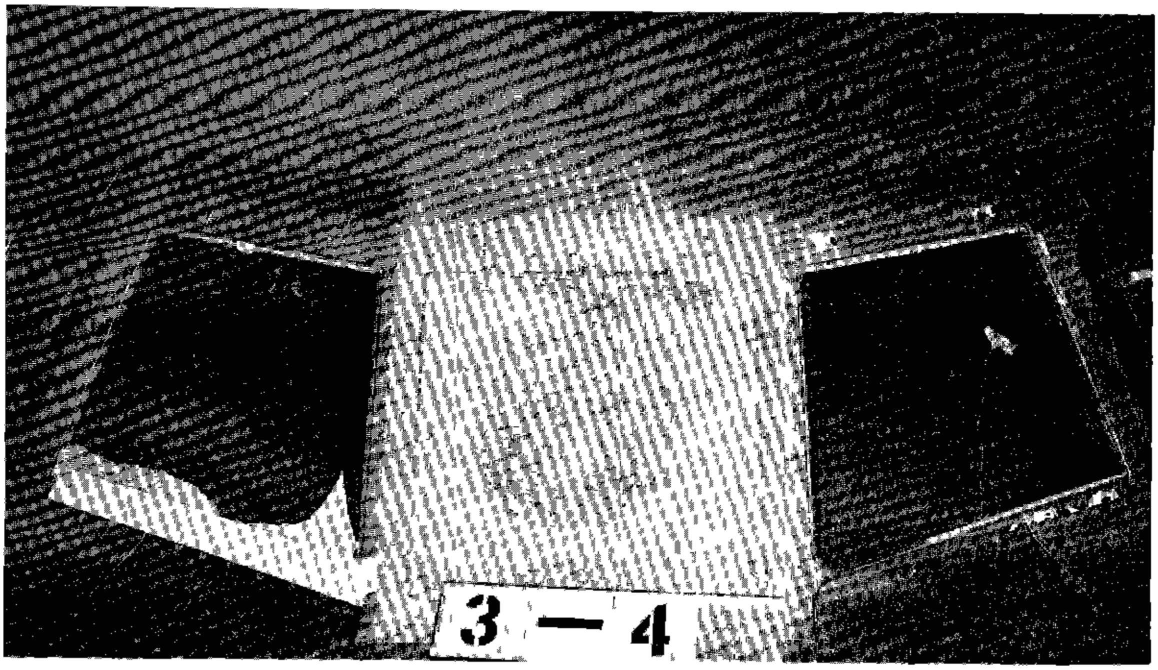


FIG 17 TEST NO 4 - EXTERIOR PANEL, PROJECTILE VELOCITY - 426 MPH

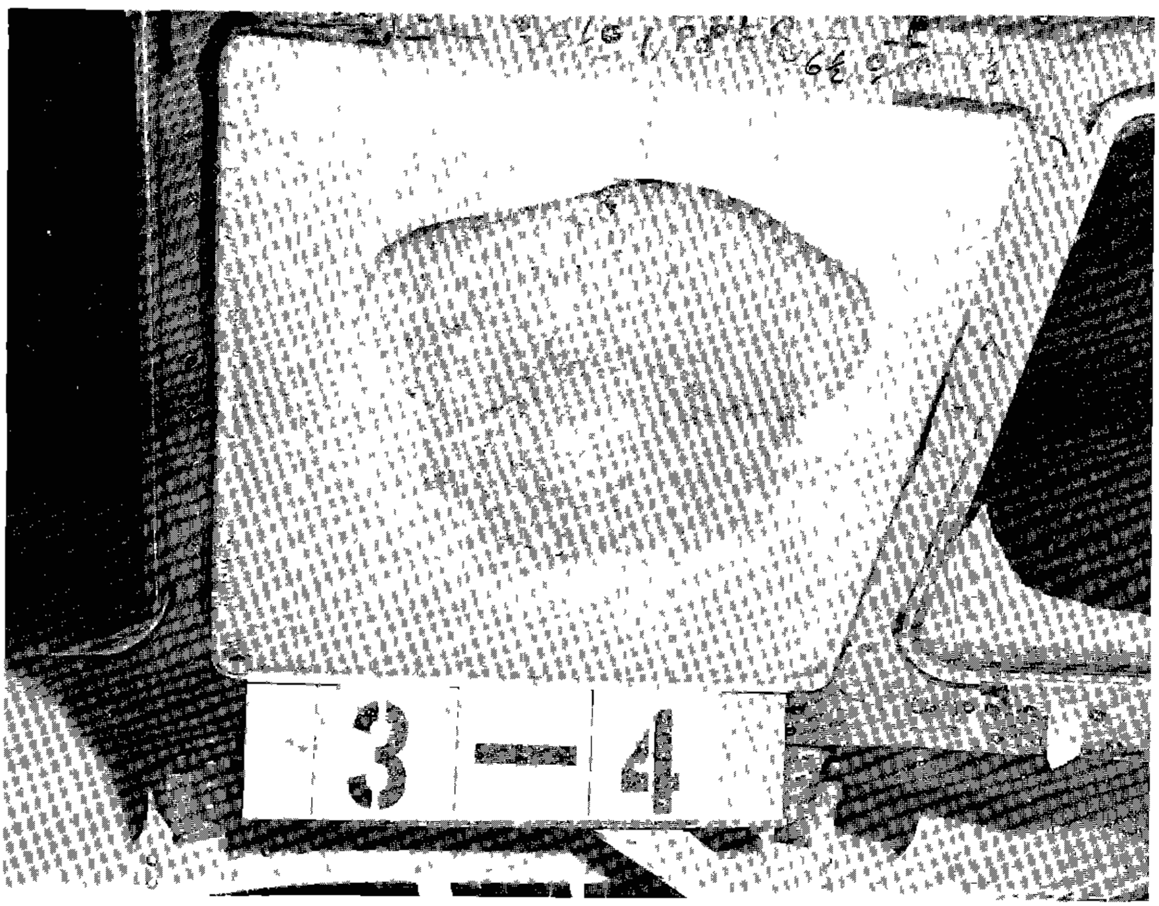


FIG 18 TEST NO 4 - INTERIOR PANEL, PROJECTILE VELOCITY - 426 MPH

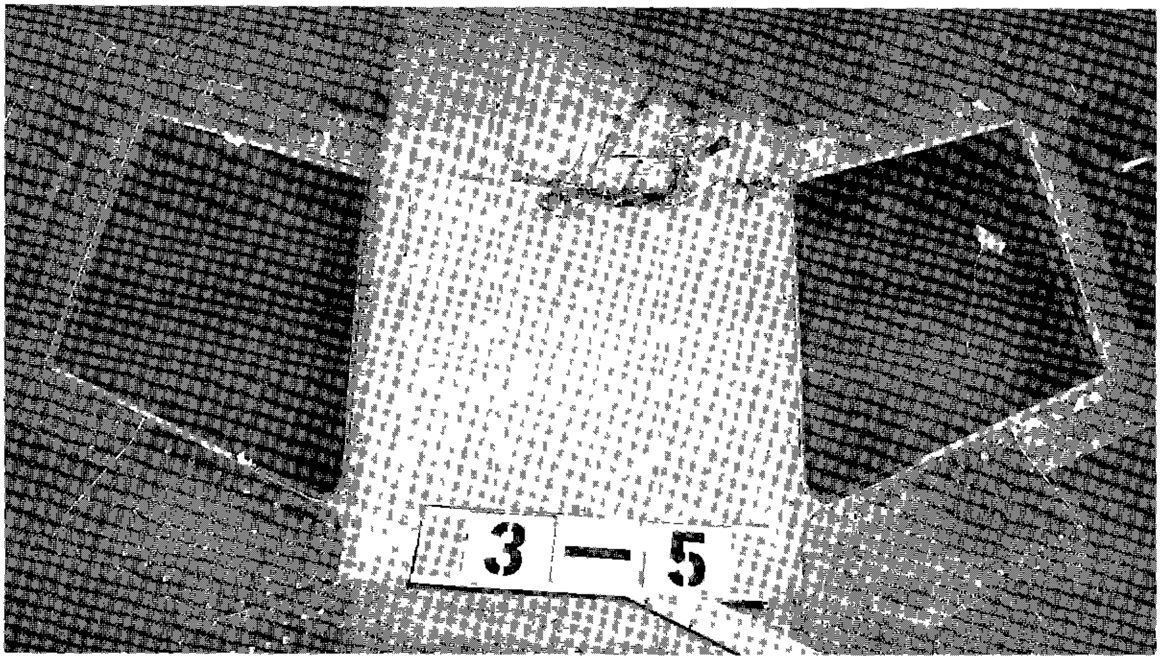


FIG 19 TEST NO 5 - EXTERIOR PANEL, PROJECTILE VELOCITY - 393 MPH

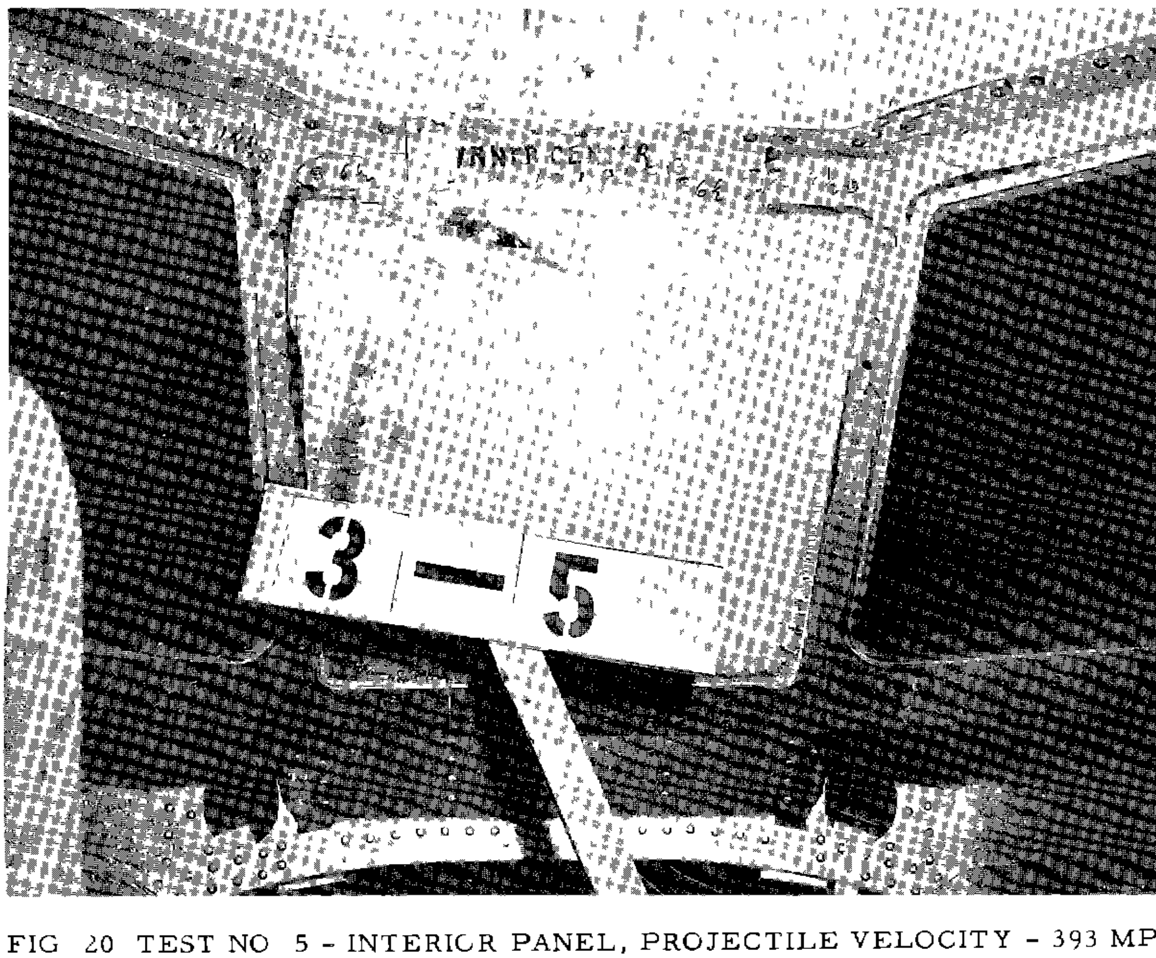


FIG 20 TEST NO 5 - INTERIOR PANEL, PROJECTILE VELOCITY - 393 MPH

FIG 21 TEST NO 5 - PILOT, PROJECTILE VELOCITY - 393 MPH

FIG 22 TEST NO 6 - INTERIOR PANEL, PROJECTILE VELOCITY - 405 MPH

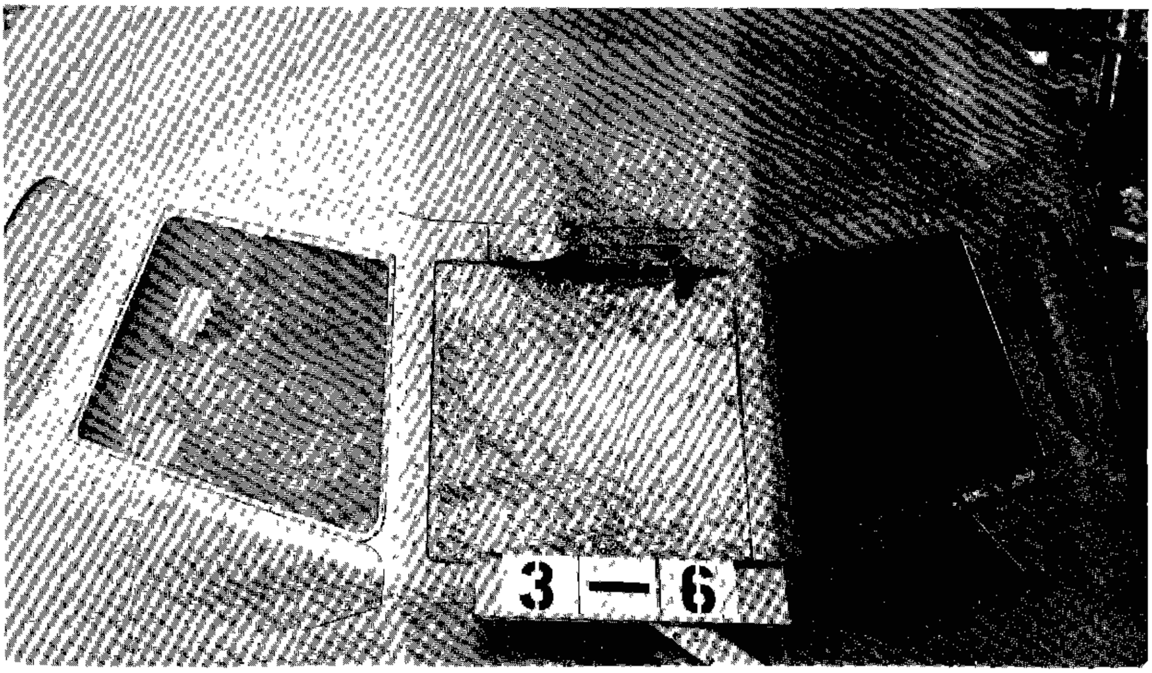


FIG 23 TEST NO 6 - EXTERIOR PANEL, PROJECTILE VELOCITY - 405 MPH

FIG 24 TEST NO 6 - PILOT, PROJECTILE VELOCITY - 405 MPH

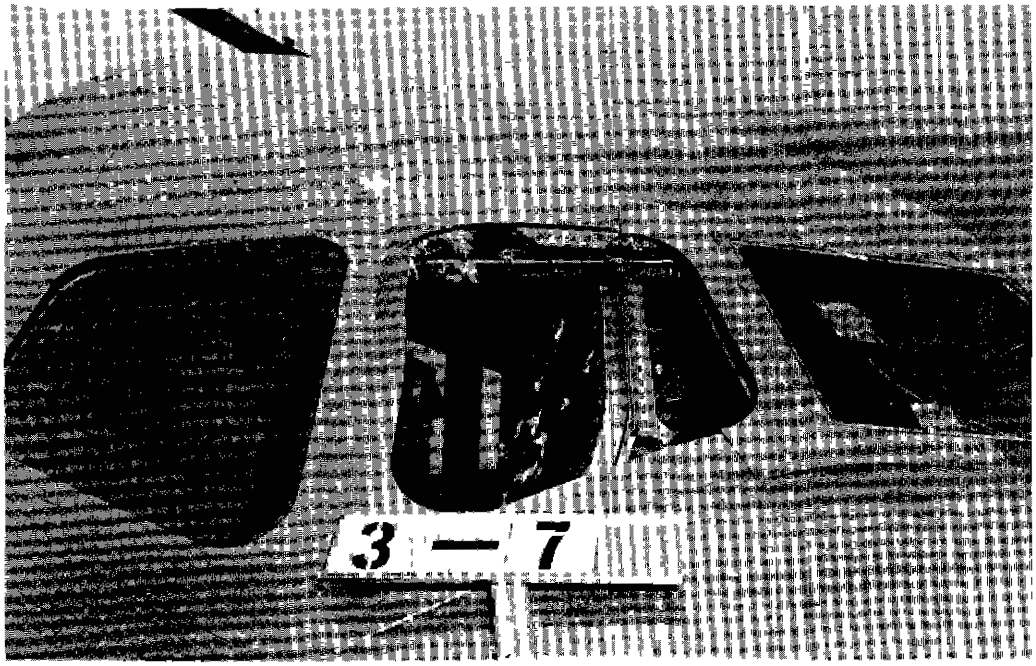


FIG 25 TEST NO. 7 - OUTSIDE COCKPIT, PROJECTILE VELOCITY - 400 MPH

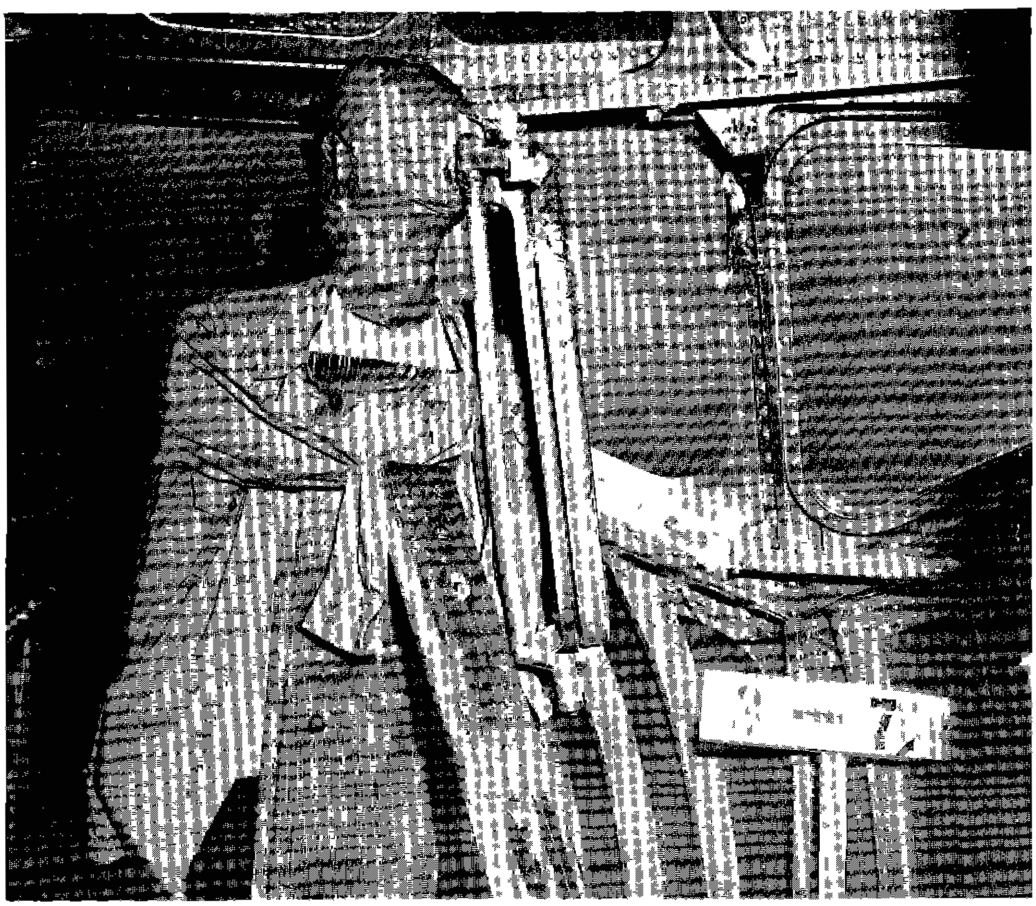


FIG 26 TEST NO 7 - INSIDE COCKPIT, PROJECTILE VELOCITY - 400 MPH

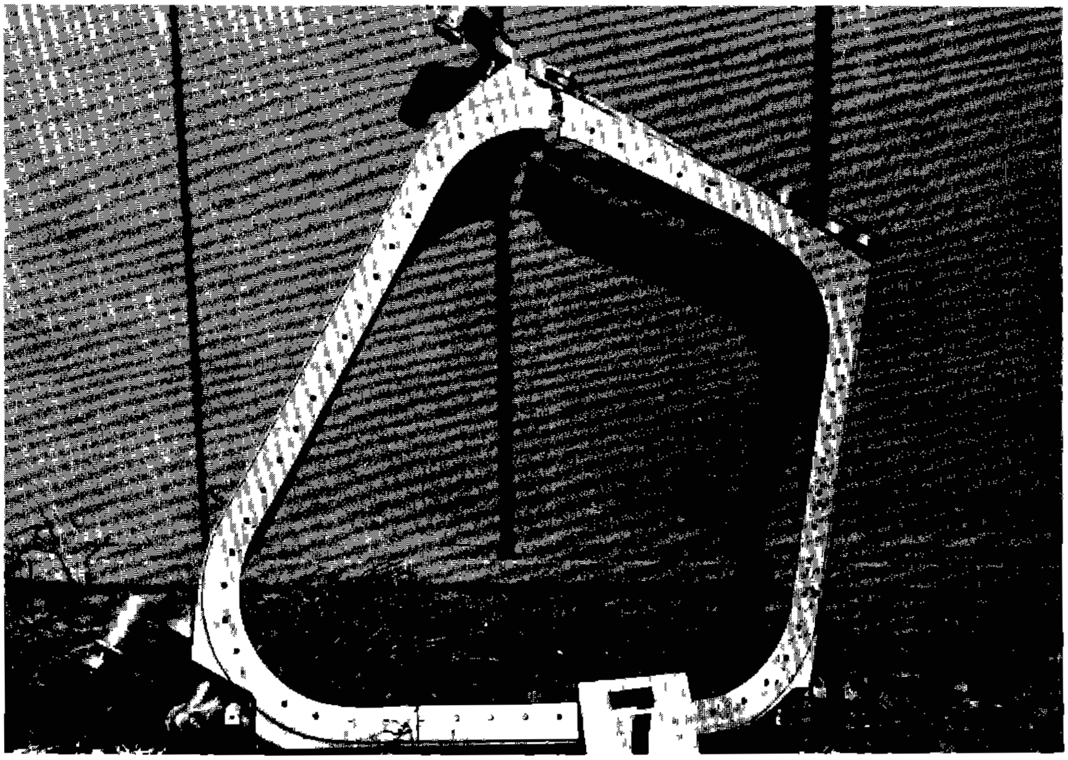


FIG 27 TEST NO 7 - WINDOW FRAME, PROJECTILE VELOCITY - 400 MPH

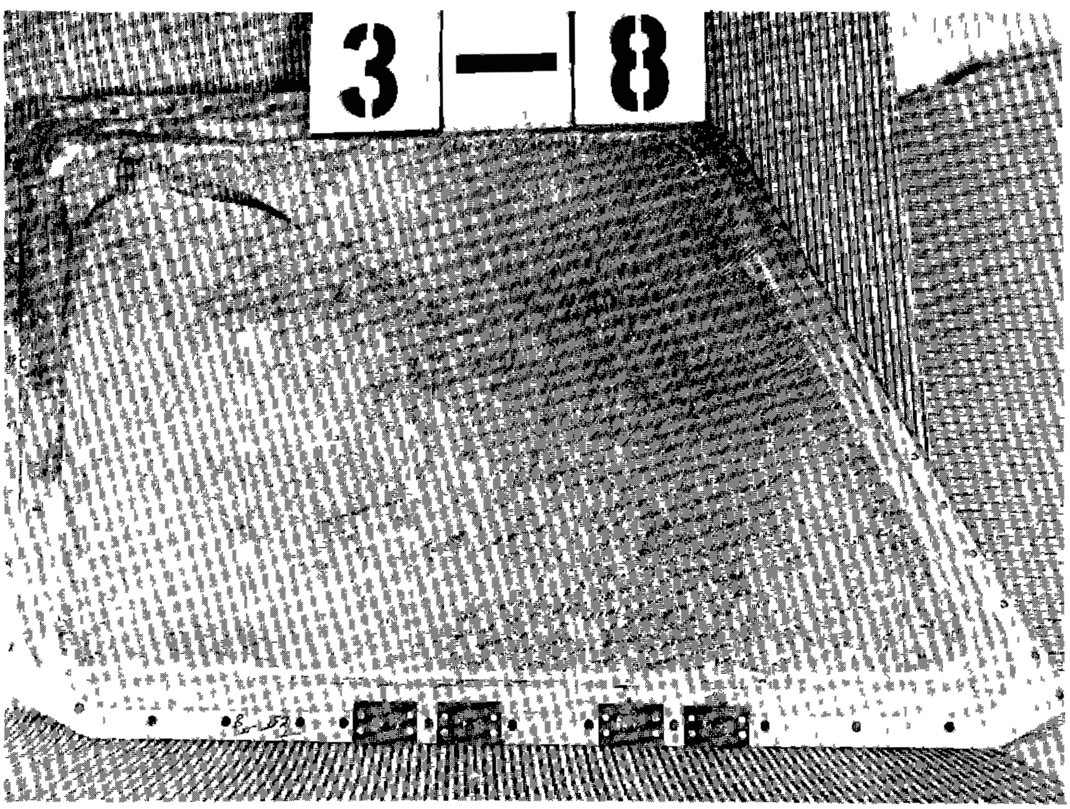


FIG 28 TEST NO 8 - EXTERIOR PANEL, PROJECTILE VELOCITY - 424 MPH

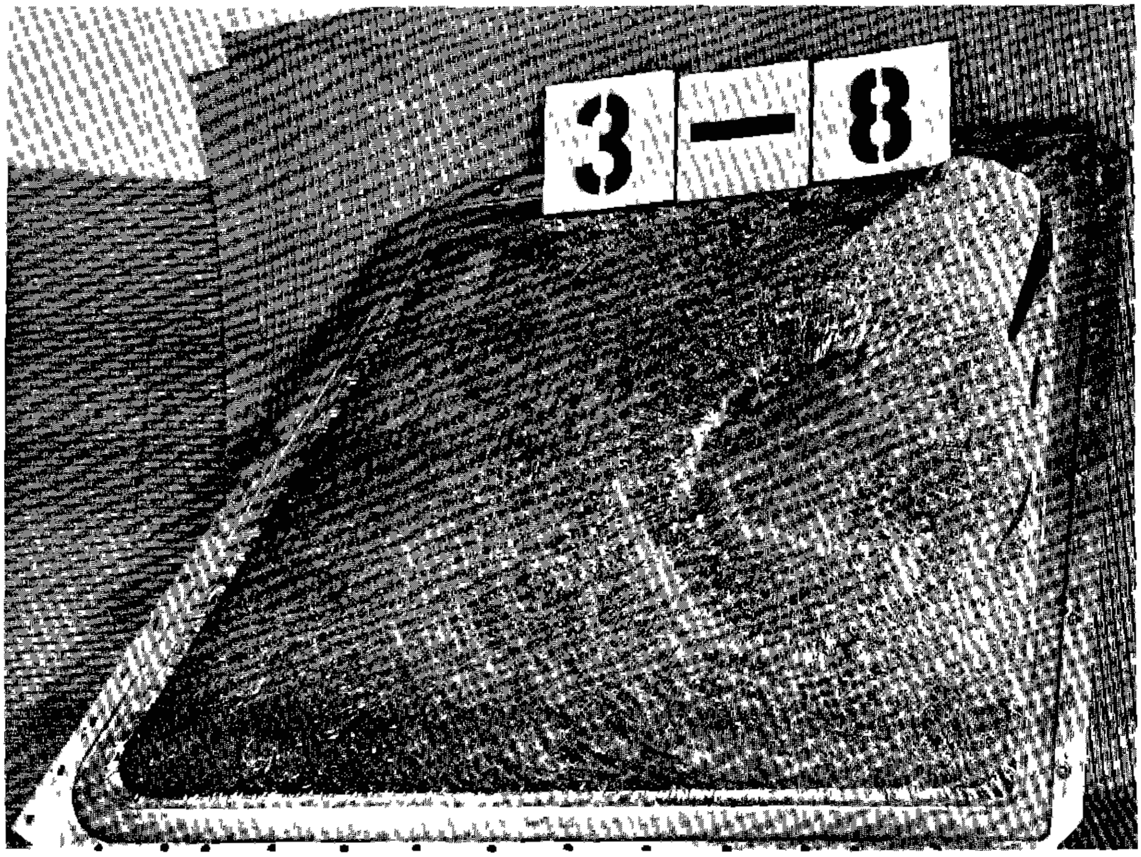


FIG 29 TEST NO 8 - INTERIOR PANEL, PROJECTILE VELOCITY - 424 MPH

FIG 30 TEST NO 8 - EXTERIOR PANEL AND COPILOT, PROJECTILE VELOCITY - 424 MPH

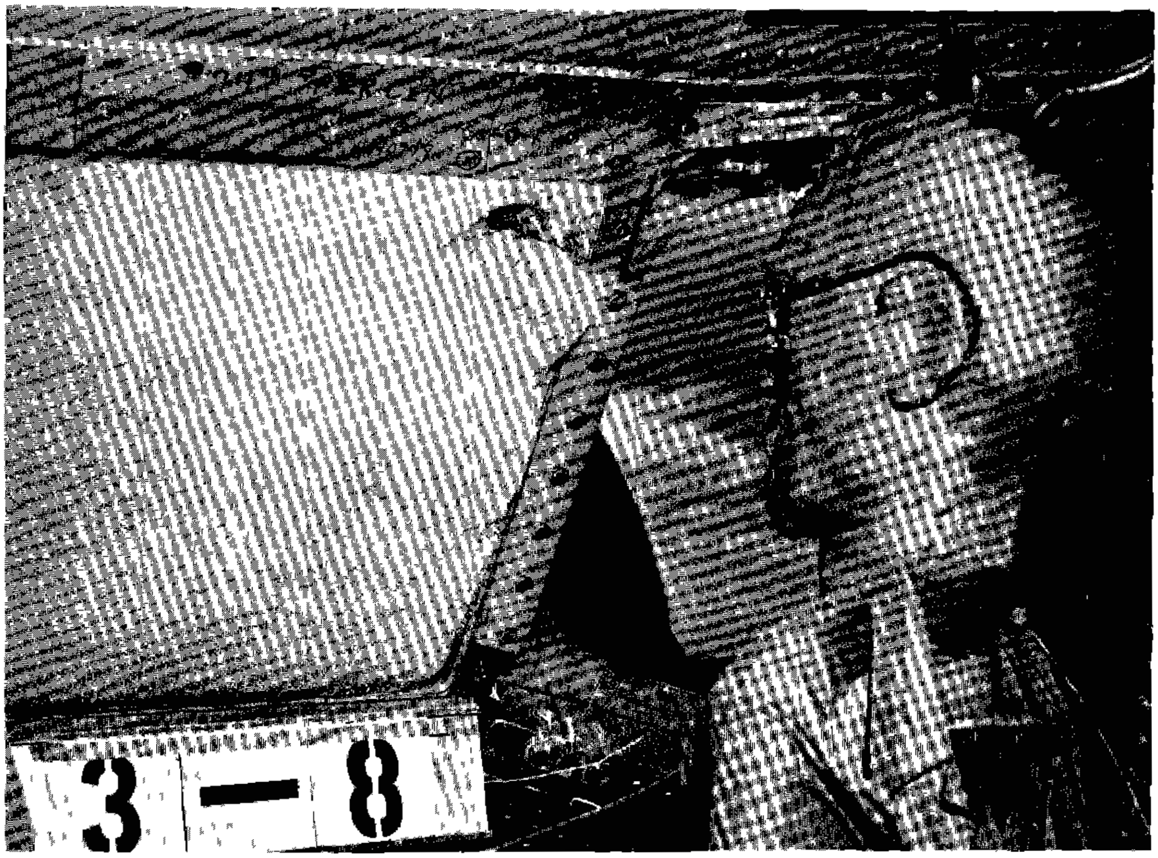


FIG 31 TEST NO 8 - INTERIOR PANEL AND COPILOT, PROJECTILE VELOCITY - 424 MPH

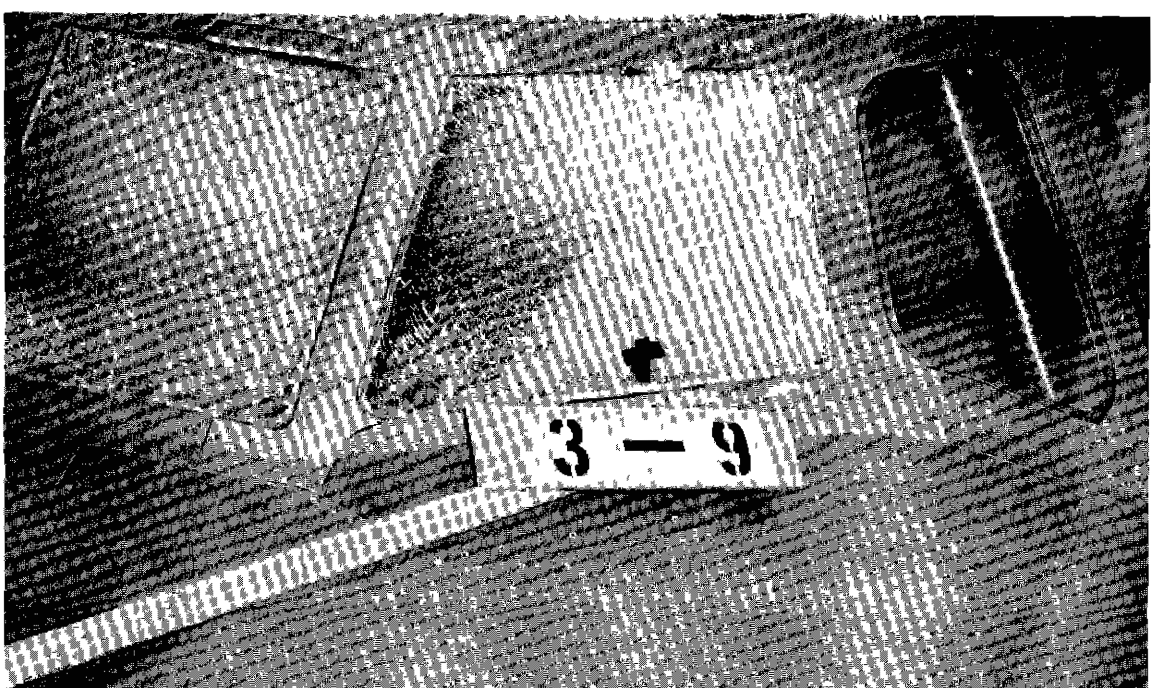


FIG 32 TEST NO 9 - EXTERIOR PANEL, PROJECTILE VELOCITY - 425 MPH

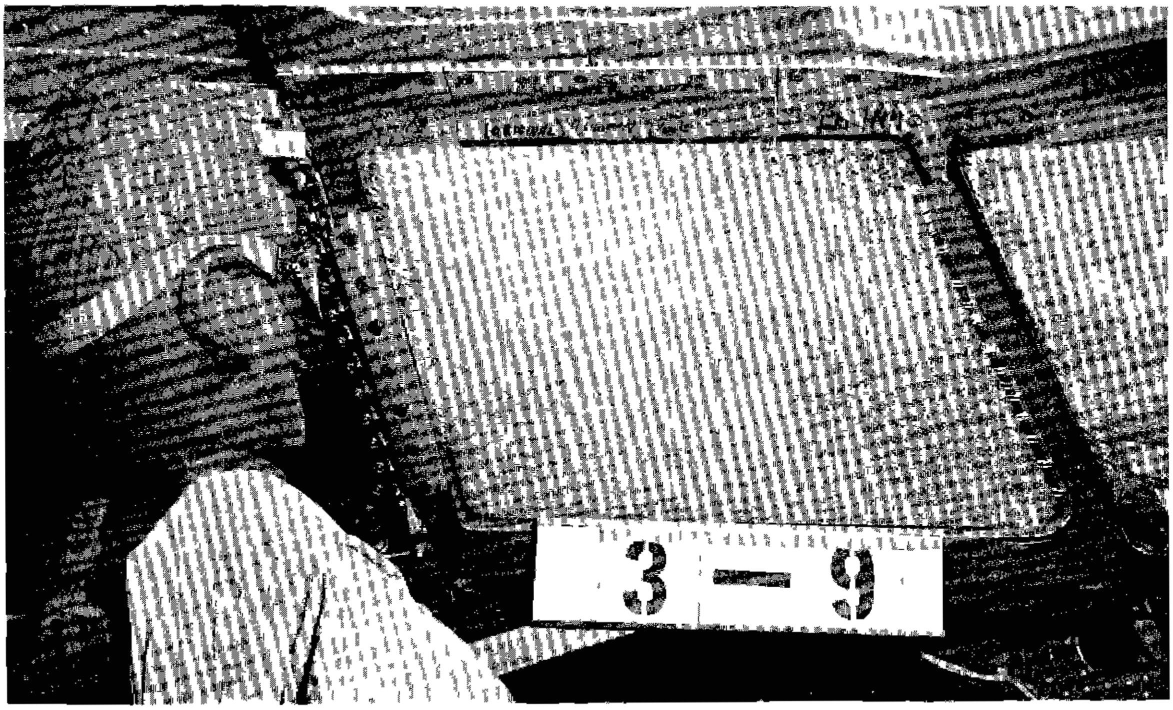


FIG. 33 TEST NO 9 - INTERIOR PANEL, PROJECTILE VELOCITY - 425 MPH

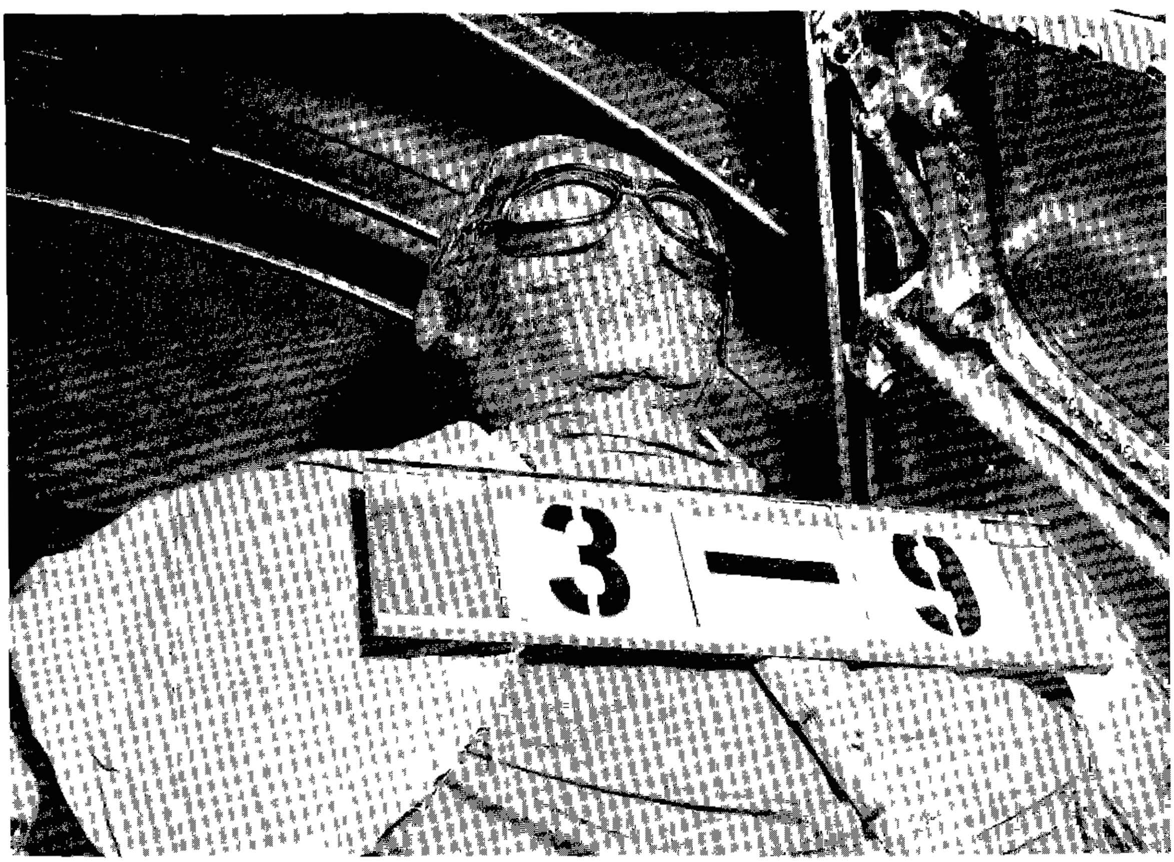


FIG. 34 TEST NO 9 - PILOT, PROJECTILE VELOCITY - 425 MPH

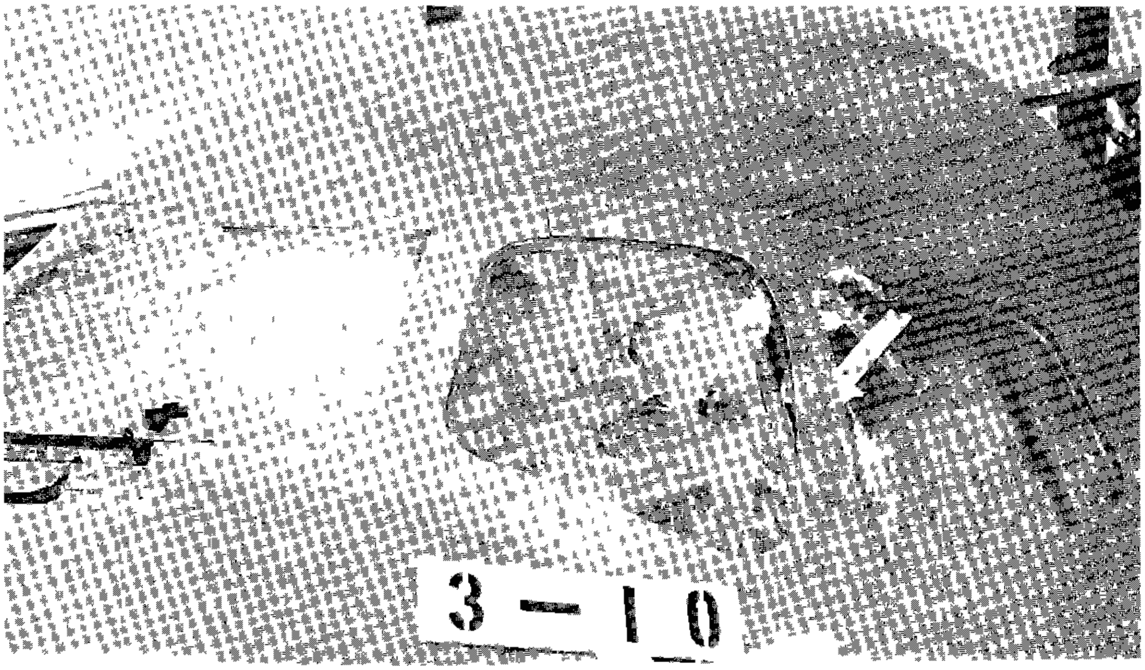


FIG 35 TEST NO 10 - EXTERIOR PANEL, PROJECTILE VELOCITY - 395 MPH

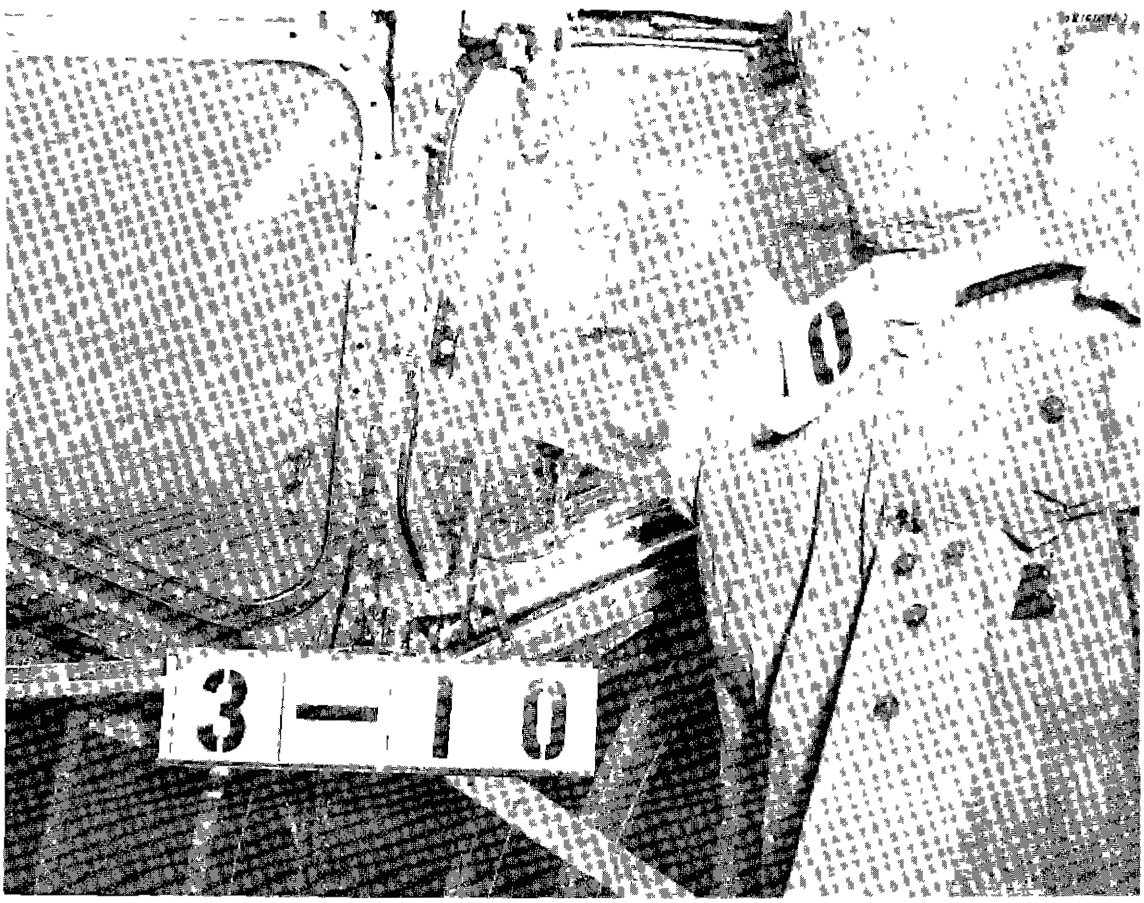


FIG. 36 TEST NO 10 - INTERIOR PANEL, PROJECTILE VELOCITY - 395 MPH

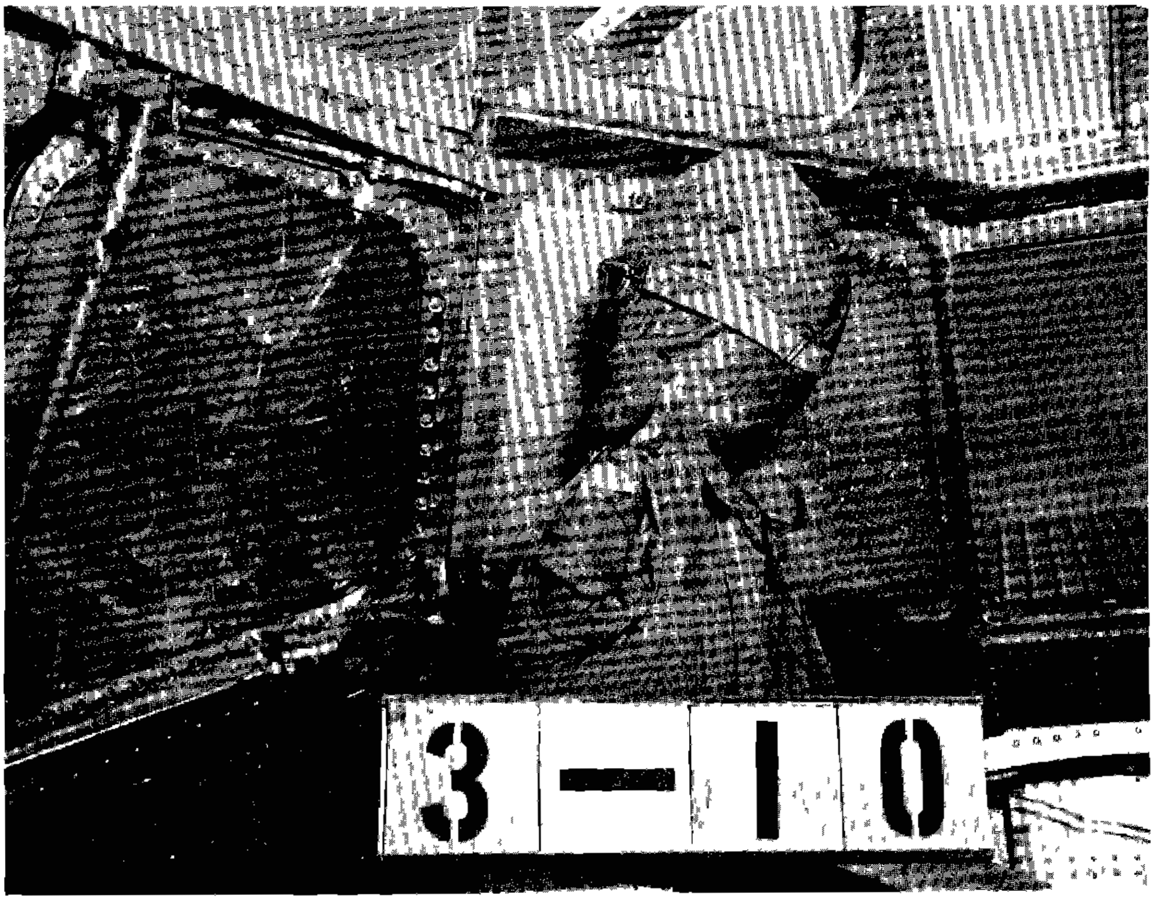


FIG. 37 TEST NO 10 - PILOT, PROJECTILE VELOCITY - 395 MPH

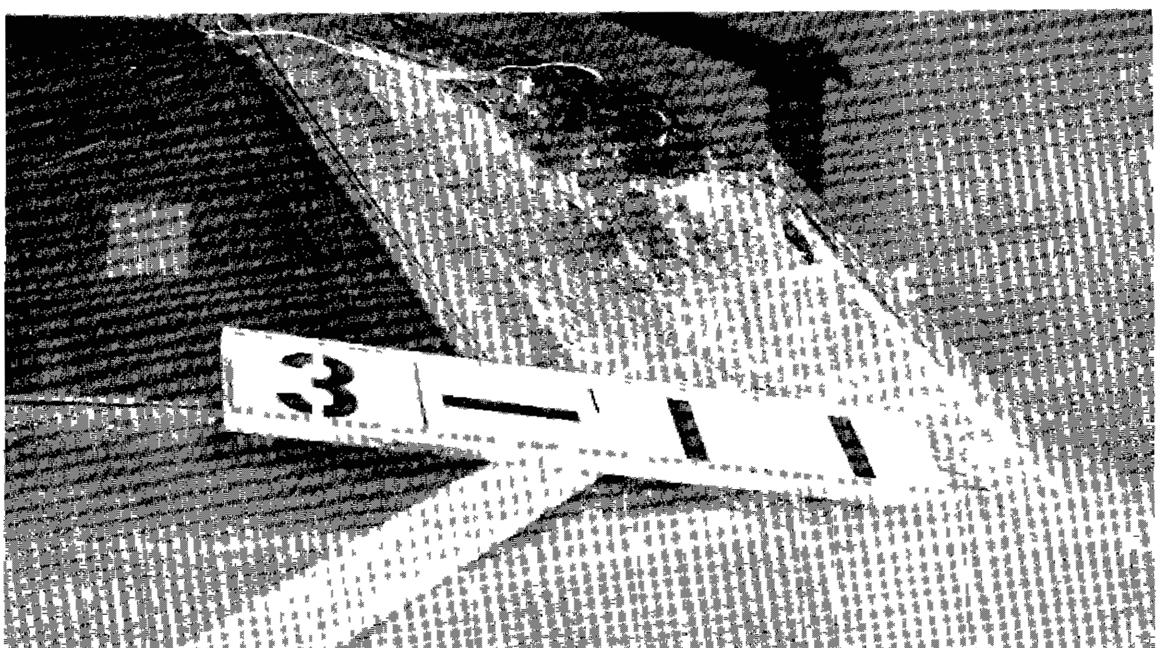


FIG 38 TEST NO 11 - EXTERIOR PANEL, PROJECTILE VELOCITY - 444 MPH

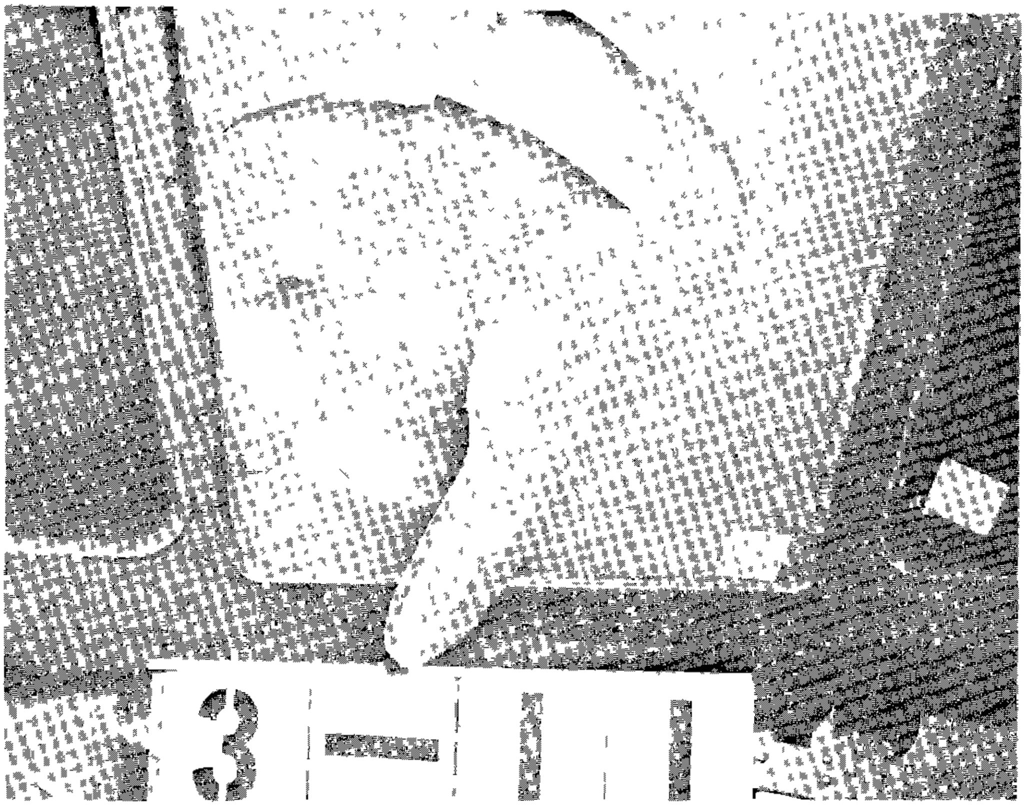


FIG 39 TEST NO 11 - INTERIOR PANEL, PROJECTILE VELOCITY - 444 MPH

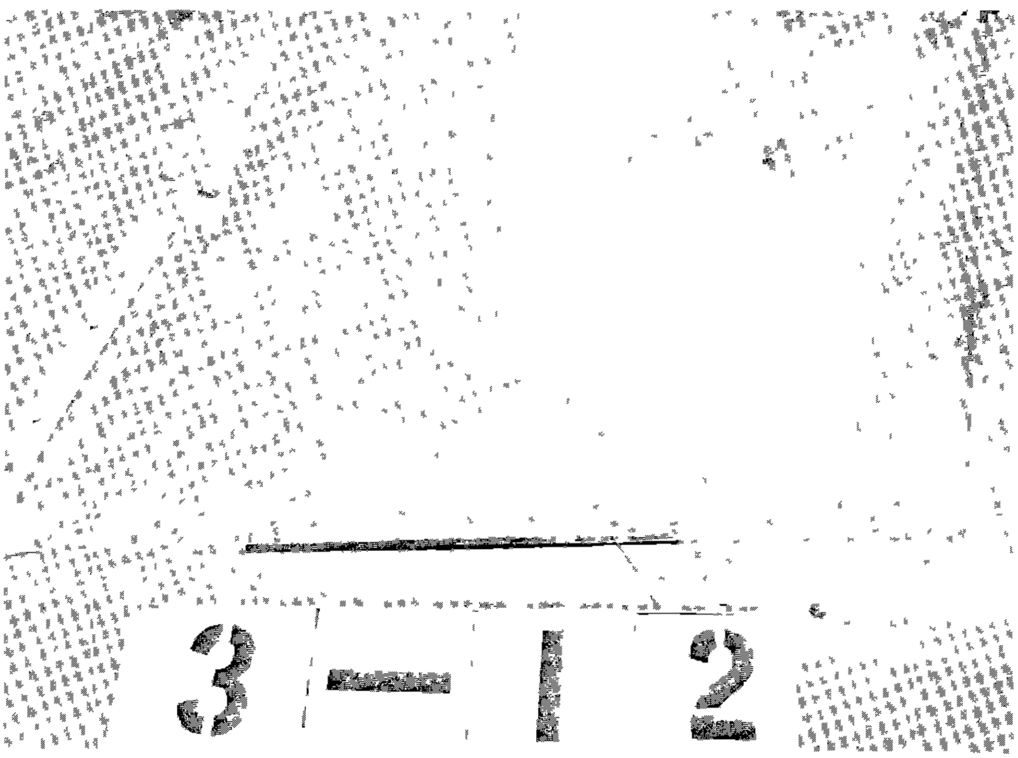


FIG 40 TEST NO 12 - EXTERIOR PANEL, PROJECTILE VELOCITY - 448 MPH

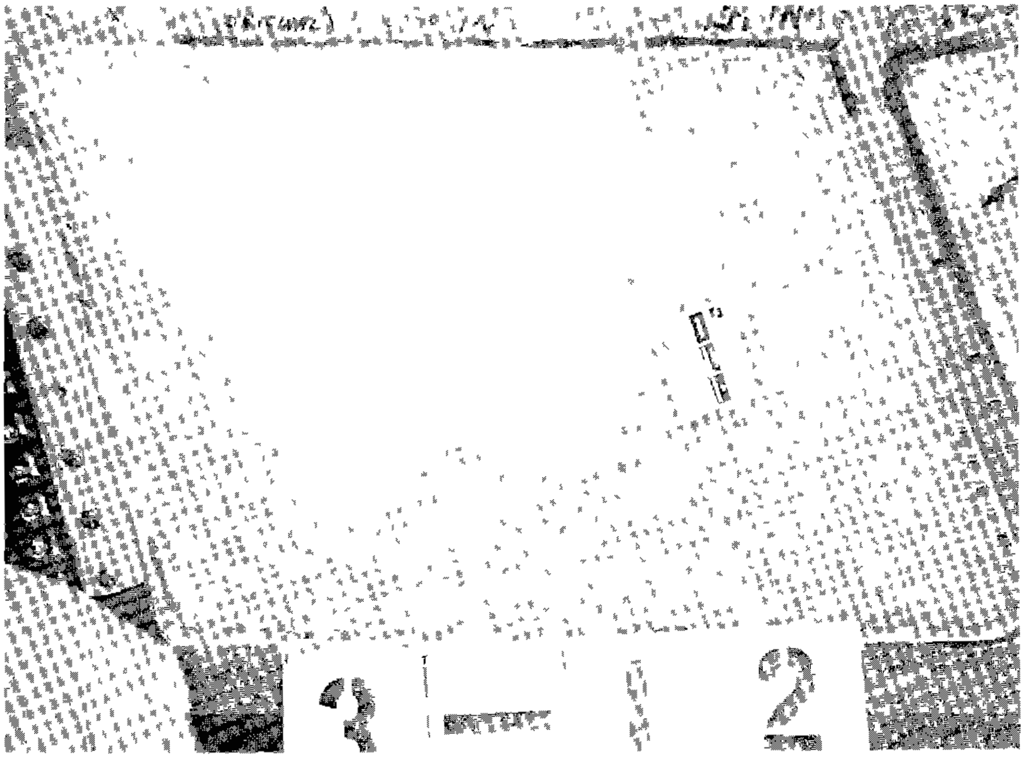


FIG 41 TEST NO 12 - INTERIOR PANEL, PROJECTILE VELOCITY - 448 MPH

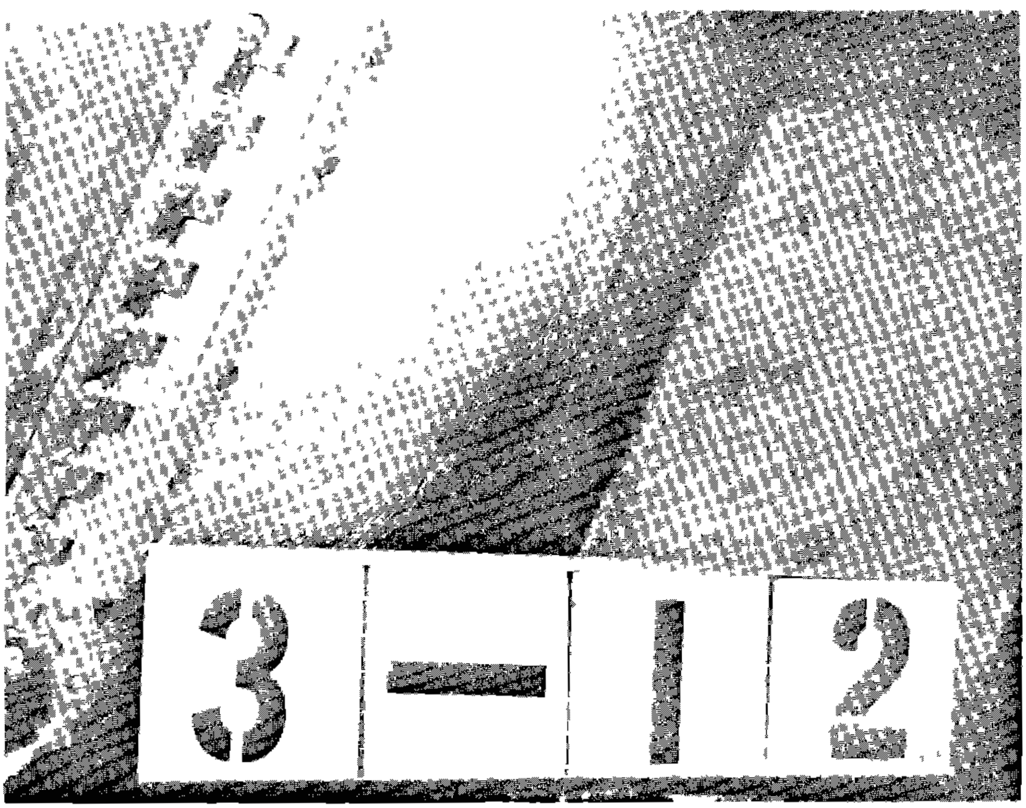


FIG 42 TEST NO 12 - INTERIOR PANEL , PROJECTILE VELOCITY - 448 MPH

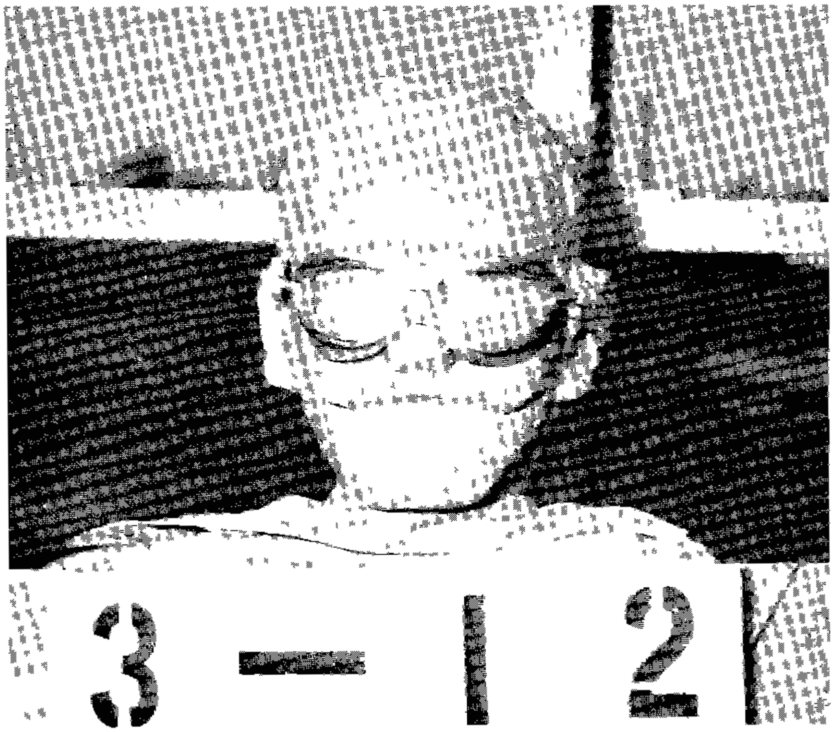


FIG 43 TEST NO 12 - PILOT, PROJECTILE VELOCITY - 448 MPH

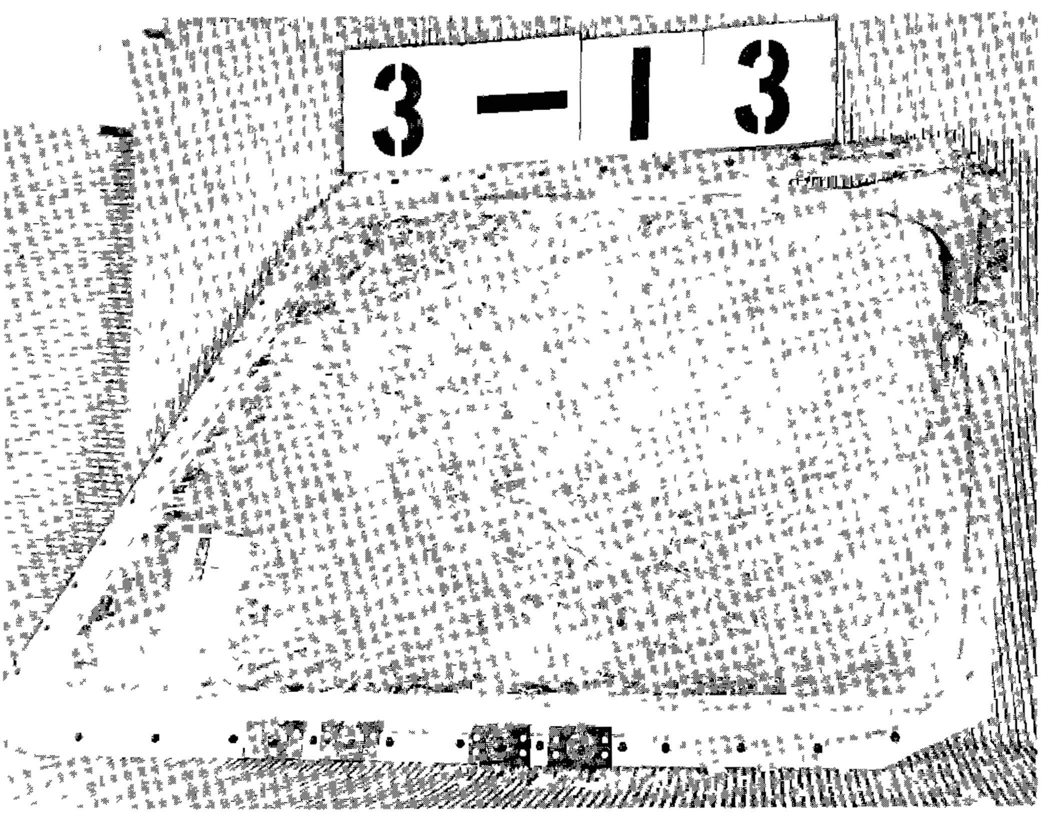


FIG 44 TEST NO 13 - EXTERIOR PANEL, PROJECTILE VELOCITY - 482 MPH

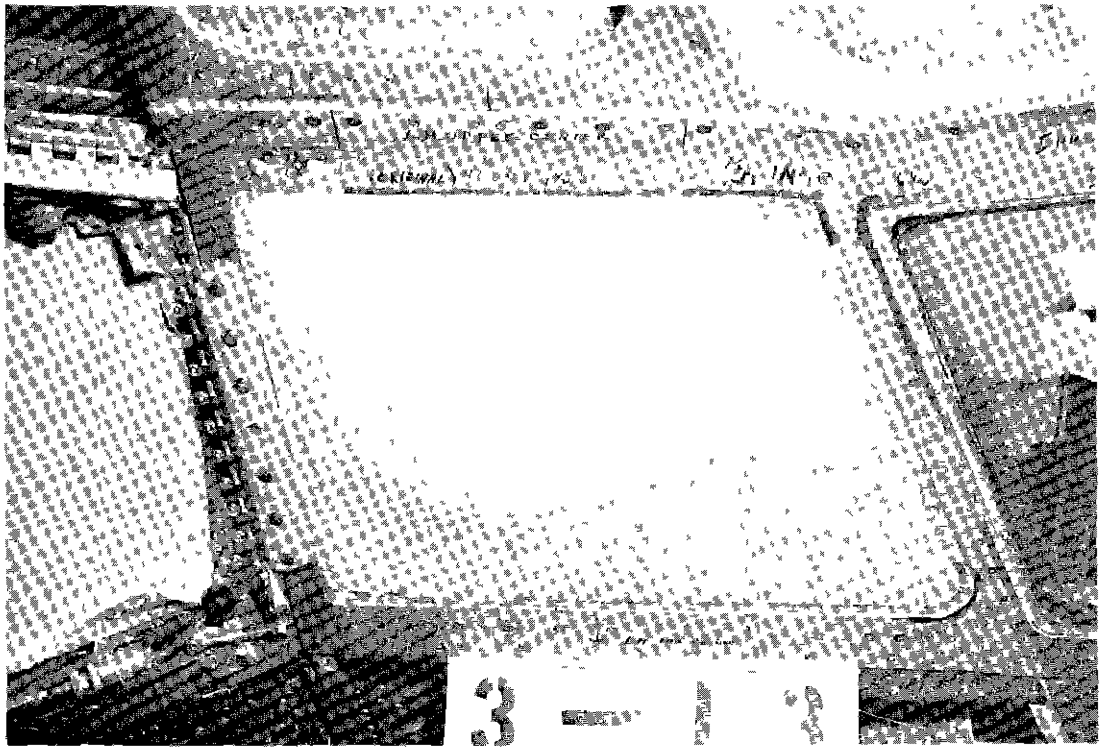


FIG 45 TEST NO 13 - INTERIOR PANEL, PROJECTILE VELOCITY - 482 MPH

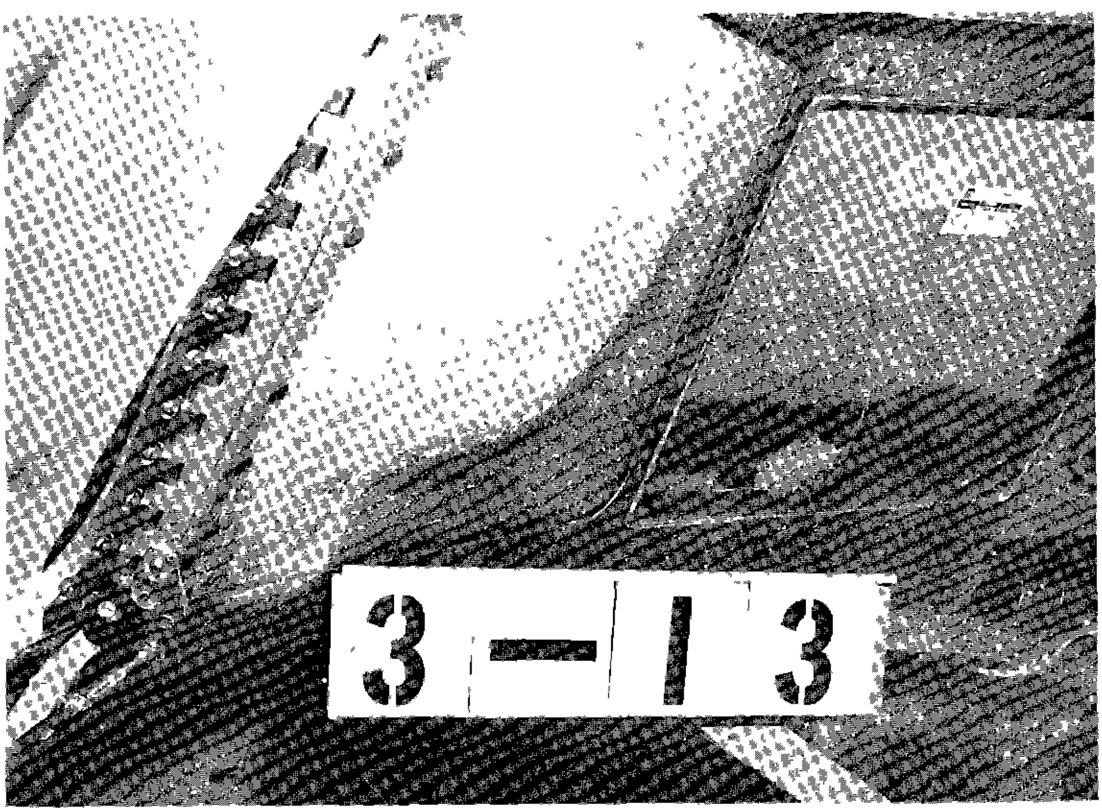


FIG. 46 TEST NO 13 - INTERIOR PANEL, PROJECTILE VELOCITY - 482 MPH

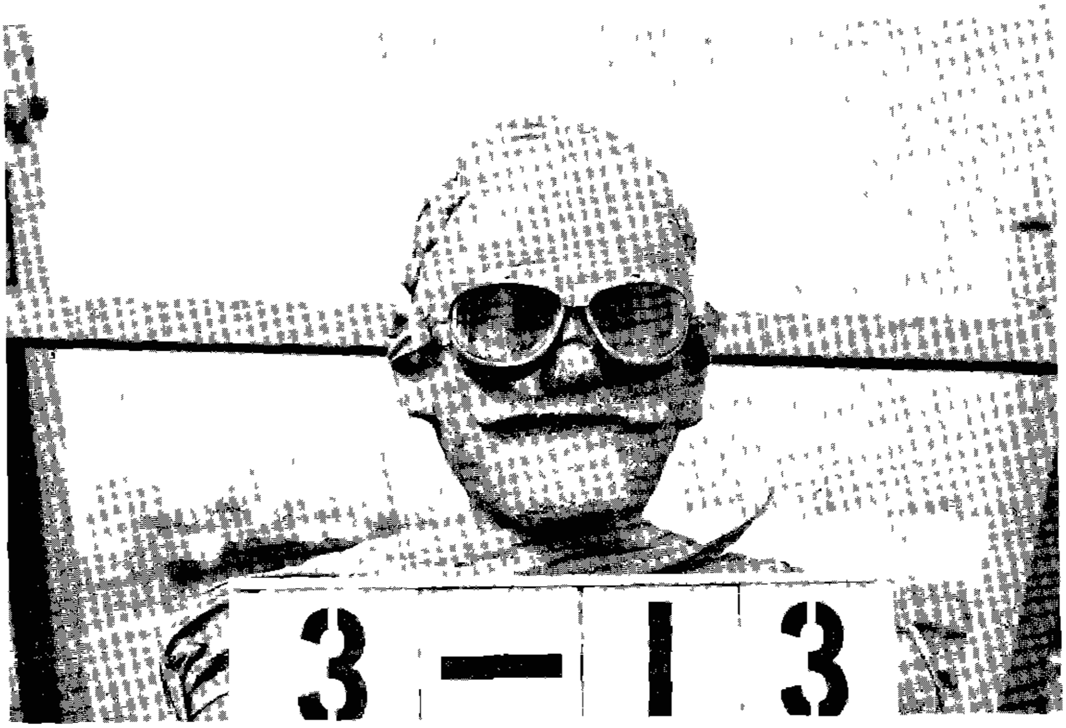


FIG 47 TEST NO. 13 - PILOT, PROJECTILE VELOCITY - 482 MPH

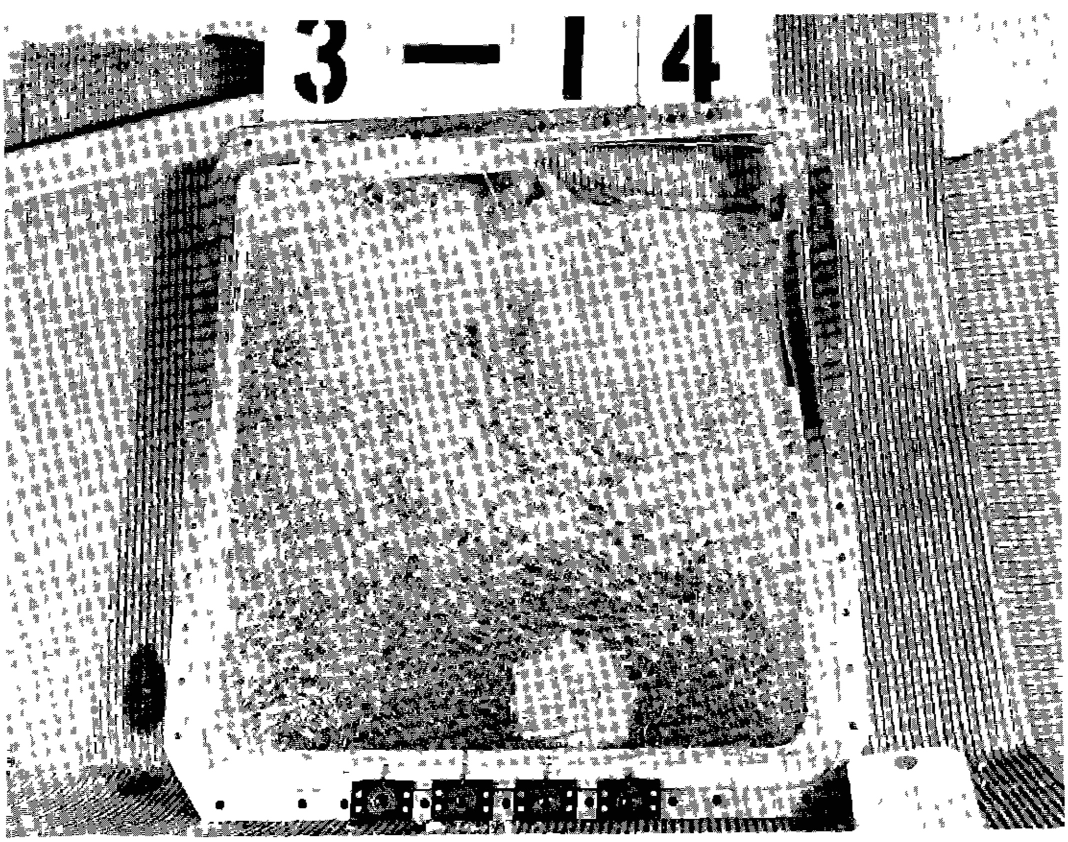


FIG 48 TEST NO 14 - EXTERIOR PANEL, PROJECTILE VELOCITY - 466 MPH

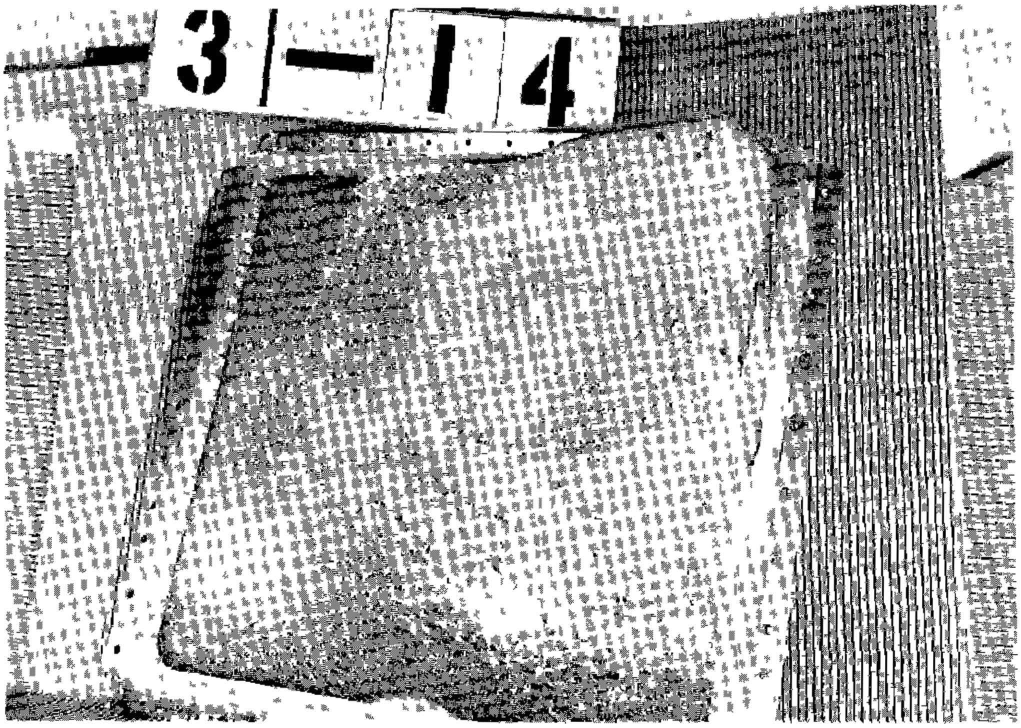


FIG. 49 TEST NO 14 - INTERIOR PANEL, PROJECTILE VELOCITY - 466 MPH

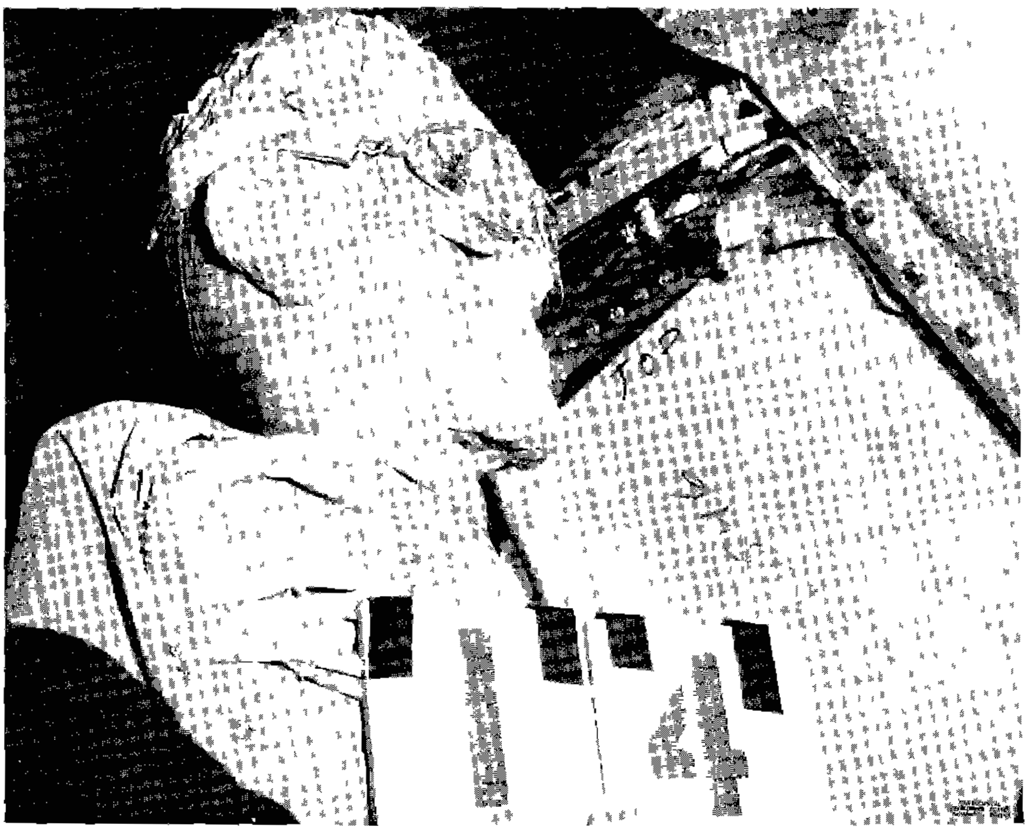


FIG 50 TEST NO 14 - PILOT, PROJECTILE VELOCITY - 466 MPH

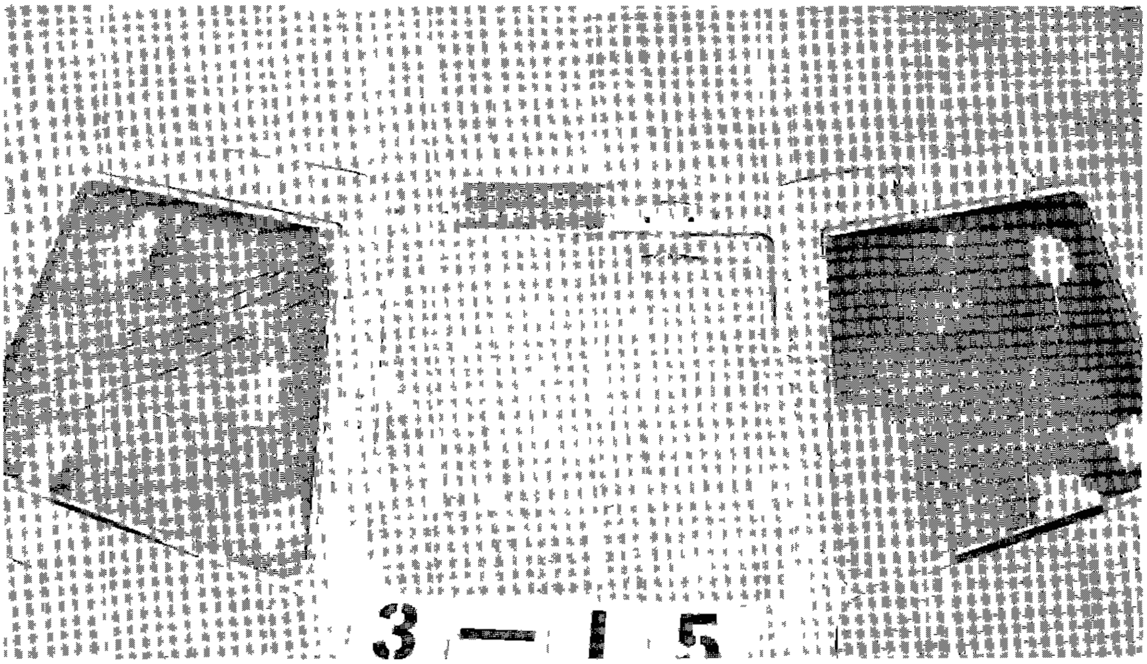


FIG 51 TEST NO 15 - EXTERIOR PANEL, PROJECTILE VELOCITY - 460 MPH

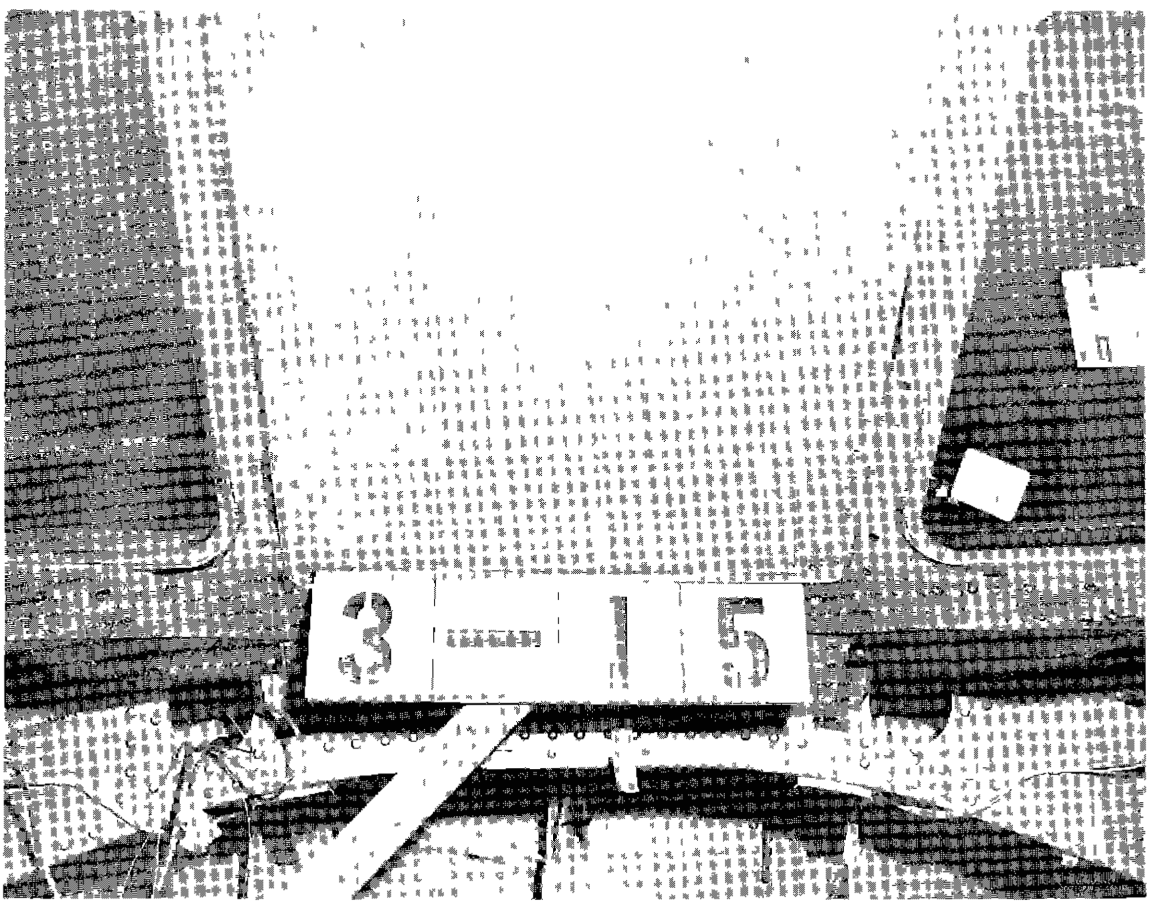


FIG 52 TEST NO 15 - INTERIOR PANEL, PROJECTILE VELOCITY - 460 MPH

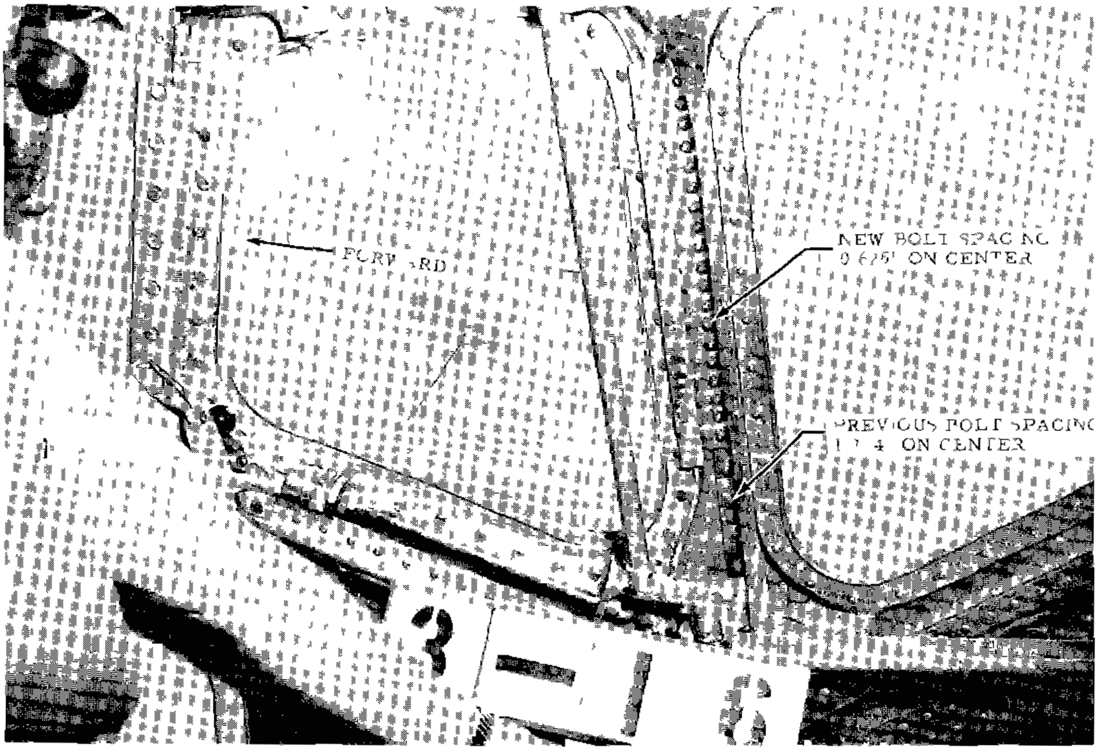


FIG. 53 TEST NO 16 - CLEAR-VIEW WINDOW PRIOR TO TEST

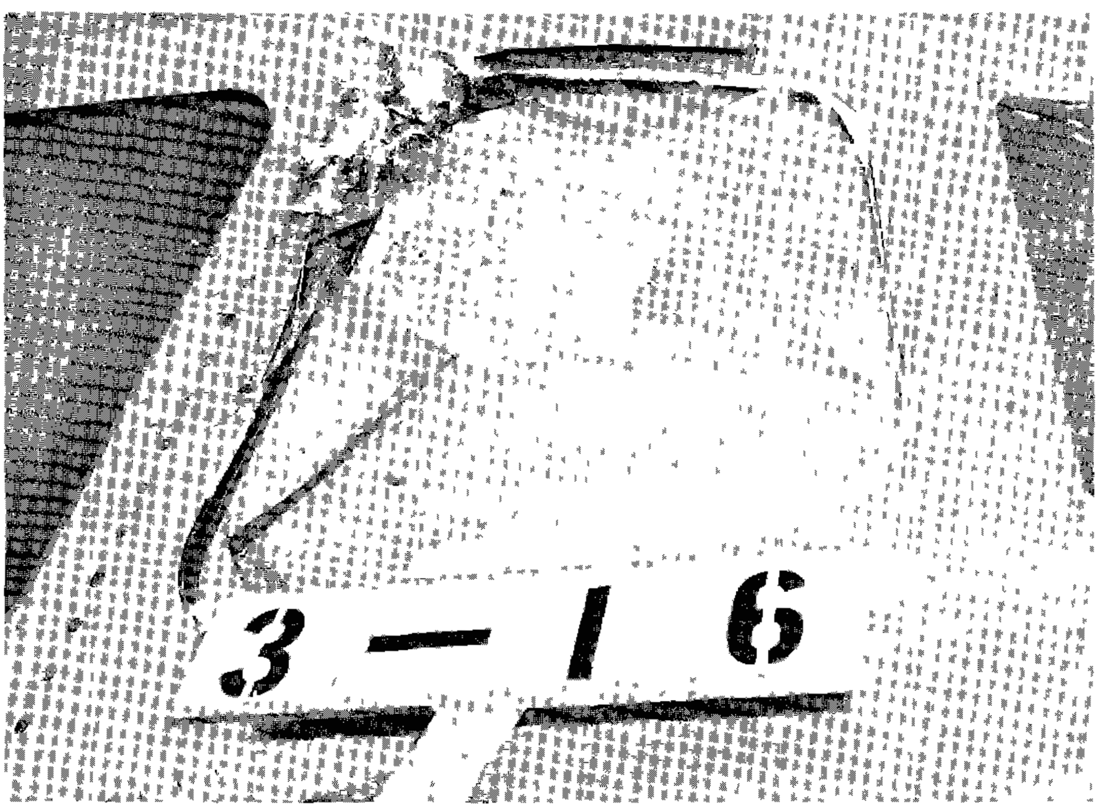


FIG 54 TEST NO 16 - EXTERIOR PANEL, PROJECTILE VELOCITY - 404 MPH

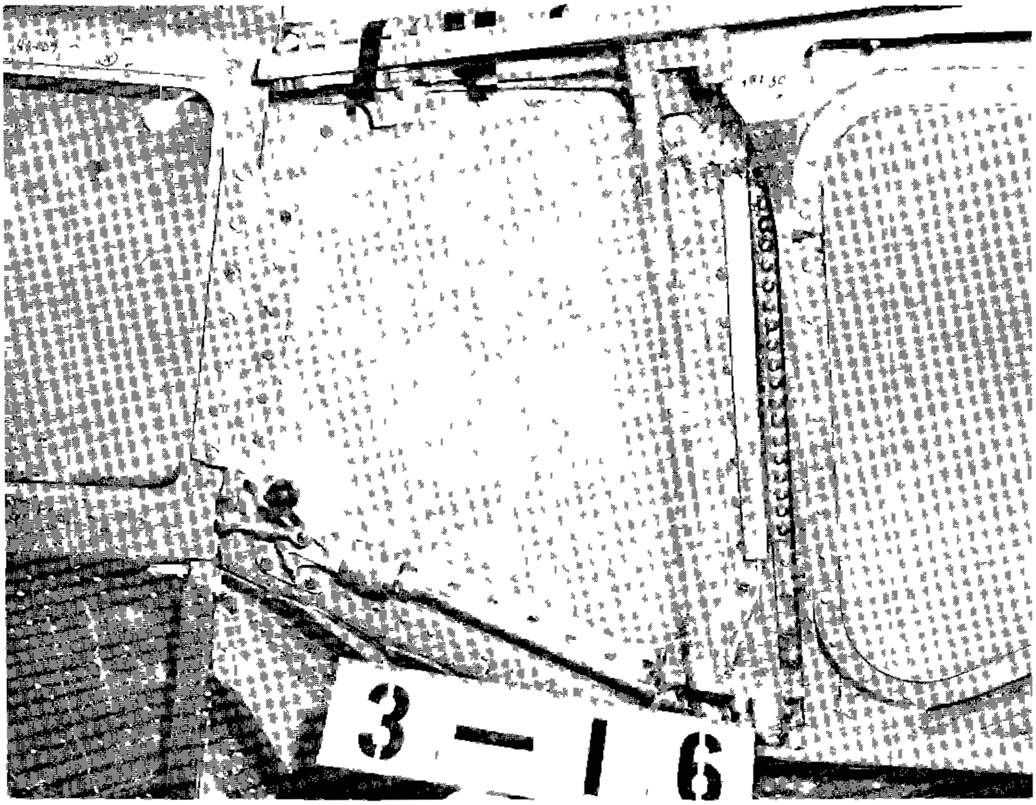


FIG 55 TEST NO 16 - INTERIOR PANEL, PROJECTILE VELOCITY - 404 MPH

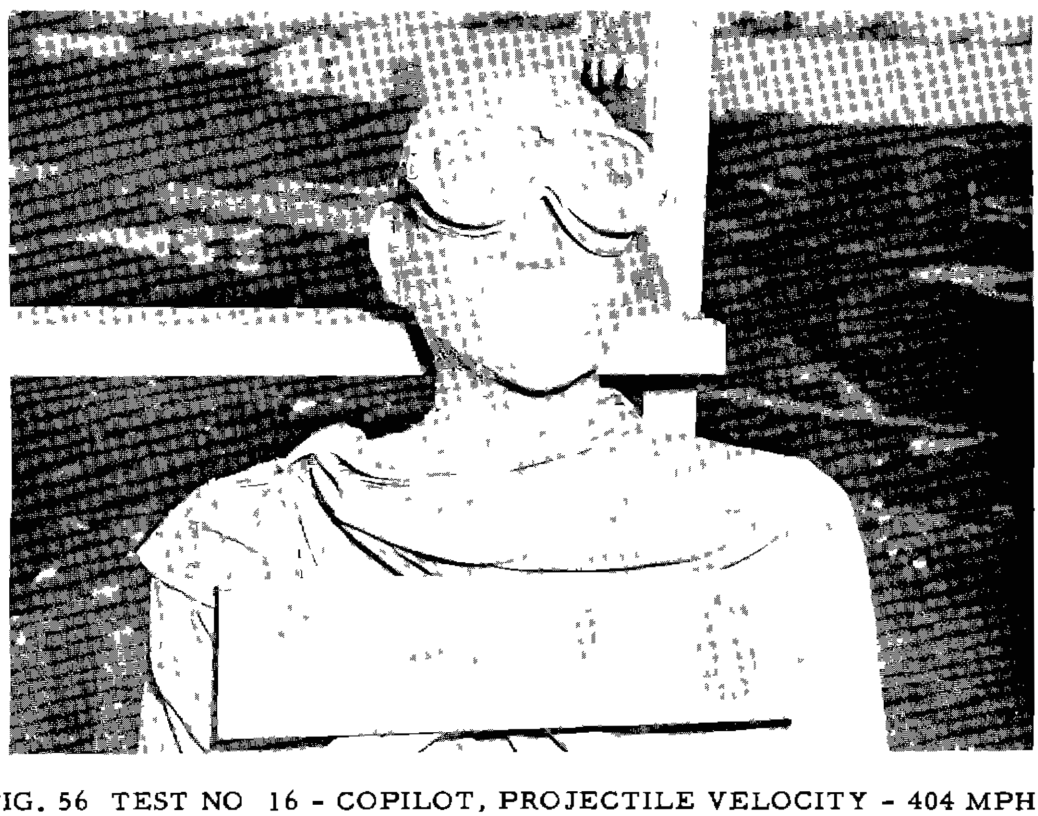


FIG. 56 TEST NO 16 - COPILOT, PROJECTILE VELOCITY - 404 MPH

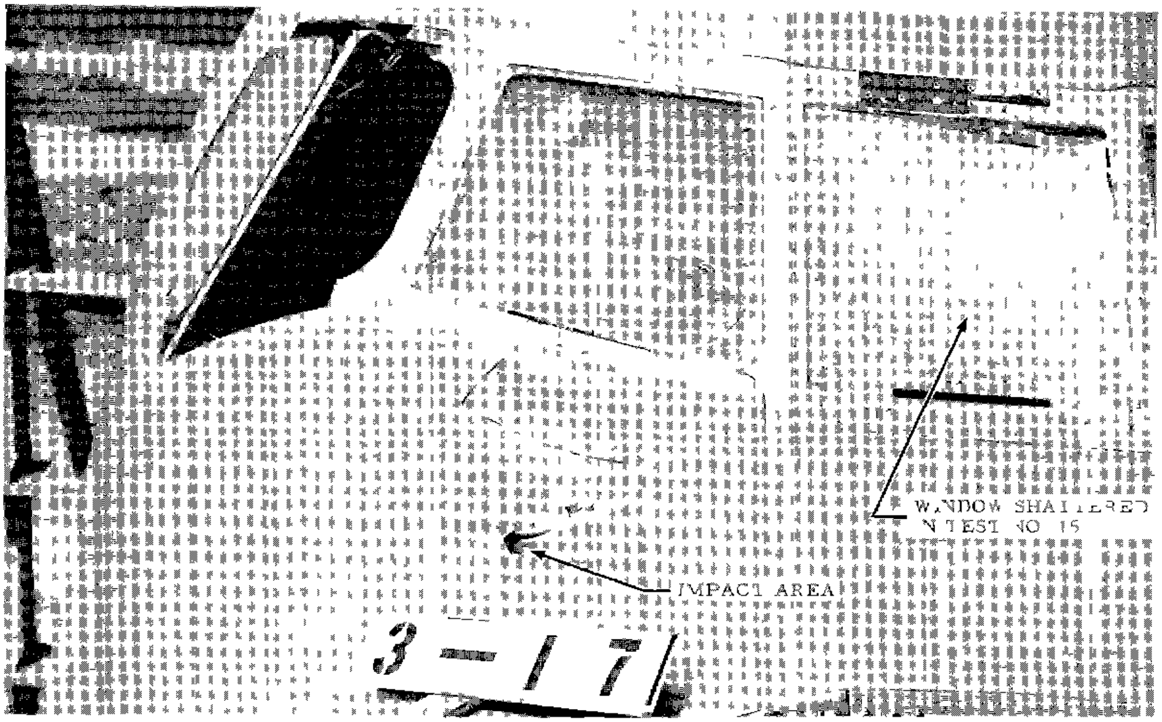


FIG 57 TEST NO 17 - OUTSIDE COCKPIT, PROJECTILE VELOCITY - 490 MPH

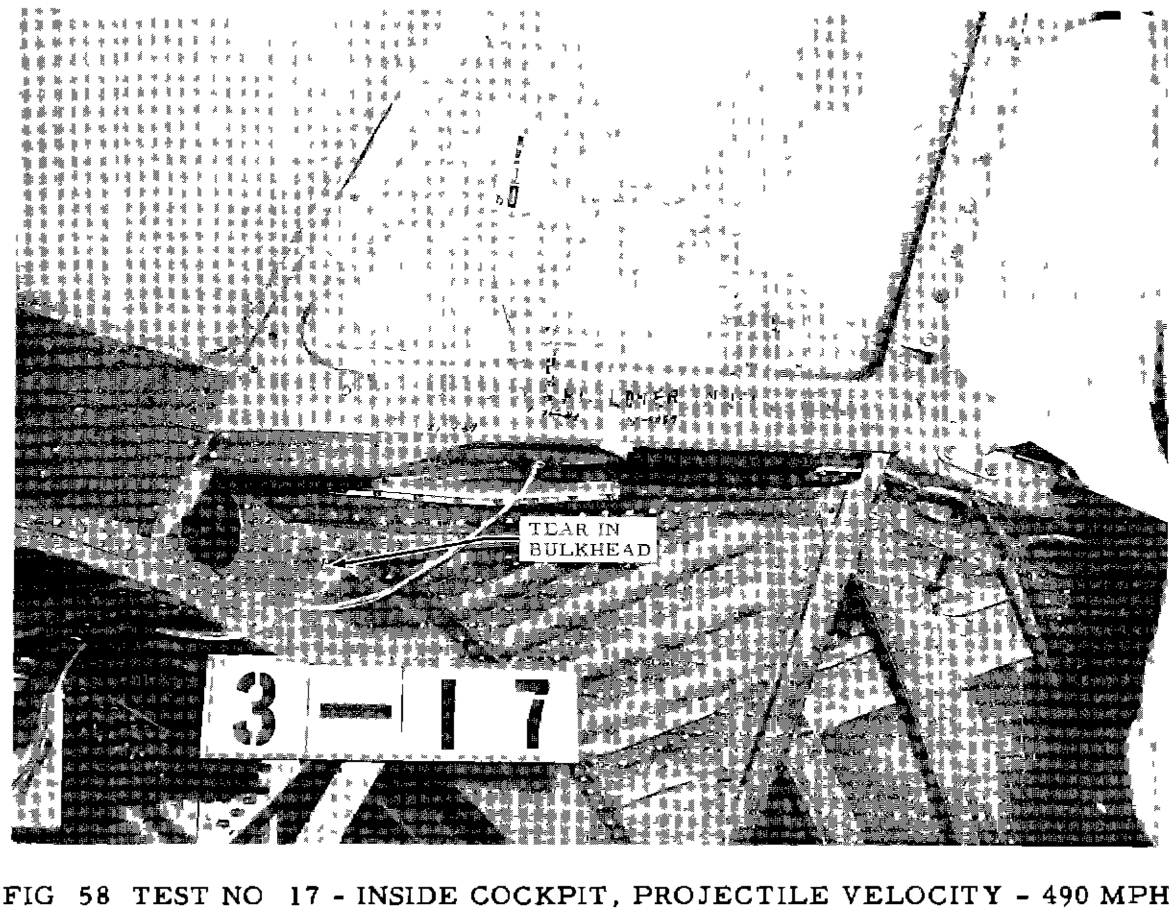


FIG 58 TEST NO 17 - INSIDE COCKPIT, PROJECTILE VELOCITY - 490 MPH

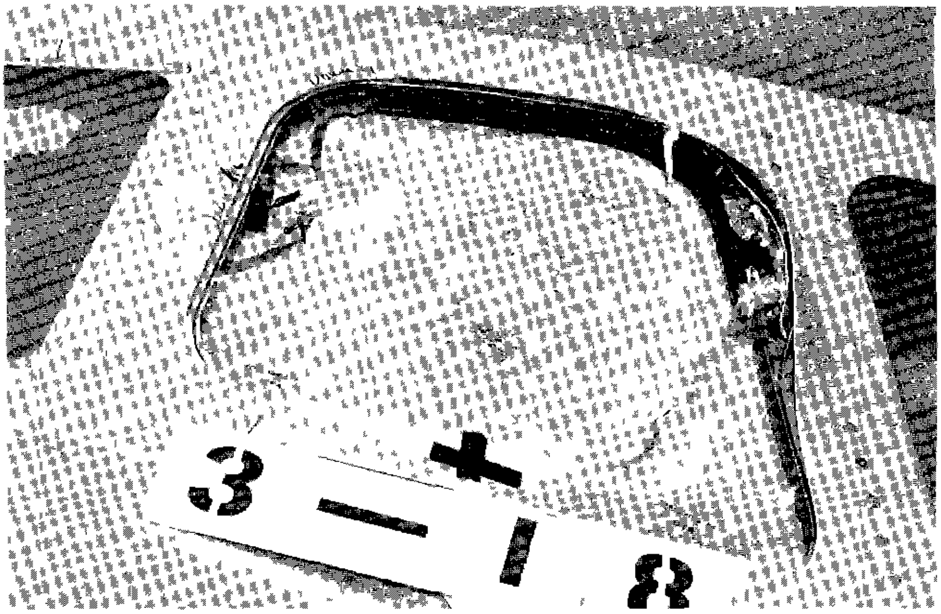


FIG 59 TEST NO 18 - EXTERIOR PANEL, PROJECTILE VELOCITY - 448 MPH

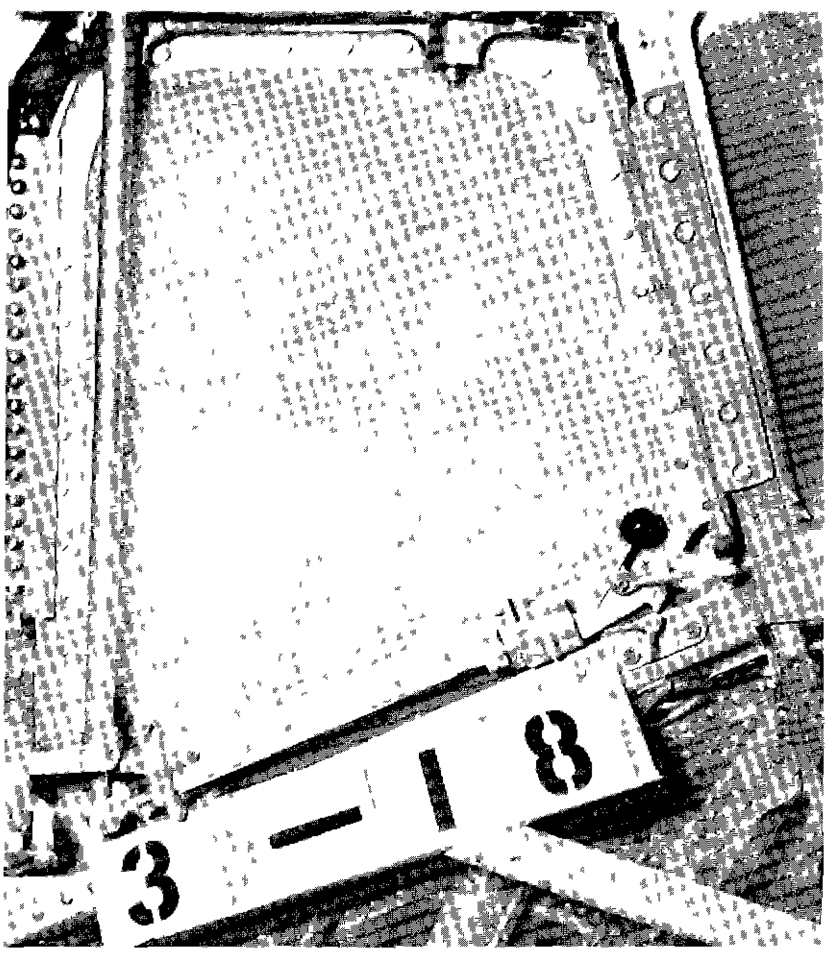


FIG. 60 TEST NO. 18 - INTERIOR PANEL, PROJECTILE VELOCITY - 448 MPH

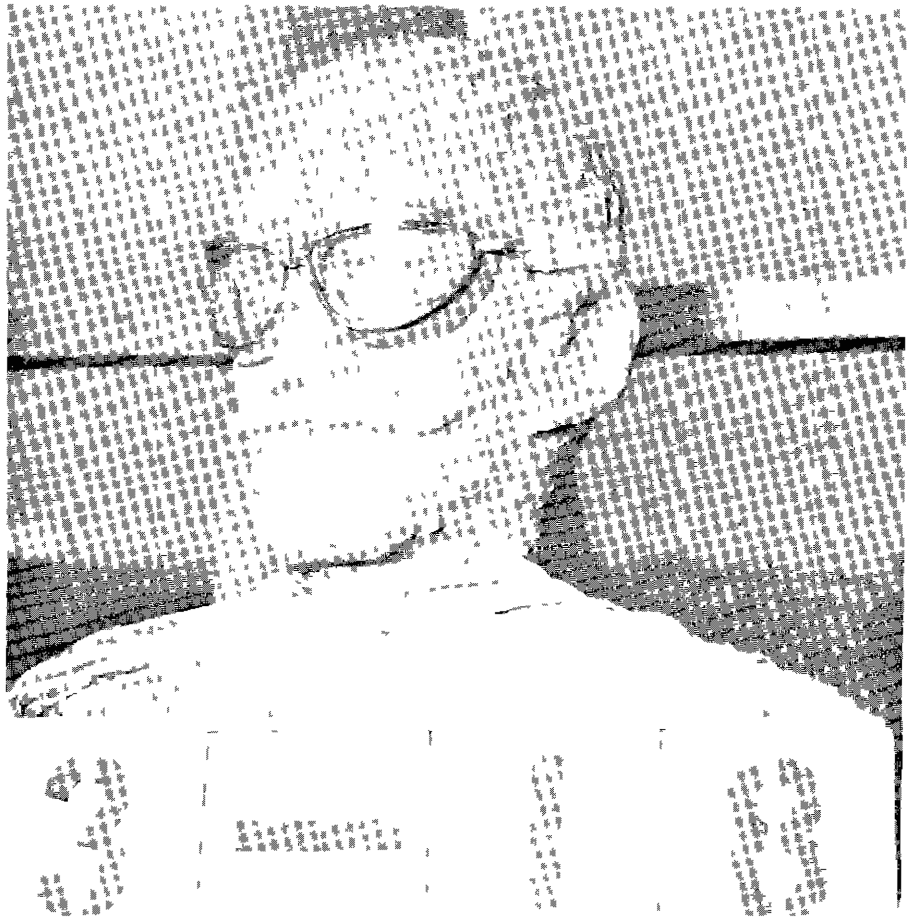


FIG 61 TEST NO 18 - PILOT, PROJECTILE VELOCITY - 448 MPH

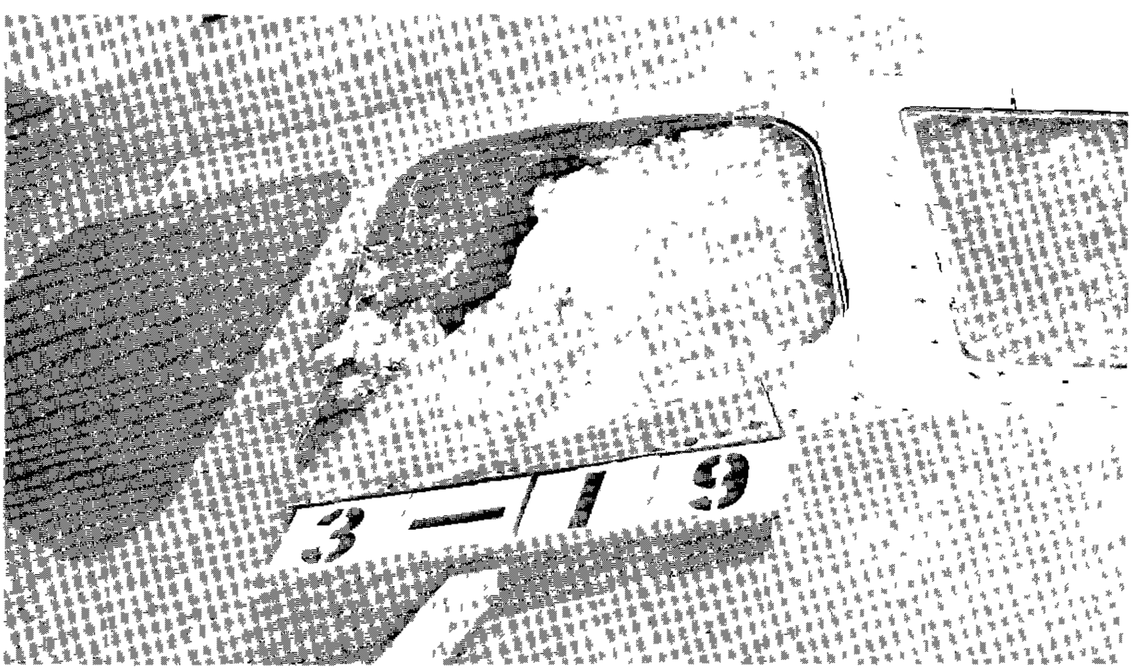


FIG 62 TEST NO 19 - EXTERIOR PANEL, PROJECTILE VELOCITY - 435 MPH

FIG 63 TEST NO 19 - INTERIOR PANEL, PROJECTILE VELOCITY - 435 MPH

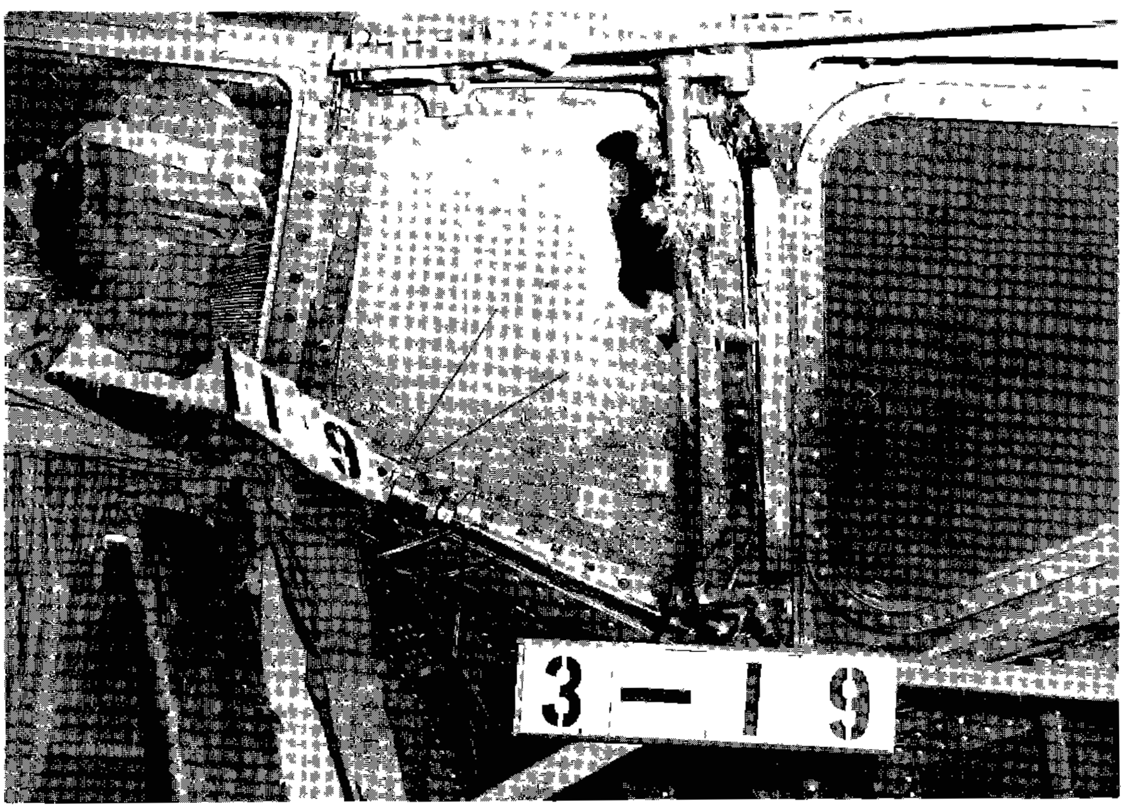


FIG. 64 TEST NO 19 - COPILOT, PROJECTILE VELOCITY - 435 MPH

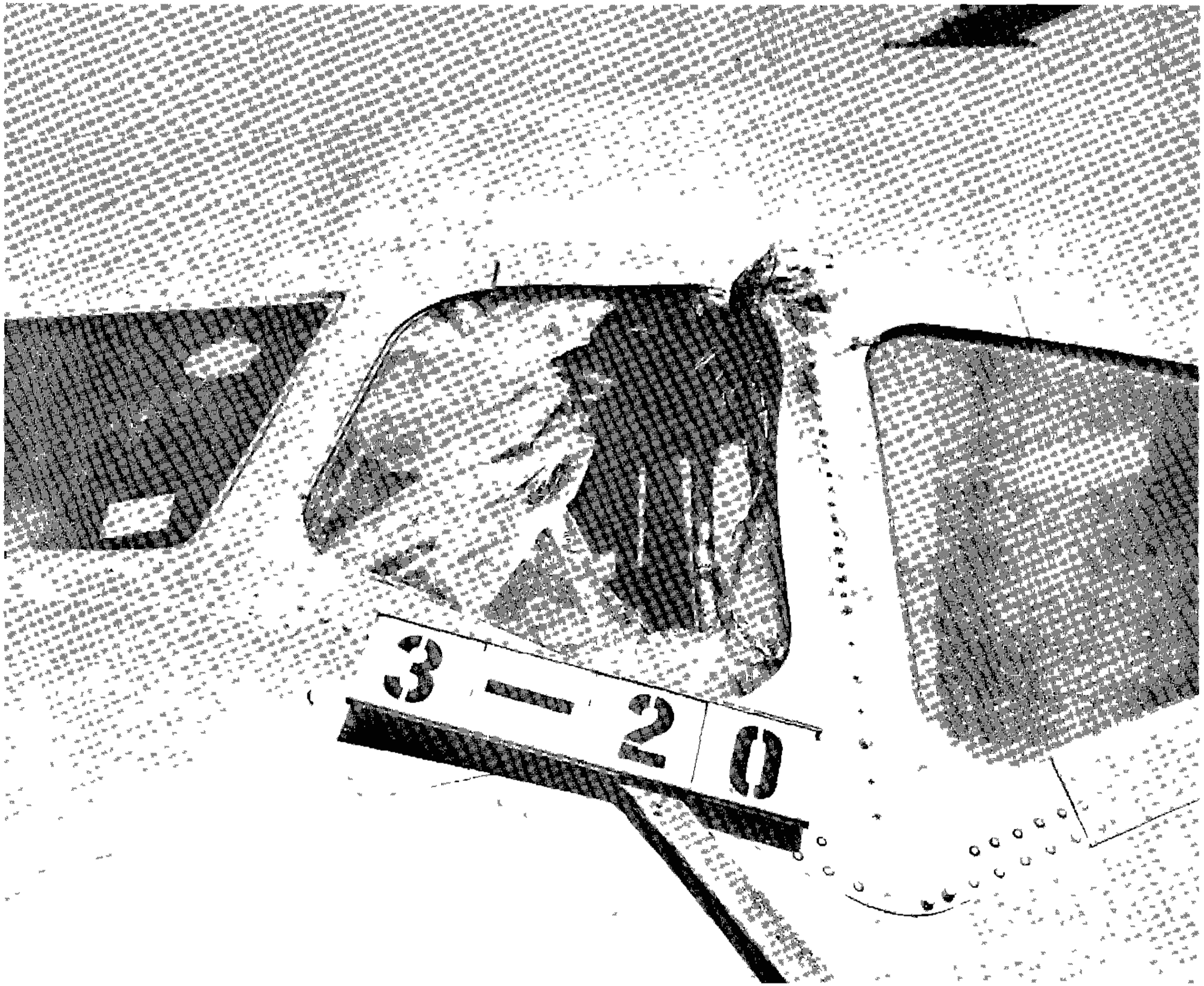


FIG 65 TEST NO 20 - EXTERIOR PANEL, PROJECTILE VELOCITY - 386 MPH

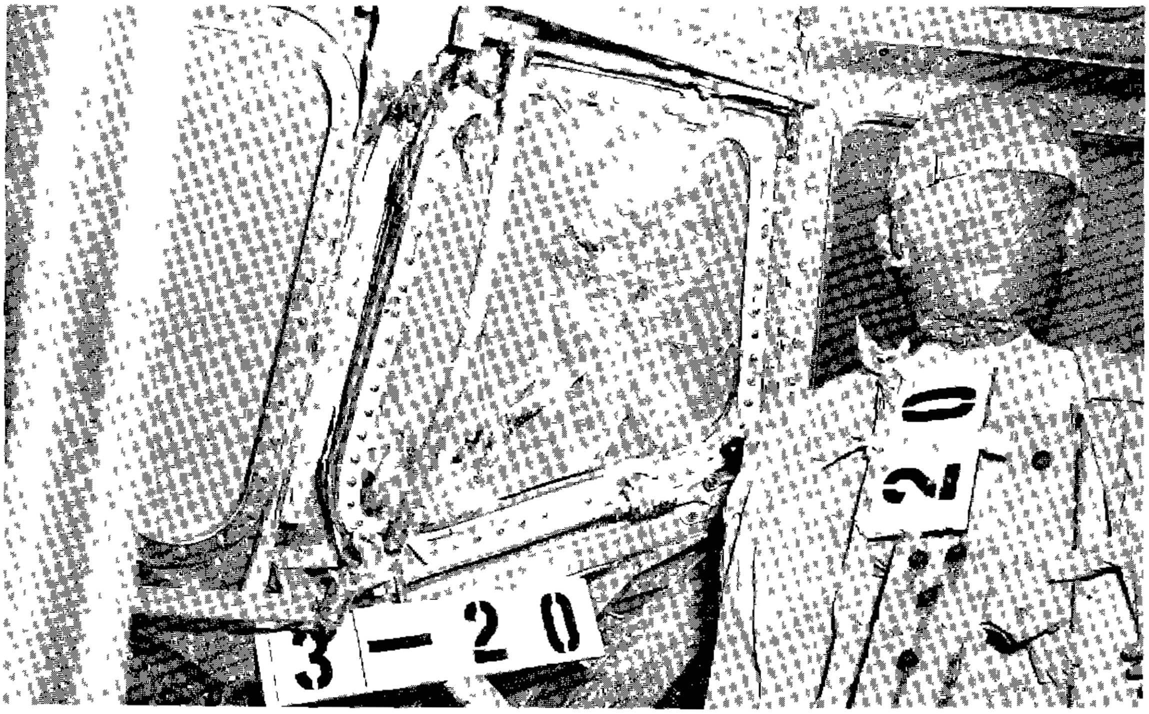


FIG 66 TEST NO 20 - INTERIOR PANEL, PROJECTILE VELOCITY - 386 MPH

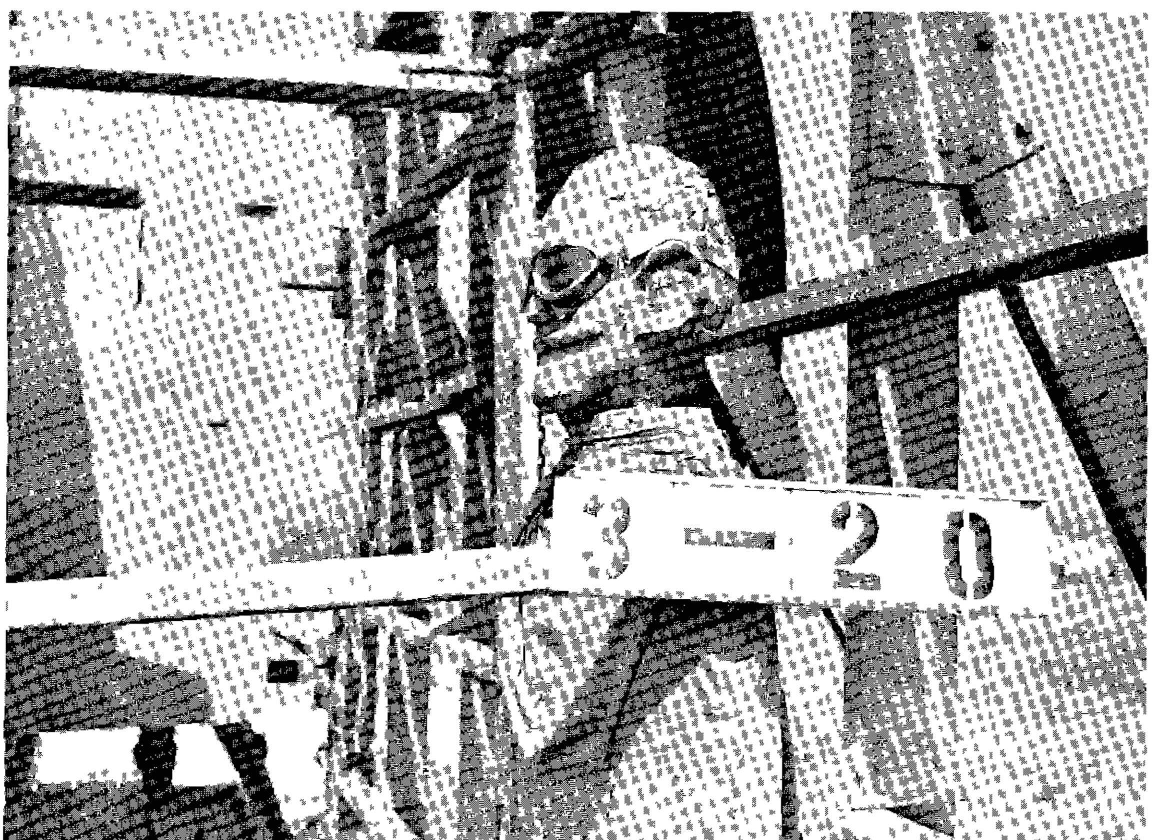


FIG. 67 TEST NO 20 - PILOT, PROJECTILE VELOCITY - 386 MPH