TECHNICAL DEVELOPMENT REPORT NO. 301

BIRD-IMPACT TESTS OF THE BOEING MODEL 707 AIRPLANE WINDSHIELD

FOR LIMITED DISTRIBUTION

by

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CIVIL AERONAUTICS ADMINISTRATION
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BIRD-IMPACT TESTS OF THE
BOEING MODEL 707 AIRPLANE WINDSHIELD

INTRODUCTION

Tests of the impact of birds on the windshield of the Boeing Model 707 airplane were conducted at the Technical Development Center of the Civil Aeronautics Administration, Indianapolis, Indiana, from July 12 to July 22, 1956. The purpose of the tests was to determine the ability of the windshield and supporting structure in front of the pilot and co-pilot of the airplane to resist penetration under the impact of a four-pound bird carcass. The Boeing Airplane Company requested that the sliding and eyebrow windows be impact tested for informational purposes only. Tests also were conducted to evaluate the possible hazard to crew members resulting from windshield fragments of flying glass. A complete resume of tests is presented in Table I.

No measurements of the angular deviation of the line-of-sight of the windshield panels were made because the panels submitted for tests were not required to have a high degree of optical quality by the Boeing Airplane Company.

The tests were conducted with the assistance of Messrs. Robert L. Peterson and Benjamin Cosgrove of the Boeing Airplane Company.

Boeing's proposal for these tests is contained in Document No. D-18454, "Procedures for Windshield Bird-Resistant Tests Model 707," dated May 15, 1956 (revised June 26, 1956).

WINDSHIELD INSTALLATION

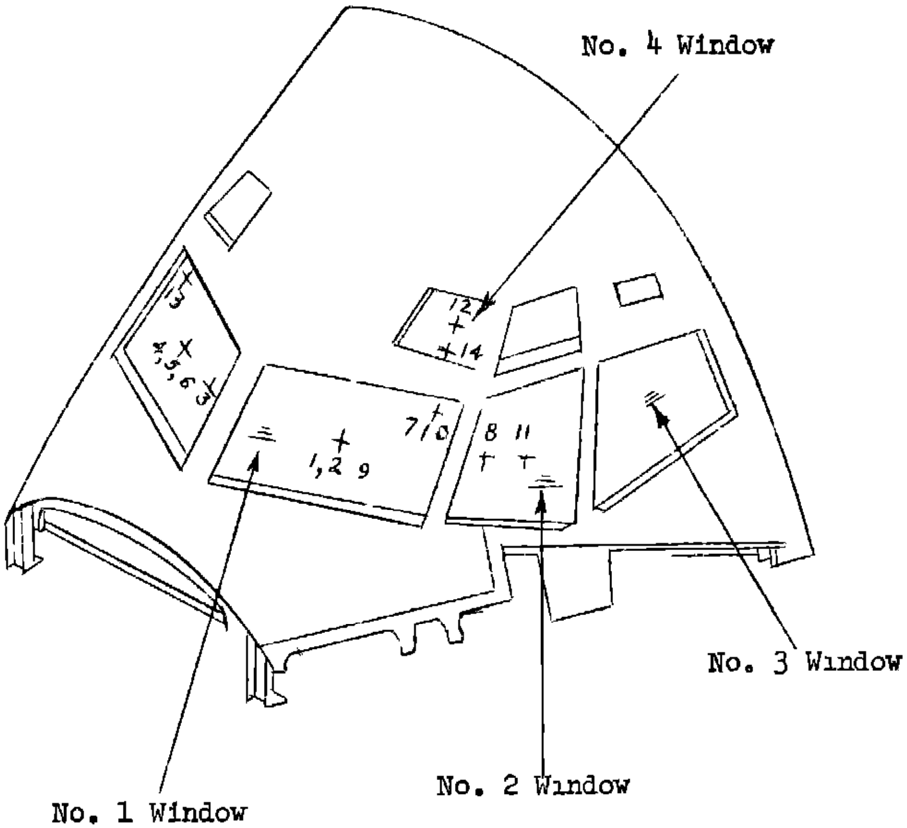
General.

The windshield-canopy structure tested was in accordance with Boeing Airplane Company drawings listed in Table II. The test article has been verified as conforming to these drawings by Mr. G. B. Hodge of that company in his letter of August 23, 1956, file No. 6-4830-3-48 to Mr. B. L. Carter, Airworthiness Engineer, Boeing Airplane Company.

The windows which Boeing agreed should be tested for compliance with Part 4b of the Civil Air Regulations consisted of two flat main panels referred to as pilot No. 1 and co-pilot No. 1. Two other windows referred to as pilot No. 2 sliding window and pilot No. 4 eyebrow window also were tested. The pilot No. 1 and co-pilot No. 1 windows are identical in

TABLE I

POSITION OF IMPACT



Test No.	Velocity (mph)	Results
1	355	Penetration*
2	380	Slight penetration*
3	393	No penetration
4	416	No penetration
5	422	No penetration
6	440	No penetration
7	380	No penetration
8	378	No penetration**
9	400	No penetration
10	460	No penetration**
11	420	No penetration
12	393	Penetration
13	450	Penetration
14	405	No penetration**

*Vinyl temperature below optimum for maximum strength.

**Supporting structure failure allowing part of carcass to enter cockpit.

TABLE II

MODEL 707 CANOPY DRAWINGS

Drawing	Title	Sheet	ADCN*	DCN**
5-61136	Intercostal Installation	2	3	-
5-71769	Seal Installation	2	13	-
5-71770	Seal Installation	-	--	-
5-71770	Frame Installation	2	--	B
5-71771	Frame Installation	2	13	-
5-71772	Sill Installation and Closure Panel	2	--	A
5-71773	Sill Installation	2	10	-
5-71774	Sill Installation	2	13	-
5-71774	Skin Installation	1	9	-
5-71775	Sill Installation	2	6	-
5-71777	Sill Installation	2	5	-
5-71778	Sill Installation	2	1	-
5-71779	Sill Installation	-	--	-
5-71795	Angle Installation	2	20	-
5-73100	Sill Installation	2	3	-
5-84402	Seal Installation	1	--	A
5-84473	Doubler Installation	1	9	-
5-84474	Intercostal Installation	2	4	-
5-84475	Splice Plate Installation	1	5	-
5-86040	Sill Installation	2	1	-
5-88446	Doubler Installation	1	1	B
5-88789	Frame Installation	2	--	A
5-88790	Frame Installation	2	2	-
5-89070	Window and Faying Seal Installation	2	11	-
90-89071	Handhold Installation	2	6	-
90-3327	Intercostal Installation	1	2	-
90-5047	Intercostal Installation	2	3	-
90-6115	Clip Installation	-	1	-
90-6184	Frame Installation	-	--	-

*Advance Drawing Change Notice
**Drawing Change Notice

construction and size. This is true also of the pilot No. 2 and co-pilot No. 2 sliding windows and of the pilot No. 4 and co-pilot No. 4 eyebrow windows.

All of the windshield panels tested incorporated the electrically operated and controlled NESA heating unit developed by the Pittsburgh Plate Glass Company.

The pilot No. 1 and co-pilot No. 1 windows are mounted by bolting the semirigid, extended vinyl, metal insert and laminated phenolic combination edge directly to the top and lower windowsills and the centerpost. The bolting arrangement consisted originally of a row of 0.1875-inch-diameter, 160,000 psi, heat-treated, NAS-517 countersunk head bolts spaced at 1.15 inches on centers along the top sill, and a row of 0.1875-inch-diameter, 160,000 psi, heat-treated, NAS-517 countersunk head bolts spaced at 2.30 inches on centers along the centerpost and lower windowsills. This mounting arrangement is shown in Figs. 1 and 2. The cornerpost window edge is retained by a series of equally spaced rectangular retainers protruding from the inside of the cornerpost sill. Upon fitting the cornerpost window edge over the rectangular retainers, the edge is held in place by an L-shaped backup bar which fits snugly against the innermost surface of each retainer and is bolted in place. This arrangement for retaining the cornerpost window edge is shown with a proposed revision in Fig. 2.

Changes Made During Tests.

During tests Nos. 2 and 6, the upper sills of the pilot No. 1 and co-pilot No. 1 windows cracked, and an 0.125-inch-thick 75-ST Alclad doubler plate was incorporated as shown in Figs. 16 and 31 to stiffen the weakened sills. The cracks which developed in both of these upper windowsills are not considered to be due to weakness on their part, but were due to continuous cold working of the sill material as it was deformed and straightened during successive impact tests.

Because of failure of the upper sill bolts during test No. 10, which was an upper aft corner strike at 460 mph, the first seven upper sill bolts counting inboard from the cornerpost were increased to 0.25-inch-diameter prior to test No. 13 as shown in Fig. 31. In addition, to provide for more positive retaining of the upper cornerpost window edge during test No. 13, the L-shaped backup bar (Part No. 5-71769-3005) was increased in length as shown in Fig. 2.

The pilot No. 2 sliding window was revised as shown in Fig. 24 prior to test No. 11 as a result of failure of the upper aft retaining point during test No. 8.

The pilot No. 4 eyebrow window retaining arrangement was revised by doubling the number of bolts and increasing their size to 0.25-inch diameter prior to test No. 14. This revision, shown in Figs. 34 and 35, was prompted by the failure of this window during test No. 12.

To protect the pilot against flying glass, a protective transparent visor-type shield was employed during tests Nos. 9, 10, and 14 as shown in Figs. 21, 22, and 35. For test No. 9, an 0.125-inch-thick sheet of stretched plex-55 acrylic was used; for tests Nos. 10 and 14, an 0.125-inch-thick sheet of cellulose acetate was used. These shields were retained at one edge only, and they were mounted adjacent to the inside face of the window as shown in the appropriate figures.

DESCRIPTION OF WINDSHIELD AND WINDOWS

Windshield, Pilot No. 1 and Co-Pilot No. 1.

Height:		16 1/2 inches
Width:		
	Top	30 1/2 inches
	Bottom	33 1/2 inches
Thickness:		
	Front Face	1/4-inch full tempered glass
	Interlayer	3/8-inch vinyl (20 per cent plasticizer)
	Rear Face	1/2-inch full tempered glass
	Metal Insert	0.103 nonmagnetic steel
	Extended Edge	1 inch outside face 5/8 inch inside face
Slope:		
	Vertical Axis	45°
	Horizontal Axis	30°
	Total Angle (measured from a line parallel to the line of flight)	49° approximately

Sliding Windows, Pilot No. 1 and Co-Pilot No. 2.

Height:		
	Front Edge	18 1/4 inches
	Aft Edge	22 1/2 inches

Width:		
	Top	16 1/2 inches
	Bottom	22 inches
Thickness:		
	Front Face	3/16-inch full tempered glass
	Interlayer	7/16-inch vinyl (20 per cent plasticizer)
	Rear Face	3/8-inch full tempered glass
	Metal Insert	0.079 24-ST aluminum
	Extended Edge	1/8 inch inside edge 11/16 inch outside edge
Slope:		
	Total Angle (measured from a line parallel to the line of flight)	70° approximately

Eyebrow Windows, Pilot No. 4 and Co-Pilot No. 4.

Height:		9 1/2 inches
Width:		
	Top	9 inches
	Bottom	11 7/8 inches
Thickness:		
	Front Face	1/8-inch full tempered glass
	Interlayer	5/16-inch vinyl (20 per cent plasticizer)
	Rear Face	1/4-inch full tempered glass
	Metal Insert	0.025 24-ST aluminum
	Extended Edge	5/8 inch inside face 1 1/8 inch outside face
Slope:		
	Total Angle (measured from a line parallel to the line of flight)	50° approximately

TEST PROCEDURE

Freshly killed chicken carcasses were propelled at the test structure by means of a compressed-air gun. To increase the efficiency and accuracy of performance of the compressed-air gun, the chicken carcasses, backed by a 4-inch-thick Styrafoam plug 6 inches in diameter, were placed in a cloth bag which was tied. This arrangement gave the appearance of a projectile approximately 12 inches long by 6 inches in diameter. The combined weight of the chicken, Styrafoam plug, and cloth sack was 4 pounds, plus or minus 2 ounces. The weight of the plug and sack was approximately 3 ounces. Points of impact were determined by an accurate system of sighting the compressed-air gun at the target.

The cockpit structure used in these tests was fastened securely to a temporary wood structure which had been built up from and was securely fastened to the test-cell bed. The back of the cockpit was supported by positioning 2- by 6-inch wood members behind the principal longitudinal structural members of the cockpit. This mounting arrangement is shown in A of Fig. 3.

Two life-sized clay torsos representing the pilot and co-pilot were positioned in the test cockpit to duplicate as nearly as possible the actual location of eye positions in the Model 707 airplane. The positioning is shown in A and B of Fig. 3. Damage to these clay torsos was repaired as required after each test by cleaning them as much as possible, after which a new layer of clay was applied.

An aluminum glare shield was clamped into the position normally occupied by the top of the instrument panel in the operational aircraft. The positioning of this shield is shown in B of Fig. 3.

Impact tests on the No. 1 windows were made at the geometric center, at a point on the horizontal centerline six inches inboard of the centerpost and at the upper aft corner of the window.

Velocity measurements were determined by the bird carcass breaking three pairs of fine steel wires positioned between the gun muzzle and the windshield canopy. Two pairs of these wires were connected to a recording oscillograph; the third pair of wires was connected to an electronic chronograph. A fourth method for determining the velocity of the bird carcass, using a high-speed camera, was employed primarily as a check on the oscillograph and chronograph. Bird-carcass velocities accepted as correct for tests Nos. 7 and 11 were those taken from the velocity versus pressure calibration chart of the gun. Bird-carcass velocities for tests Nos. 9 and 14 ultimately were obtained through the use of the high-speed camera because apparently faulty velocity indications were obtained from the oscillograph and chronograph. In test No. 9 at 75 pounds per square inch gage pressure (psig) the bird-carcass velocity was expected to be near 475 mph. The velocities which were determined from the timing devices were 555, 570, and 650 mph. High-speed pictures of this test showed that the Styrafoam plug preceded the bird carcass out of the gun muzzle. The velocity of the plug as determined by the high-speed film was 630 mph. This estimate is based upon the plug traveling a distance of 9.59 feet in 15 frames of film at a camera speed of 1440 frames per second. The bird carcass traveled this same distance in 24 frames at the same camera speed, indicating that it was traveling at slightly less than two-thirds, or 0.625 times the speed of the plug. In computing the finalized velocity for test No. 9, the value of 640 mph, which is the average of the highest recorded velocity of 650 mph and the high-speed film velocity of 630 mph, was used. The resulting speed of the bird carcass then was determined to be 0.625 x 640 = 400 mph.

Heating of the test windows was accomplished by applying the required voltage to the NESA heating units on each window. Temperature readings were obtained from the window-sensing unit. After tests Nos. 1 and 2, window temperatures were maintained between 105° and 115° F. just prior to firing.

TEST RESULTS

The conditions and results of the individual impact tests are as follows:

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
1	7/12/56	No. 1 pilot	Center of window	355	69

The carcass hit approximately 3 inches below the aiming point. Part of the carcass passed through the window and part was deflected over the top of the canopy. Three-fourths of the window was completely destroyed, and the center section of the upper sill was bent inward by the impact. The glare shield originally positioned as shown in B of Fig. 3 was bent downward. The clay dummy in the pilot's position received a concentration of flying glass in the lower right chest area in addition to a few particles of glass mixed with bird entrails full in the face. This was not considered to be a valid test of maximum impact-absorbing qualities of the window and supporting structure because the vinyl was maintained at a temperature of only 69° F. Results of this test are shown in Fig. 4.

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
2	7/13/56	No. 1 pilot	Center of window	380	90

The carcass hit approximately 2 inches above the target point. The upper sill cracked open horizontally, allowing penetration of an undetermined amount of the carcass, and the fuselage skin was peeled back directly above the cracked section of the sill as shown in Fig. 5. There was slight penetration of the vinyl through a small tear near the upper sill as shown in Fig. 6. The clay dummy received a heavy concentration of glass particles in the upper chest and right arm area. Much of this glass merely impinged upon the clay, and it is doubtful that the apparently heavy damage shown in Fig. 5 would have occurred if the dummy had been clothed. A few particles of glass and a small amount of bird entrails hit the clay dummy's face. The glare shield again was buckled downward as in the previous test. Vinyl temperature for this test was considered too low for best results.

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
3	7/14/56	No. 1 co-pilot	Horizontal centerline 6 inches outboard of centerpost	393	115

The actual strike position was 6 inches outboard of centerpost and 1 inch below the horizontal centerline. There was no penetration of either the No. 1 window or supporting structure. The upper sill was bent inward slightly. The clay dummy in the co-pilot's position was unmarked by flying glass. Small flake-like particles which could be brushed off impinged upon the dummy's clothing. The glare shield again was forced downward by the heavy concentration of glass departing from the inside face of the window. Figs. 7, 8, and 9 show the results of this test.

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
4	7/14/56	No. 1 co-pilot	Center of window	416	115

The carcass hit on the vertical centerline of the window approximately 1 1/2 inches below the horizontal centerline. There was no penetration of the windshield. The upper windowsill was bent inward slightly. Small flake-like particles of glass impinged upon the face of the clay dummy. These could be brushed away. The left shoulder and arm area of the dummy was penetrated by chunks of glass averaging about 1/4 inch on edge. The glare shield again was bent downward by the force of the impact. Results of this test are shown in Figs. 10 and 11.

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
5	7/15/56	No. 1 co-pilot	Center of window	422	115

The carcass hit on the vertical centerline about 1 1/2 inches below the horizontal centerline. There was no penetration of the windshield. The upper sill again was bent inward. Two chunks of glass, cubic in general shape and about 1/4 inch along the edge, penetrated the face of the dummy, one below the left eyebrow and one at chin level on the left side. All other particles of glass which impinged upon the dummy's face and clothes could be removed by gentle brushing. The glare shield had been removed prior to this test because it was damaged beyond repair in previous tests. Results of this test are shown in Figs. 12 and 13.

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
6	7/16/56	No. 1 co-pilot	Center of window	440	105

The carcass hit on the horizontal centerline slightly outboard of the vertical centerline. There was no penetration of the windshield. The top windowsill was bent inward and had developed a crack. Action of the bird carcass as it traveled up the windshield caused tearing of the fuselage skin above the top windowsill. The clay dummy received a face full of glass chunks, many of which were imbedded as much as 1/4 inch in the clay. In addition, the left side of the clay dummy from the neck to the waist area contained numerous chunks of glass which had torn through the dummy's clothing. Results of this test are shown in Figs. 14 and 15.

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
7	7/17/56	No. 1 pilot	Upper left corner	380	105

The carcass hit the vertical centerline of the pane 6 inches inboard of the cornerpost. There was no penetration of the window. Apparent damage to the supporting structure of the window was superficial in nature in that the aluminum skin covering the cornerpost peeled off. Hidden damage included shearing of one of the cornerpost window edge rectangular retainers. The face and left side of the clay dummy received quite a few chunks of flying glass which penetrated the clothing and imbedded themselves in the clay. Results of this test are shown in Figs. 16 and 17.

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
8	7/18/56	No. 2 pilot	Center of window	378	106

The center of impact was on the horizontal centerline approximately 4 inches aft of the forward windowsill. There was no penetration of the window. The upper aft window-frame retaining structure failed, allowing the window frame to rotate inward and strike the clay dummy on the left side of the head. In addition, the left side of the clay dummy's head and neck was penetrated by numerous particles of glass which were not deeply imbedded. Results of this test are shown in Figs. 18 and 19.

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
9	7/18/56	No. 1 pilot	Center of window	400	105

The center of impact was extremely close to the geometric center of the window. There was no penetration of the windshield. A visor-type transparent acrylic shield mounted adjacent to the window shattered upon impact. The right side of the dummy's face and neck was cut by flying plastic. Results of this test are shown in Figs. 20 and 21.

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
10	7/19/56	No. 1 pilot	Upper left corner	460	105

The center of impact was on the horizontal centerline approximately 8 inches inboard of the cornerpost. There was no penetration of the window, although failure of the cornerpost retaining member and the upper sill bolts allowed part of the bird carcass to enter the cockpit. The 0.125-inch cellulose acetate visor mounted as shown in Fig. 22 apparently was forced back across the face of the dummy upon impact. The clay dummy's face was covered with bird entrails and chunks of glass which penetrated into the clay. Results of this test are shown in Figs. 22 and 23.

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
11	7/20/56	No. 2 pilot sliding window	Center of window	420	105

The center of impact was on the horizontal centerline approximately one-third of the distance from the fore window's edge to the aft edge. The upper forward corner of the window frame was pushed inward, but no failure of the frame resulted. The carcass did not penetrate the window. The sidepost sill was bent slightly and the sidepost doubler plate strip was peeled off. The reinforced upper aft and lower aft window frame retaining arrangement remained intact. The left side of the clay dummy's head and neck area was eroded quite severely by flying glass, although the Navy-type plastic goggles which were employed protected the dummy's eye area. The window prior to testing and results of this test are shown in Figs. 24, 25, 26, and 27.

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
12	7/21/56	No. 4 pilot eyebrow	Center of window	393	90

The center of impact was within 1/4 inch of the geometric center of the window. The upper sill and outboard side-sill retaining bolts tore through the window edge, allowing part of the carcass to pass into the cockpit over the head of the clay dummy. The clay dummy received a severe blow on the forehead apparently from a concentration of glass particles which departed from the inner face of the window upon impact. The Navy-type goggles with plastic lens protected the clay dummy's eye area from severe damage. Results of the test are shown in Figs. 28, 29, and 30.

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
13	7/21/56	No. 1 co-pilot	Upper right corner	450	106

The actual strike area was approximately 8 inches inboard of the cornerpost and 6 inches below the top windowsill. The force of the impact resulted in failure of two 3/16-inch-diameter top sill retaining bolts in tension directly above the point of impact. The six 1/4-inch-diameter bolts outboard of the 3/16-inch-diameter bolts remained intact. A third 3/16-inch-diameter bolt did not fail, but the nut pulled through the backup stripping. Failure of the windowsill attachment in this manner allowed the window edge to be forced inward from its normal position, thereby tearing the vinyl from the window edge downward into the center of impact area. Part of the bird carcass passed through this opening, hitting the face of the clay dummy. Numerous chunks of glass eroded and became lodged in the clay dummy's head from the chin level up to the forehead level. The Navy-type goggles which were employed deflected much of the glass and bird entrails at the dummy's eye level. Results of this test are shown in Figs. 31, 32, and 33.

Test No.	Date of Test	Window Tested	Aiming Point	Carcass Velocity (mph)	Vinyl Temperature (degrees F.)
14	7/22/56	No. 4 pilot eyebrow	Center of window	405	95

The center of impact was near the lower edge of the window. There was no penetration of the window. The upper sill failed, allowing part of the carcass to pass into the cockpit over the clay dummy's head. The force of a concentration of flying glass from the inside face of the window shattered the cellulose acetate shield, a piece of which imbedded itself in the clay dummy's forehead. In addition, the forehead of the clay dummy was badly eroded by an apparently severe blow although the force of this blow was not as great as that of test No. 12. The window prior to testing and results of this test are shown in Figs. 34, 35, 36, 37, and 38.

CONCLUSIONS

The following conclusions are based on an analysis of test results.

Pilot and Co-pilot No. 1 Windows.

1. The windshields and their supporting structures as originally submitted for bird-impact tests will withstand without penetration the impact of a 4-pound bird on the geometric center of the window at a velocity in excess of 440 mph. By incorporation of the structural modifications shown in Figs. 1 and 2, it is reasonable to assume that this velocity can be increased by approximately 5 per cent to 462 mph.

2. The windshields and supporting structures as originally submitted for tests will withstand with little or no penetration an impact near an upper outboard corner at a velocity of 420 mph. This velocity is an average of a nonpenetration velocity of 380 mph obtained in test No. 7 and a velocity of 460 mph obtained in test No. 10 which resulted in penetration due to failure of the supporting structure. Examination and comparison of the damage experienced by the two windshield specimens and supporting structures during these tests have substantiated, in this case, the validity of averaging the velocities of the two tests to obtain an estimate of actual penetration velocity. By incorporation of the modifications shown in Figs. 1 and 2, this velocity reasonably may be assumed to be increased by 5 per cent to 441 mph.

3. Windshield strength near the centerpost is considered equal to or better than that of the upper outboard corner. See Item 2.

4. For an impact at the geometric center of the windshield, flying glass will strike the face of the pilot crew member seated behind the target window at impact velocities approaching 440 mph. The resulting glass-impingement pattern for a center impact position will be essentially the same as shown on the clay dummies in Figs. 11, 13, and 15 for carcass velocities of 415, 422, and 440 mph respectively. In the event of an upper outboard corner impact the pilot crew member seated behind the target window will be struck in the face by flying glass at velocities as low as 380 mph. See Test Nos. 7, 10, and 13. The glass-impingement pattern for an upper outboard corner impact is shown on the dummy of Fig. 17 for a carcass velocity of 380 mph.

5. The minimum window temperature required for the Boeing 707 windshield to develop the resistance to penetration as determined from these tests is 105° F. No information on maximum permissible temperature was

determined, although temperatures as high as 115° F. were maintained during some of the tests without detrimental effects on bird-penetration qualities.

Pilot and Co-pilot No. 2 Sliding Windows.

1. The upper aft retaining arrangement for the sliding window failed at an impact velocity of 378 mph, allowing the window frame to rotate inward about its two lower track-level retaining points, striking the clay dummy on the side of the head just above the ear. See test No. 8. In order that the sliding window may successfully withstand a 4-pound bird impact, the upper and lower aft retaining arrangements should be increased in strength to equal that of the lower forward retaining arrangement.

2. An analysis of the flying glass problem indicates that the pilot crew member seated adjacent to this window will be struck by glass particles at bird-impact velocities as low as 378 mph. Both the amount and energy of glass emitted from sliding windows in the direction of the pilot's face are negligible at 378 mph. As impact velocities increase, however, the problem becomes more critical as indicated by the condition of the clay dummy's face following an impact test at 420 mph. See test No. 11.

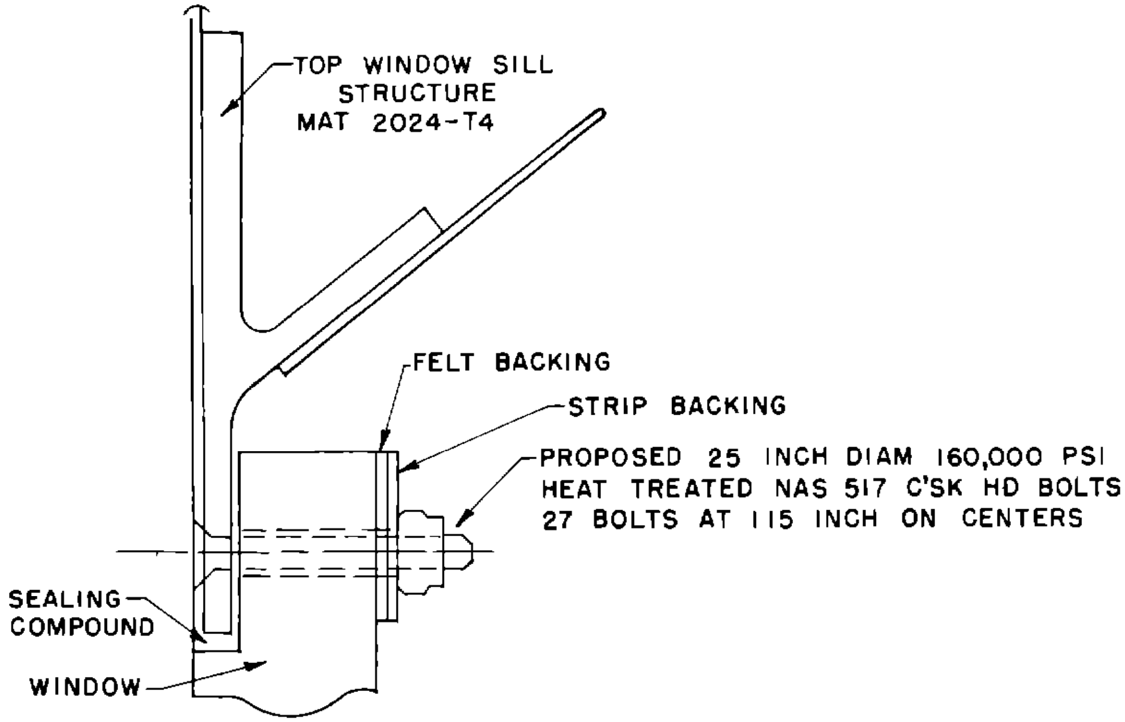
Pilot and Co-pilot No. 4 Eyebrow Window.

1. The eyebrow window will withstand a 4-pound bird impact at a velocity of slightly more than 405 mph, provided the number of retaining bolts is doubled and if they are increased in size to 1/4 inch. This is shown in Figs. 34 and 35.

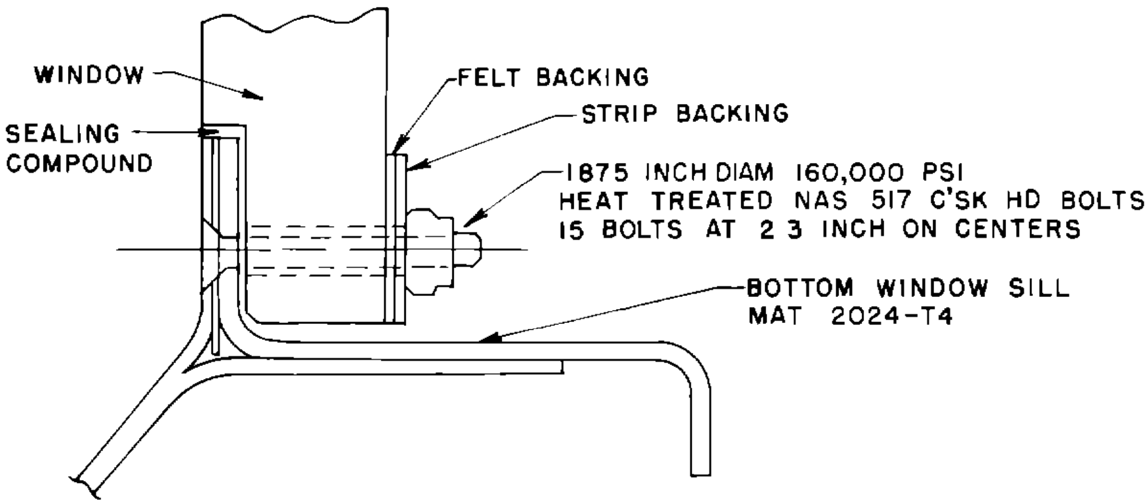
2. An analysis of the flying glass problem indicates that a particularly dangerous hazard to the pilot or co-pilot exists upon bird impact of an eyebrow window at velocities at or lower than 393 mph. See tests Nos. 12 and 14.

Protective Measures Taken to Minimize the Flying Glass Hazard.

The 0.125-inch-thick plastic visor-type transparent shields described in this report, which were utilized during tests Nos. 9, 10, and 14 in an attempt to provide the dummy pilot with protection from flying glass, proved to be inadequate. These shields shattered and tore loose from their fixed retaining hinges upon impact, thereby introducing another hazardous condition. Some success was realized, however, in the use of Navy-type, full-vision, plastic-lens goggles to protect the dummy pilot's eye area. It was evident from the type of failures which occurred when using the visor-type shields that the shields were mounted too close to the inside face of the target window. When evaluating the use of visor-type shields together with goggles, it becomes apparent that, to be effective, a protective shield would have to be mounted as close to the pilot and co-pilot as feasible.



TOP SILL WINDOW ATTACHMENT
D-3 REF-BAC DWNG 5-71761 SHT. 1-A



BOTTOM SILL WINDOW ATTACHMENT
B-3 REF BAC DWNG 5-71761 SHT 1-A

FIG 1 UPPER AND LOWER SILL AND WINDOW ARRANGEMENT – NO 1 WINDOW

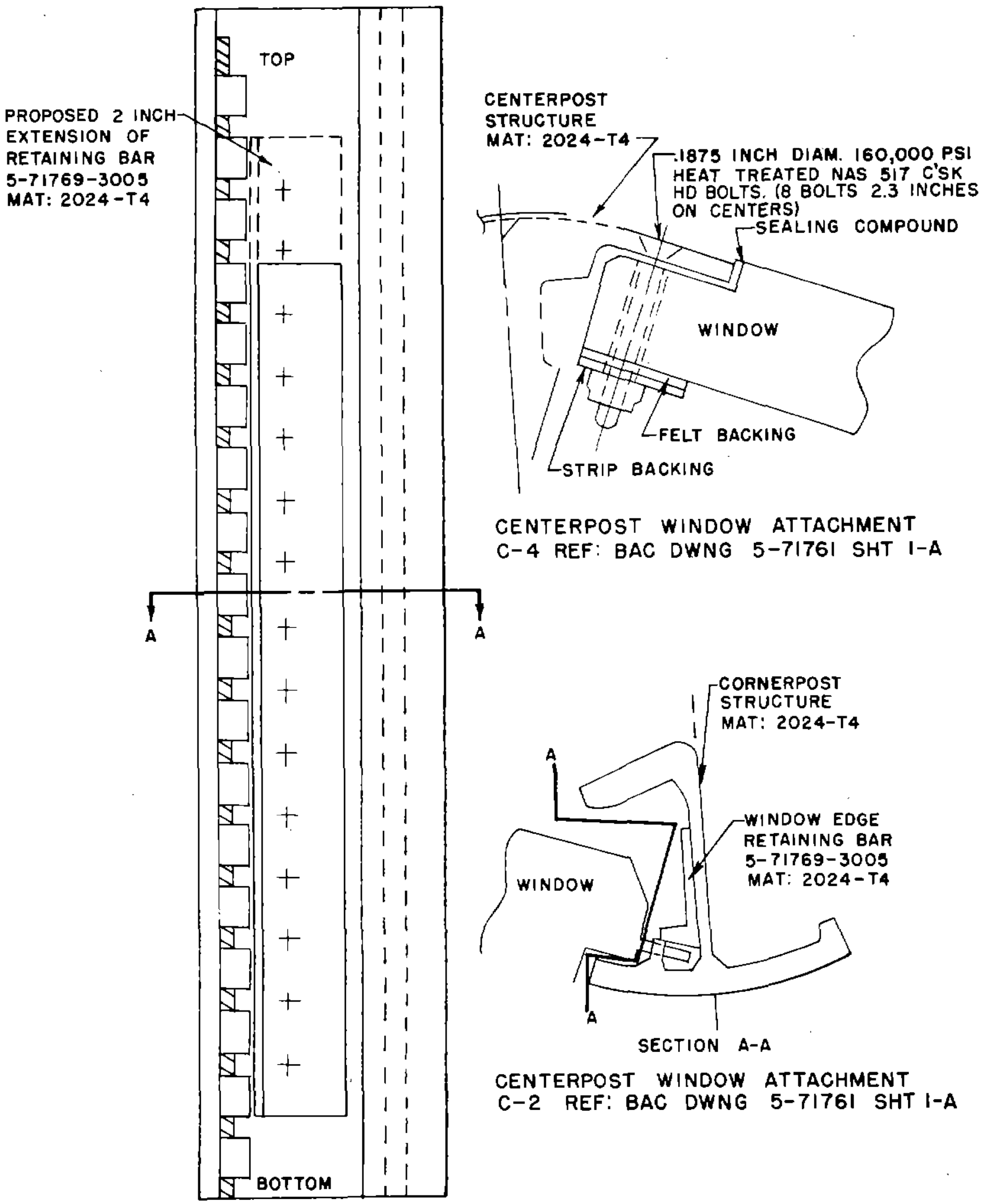


FIG. 2 SIDEPOST AND CORNERPOST SILL WINDOW MOUNTING ARRANGEMENT — NO. I WINDOW

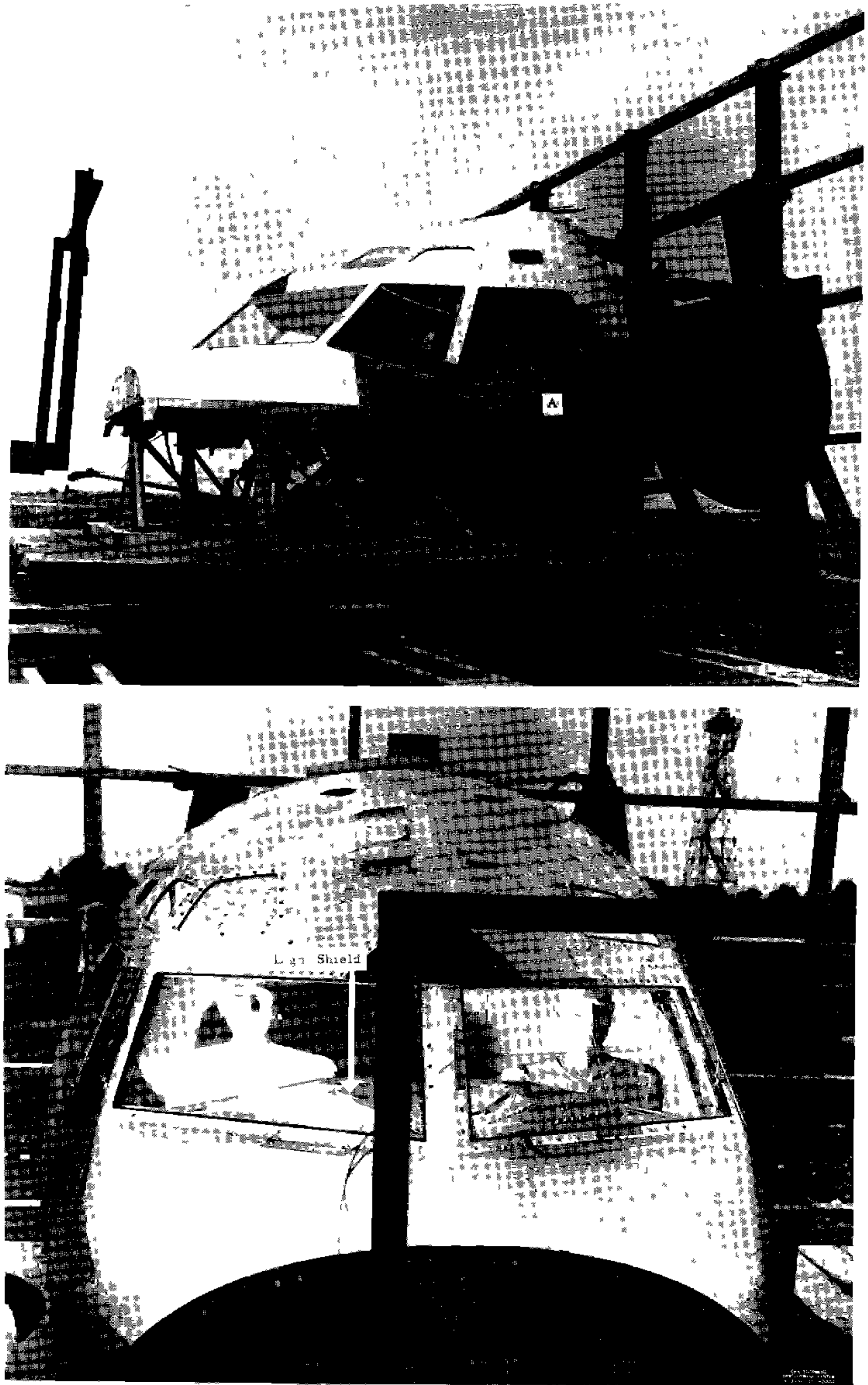


FIG 3 COCKPIT TEST-STAND MOUNTING ARRANGEMENT

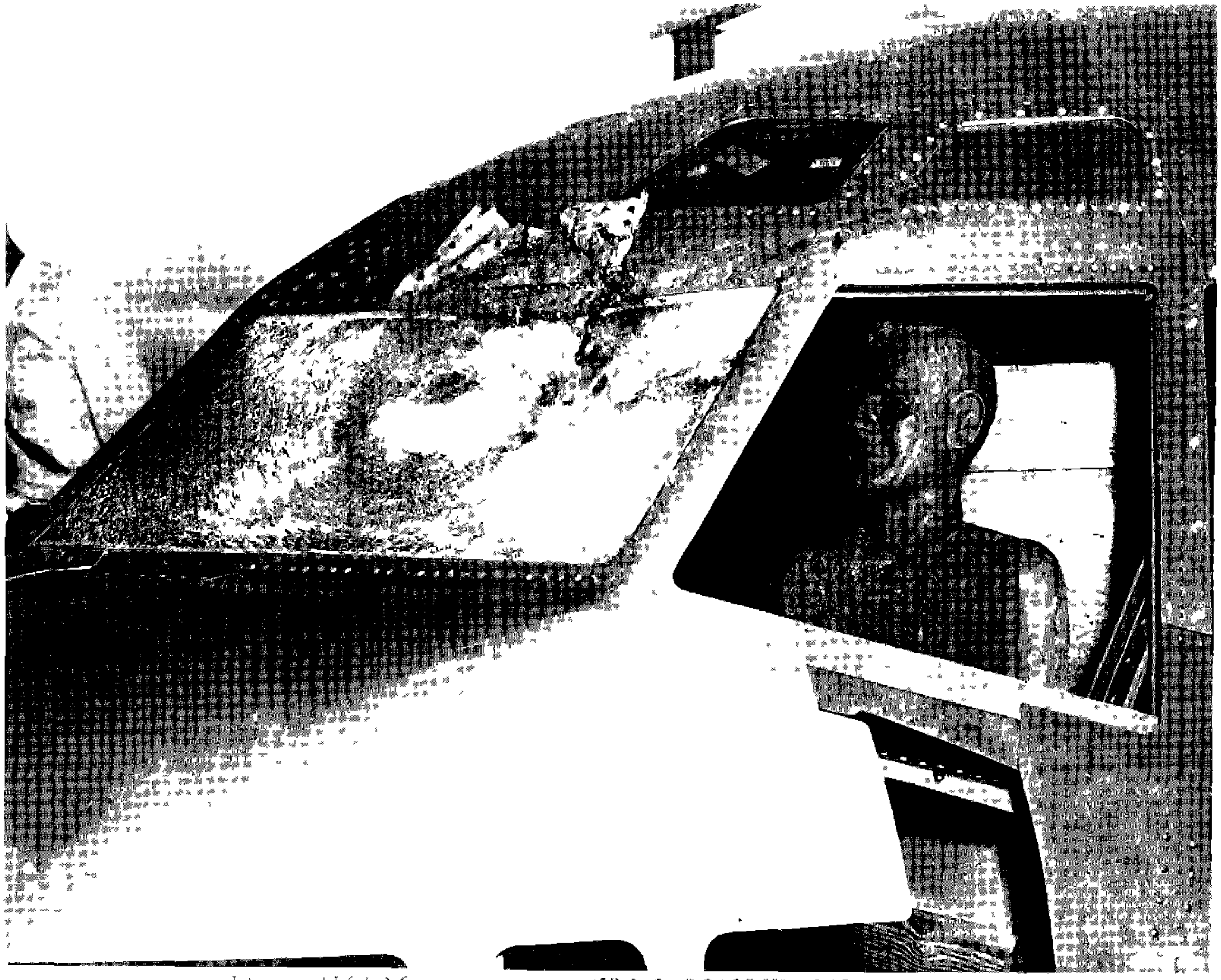


FIG. [illegible] TEST NO. [illegible]/58 - BIRD-CARCASS VELOCITY [illegible] mph

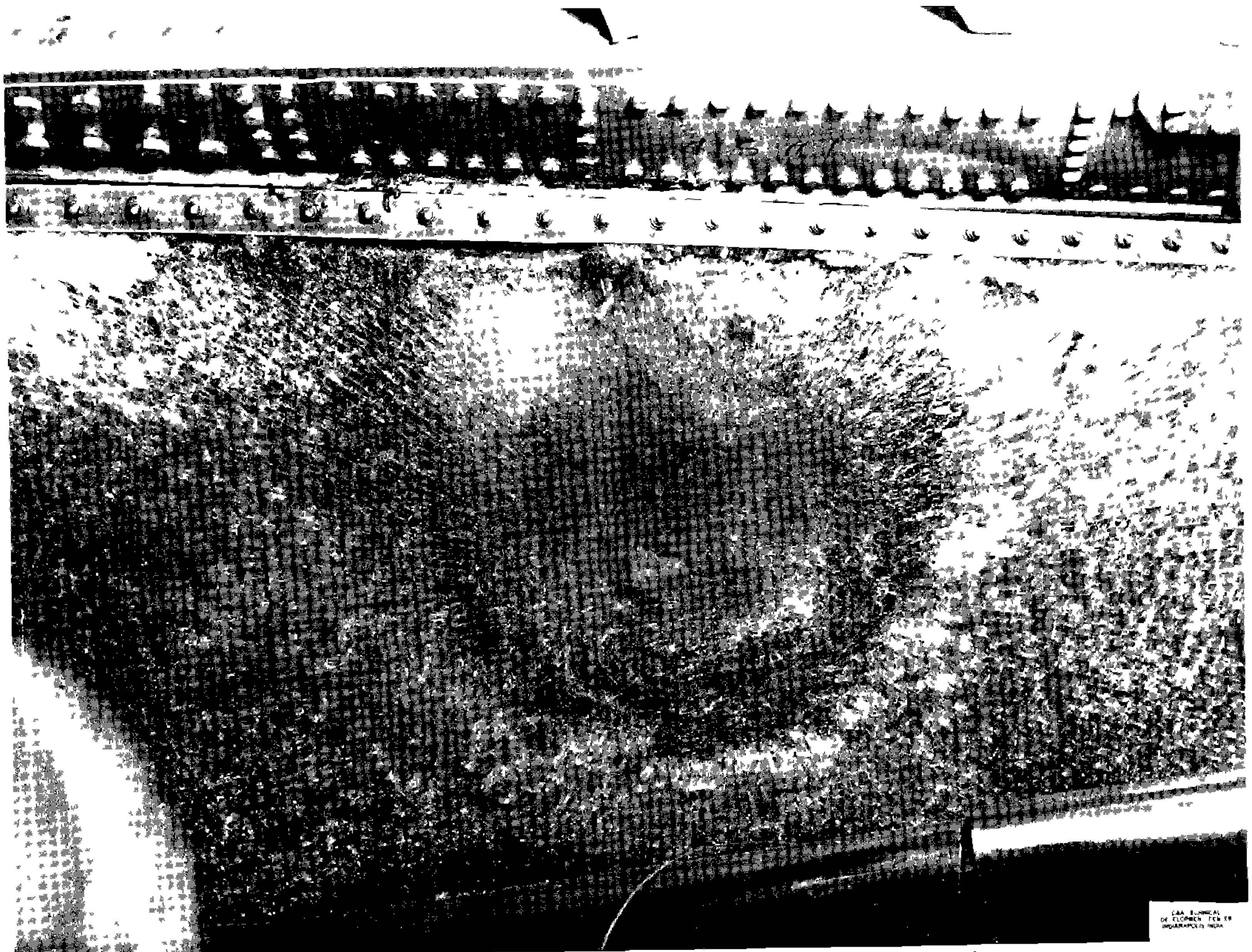


FIG 6 TEST NO 2 - 7/13/56 - BIRD-CARCASS VELOCITY 380 mph

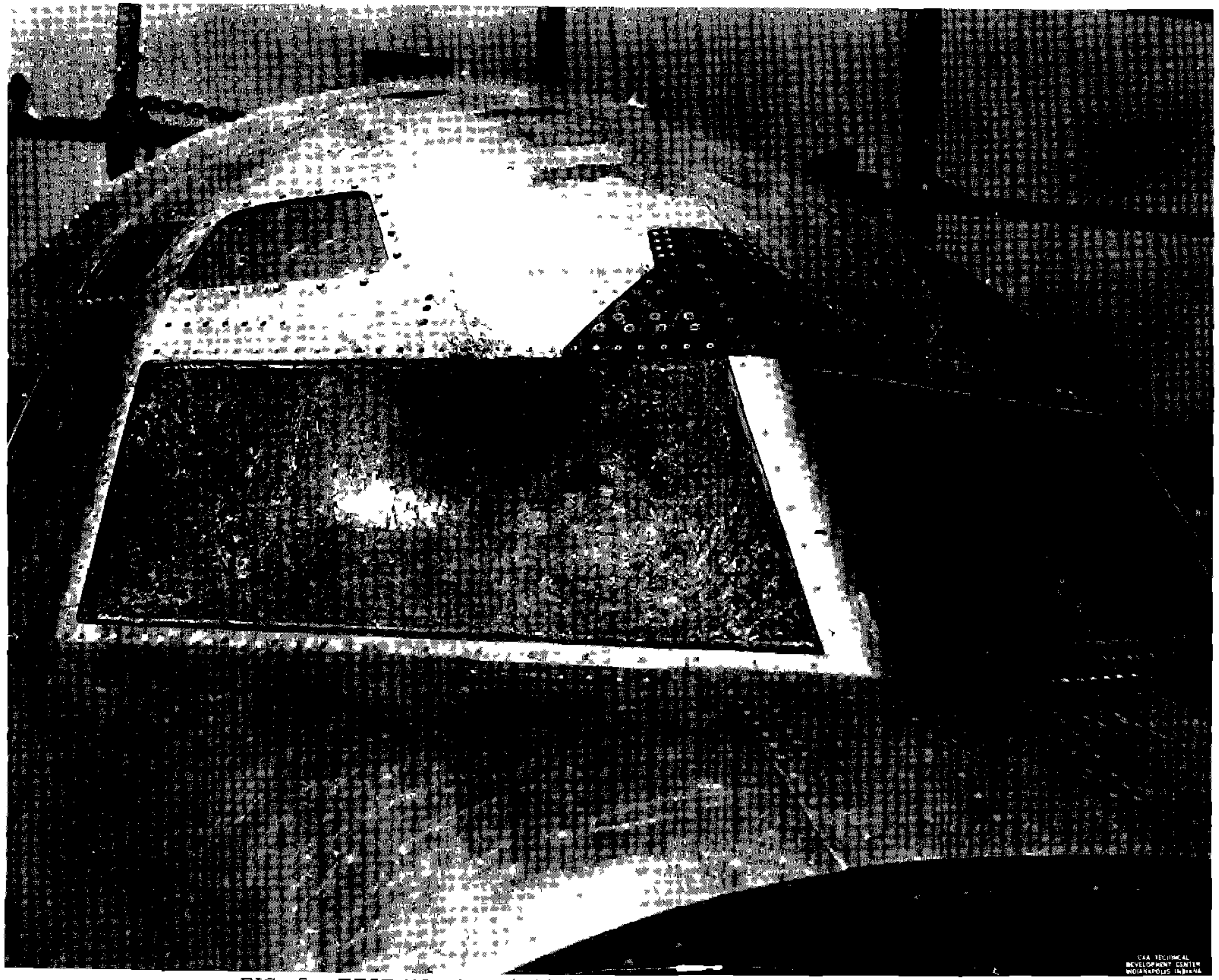


FIG 7 - TEST NO 3 - 7/14/56 - BIRD-CARCASS VELOCITY 393 mph

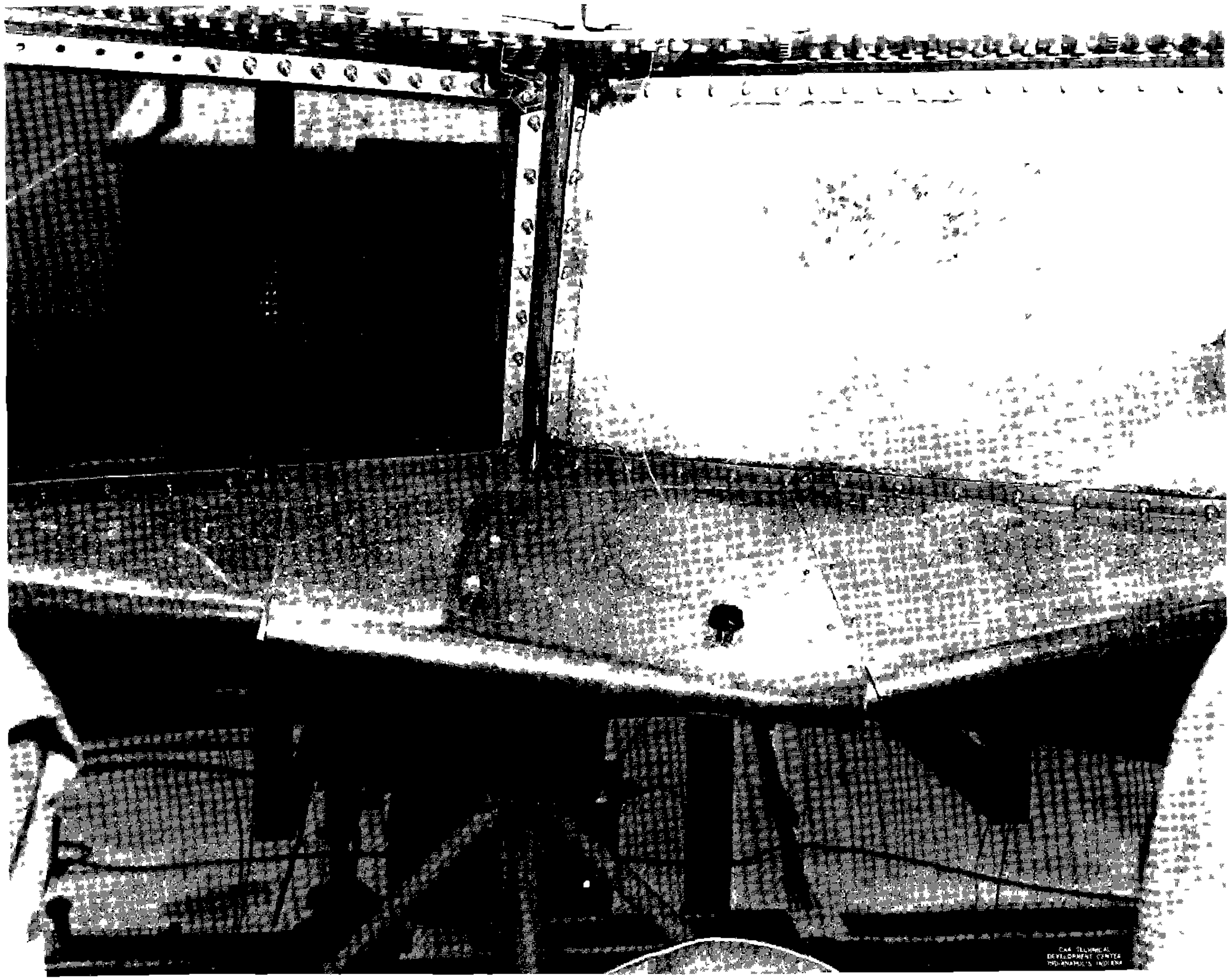


FIG 8 - TEST NO 3 - 7/14/56 - BIRD-CARCASS VELOCITY 393 mph

FIG. 9 - TEST NO 3 - 7/14/56 - BIRD-CARCASS VELOCITY 393 mph

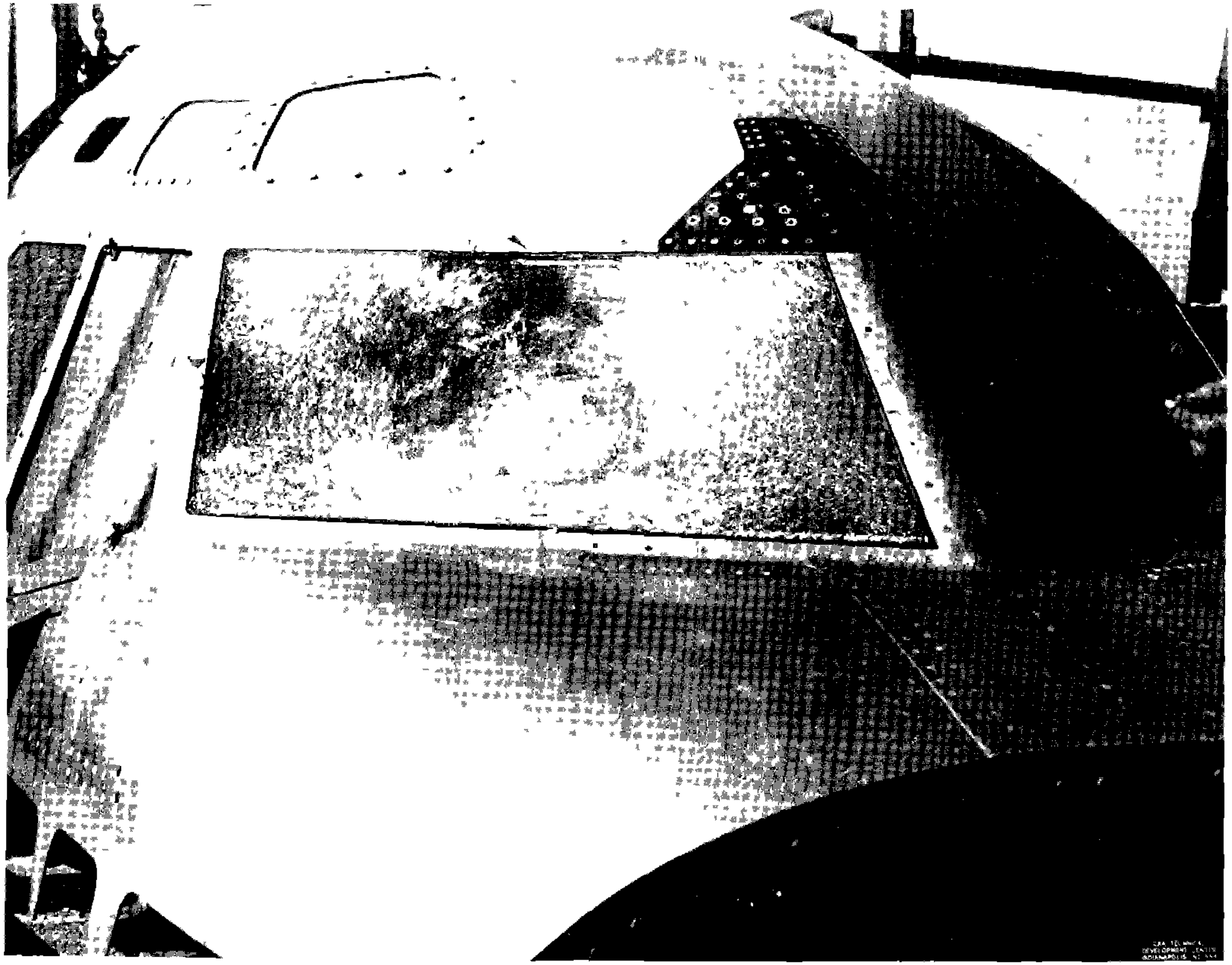


FIG 10 - TEST NO 4 - 7/14/56 - BIRD-CARCASS VELOCITY 415 mph

FIG. 11 - TEST NO. 4 - 7/14/56 - BIRD-CARCASS VELOCITY 415 mph

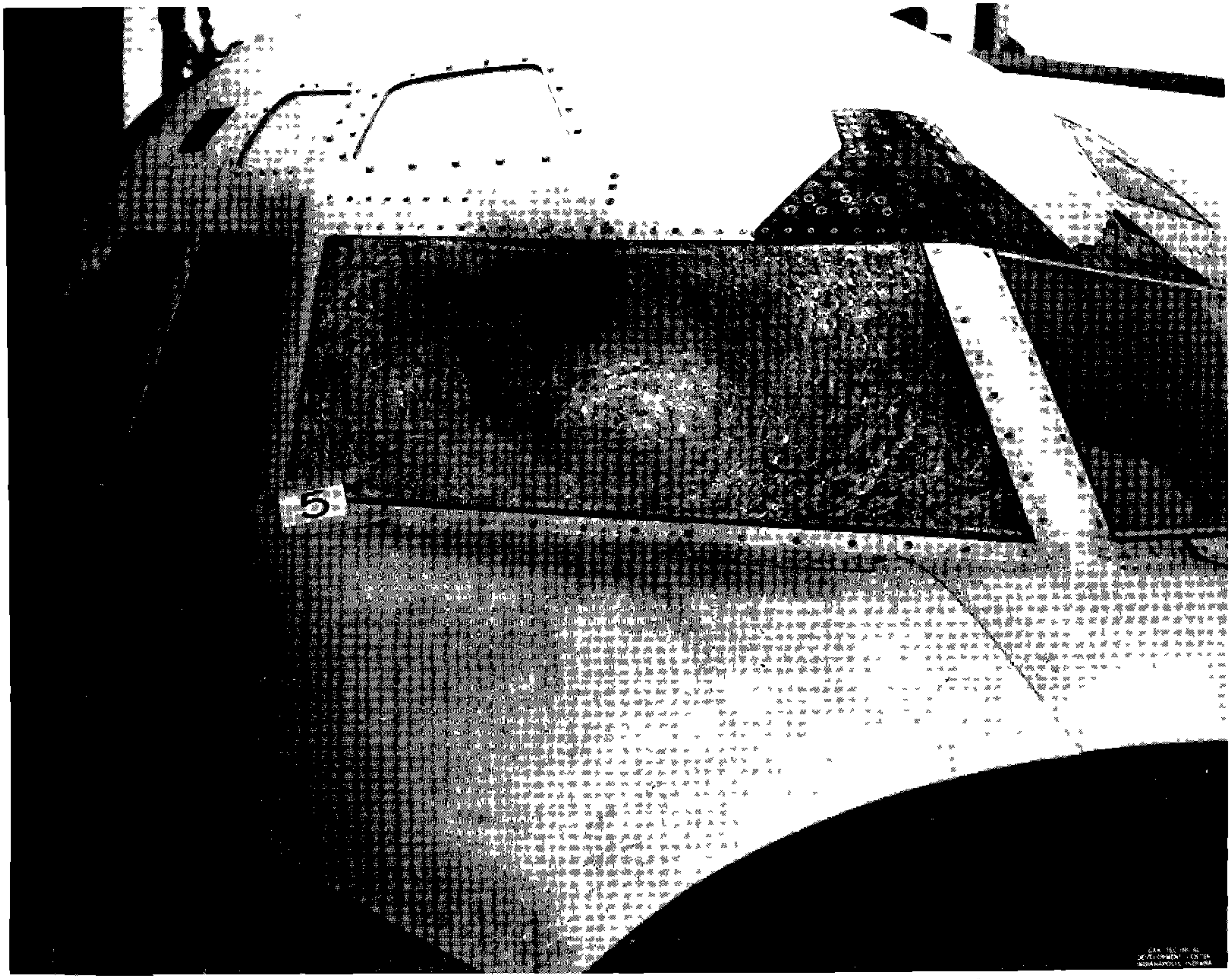


FIG. 12 - TEST NO. 5 - 7/15/56 - BIRD-CARCASS VELOCITY 422 mph

FIG. 13 - TEST NO. 5 - 7/15/56 - BIRD-CARCASS VELOCITY 422 mph

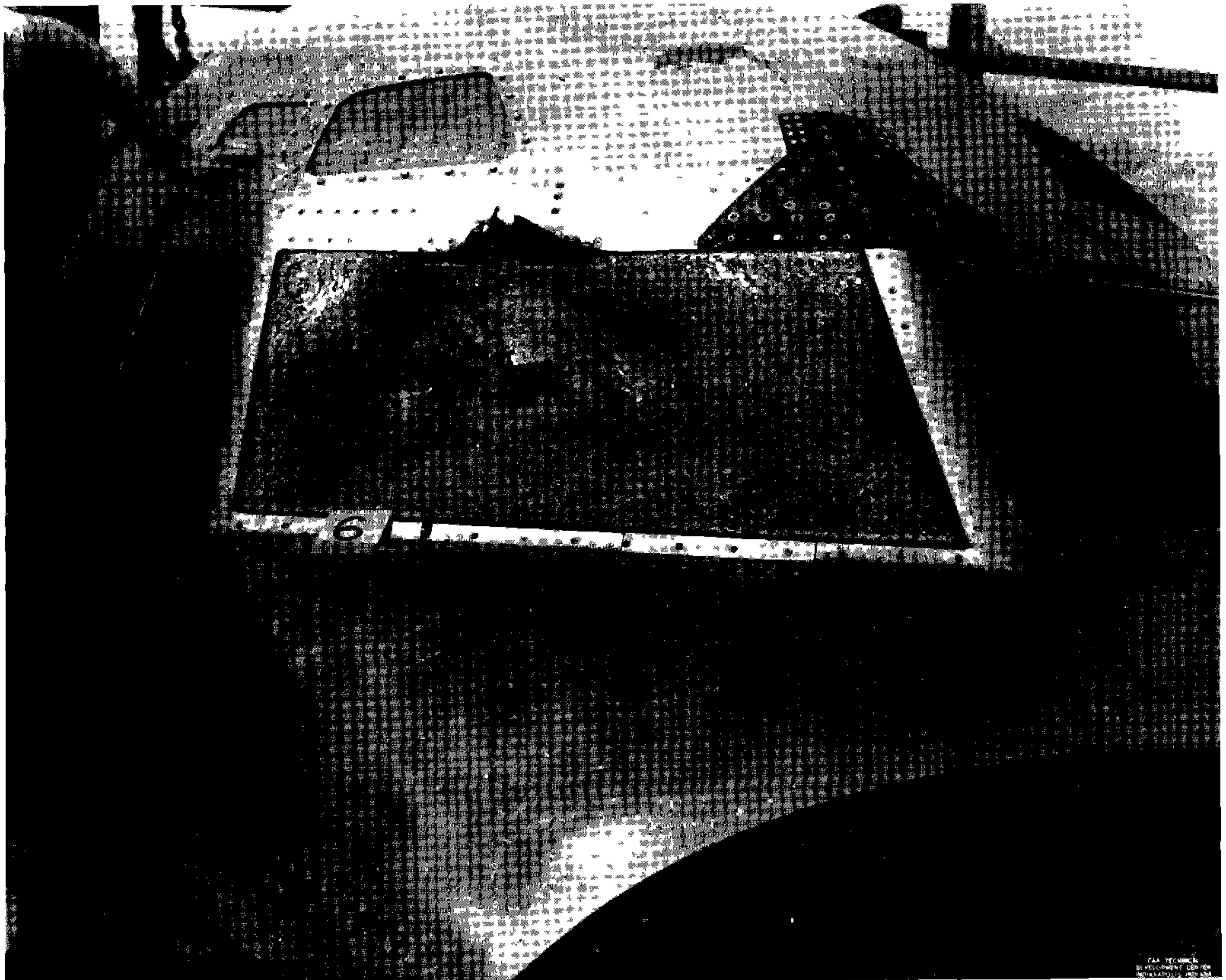


FIG. 14 - TEST NO. 6 - 7/16/56 - BIRD-CARCASS VELOCITY 440 mph

FIG 15 - TEST NO. 6 - 7/16/56 - BIRD-CARCASS VELOCITY 440 mph

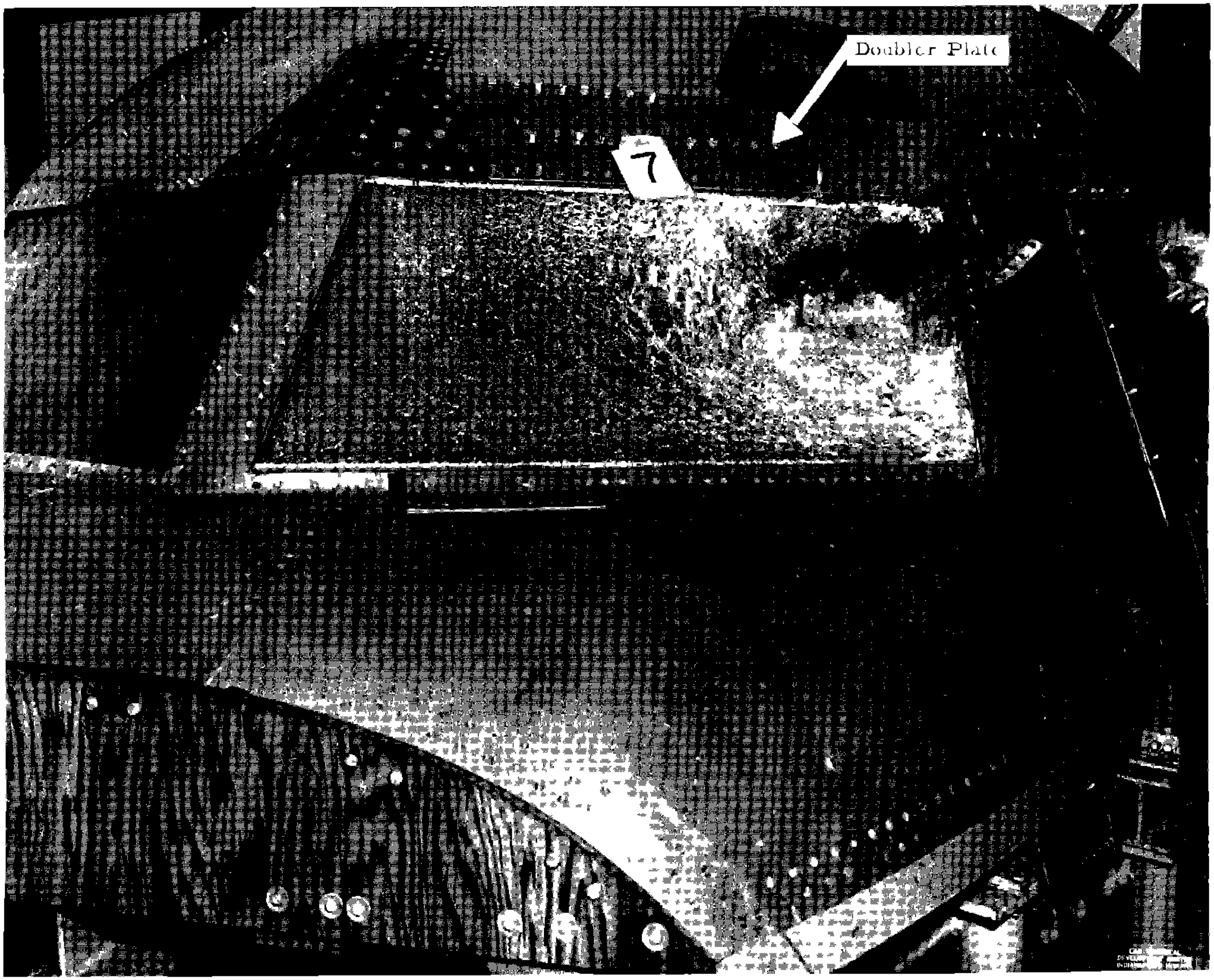


FIG 16 - TEST NO 7 - 7/17/56 - BIRD-CARCASS VELOCITY 380 mph

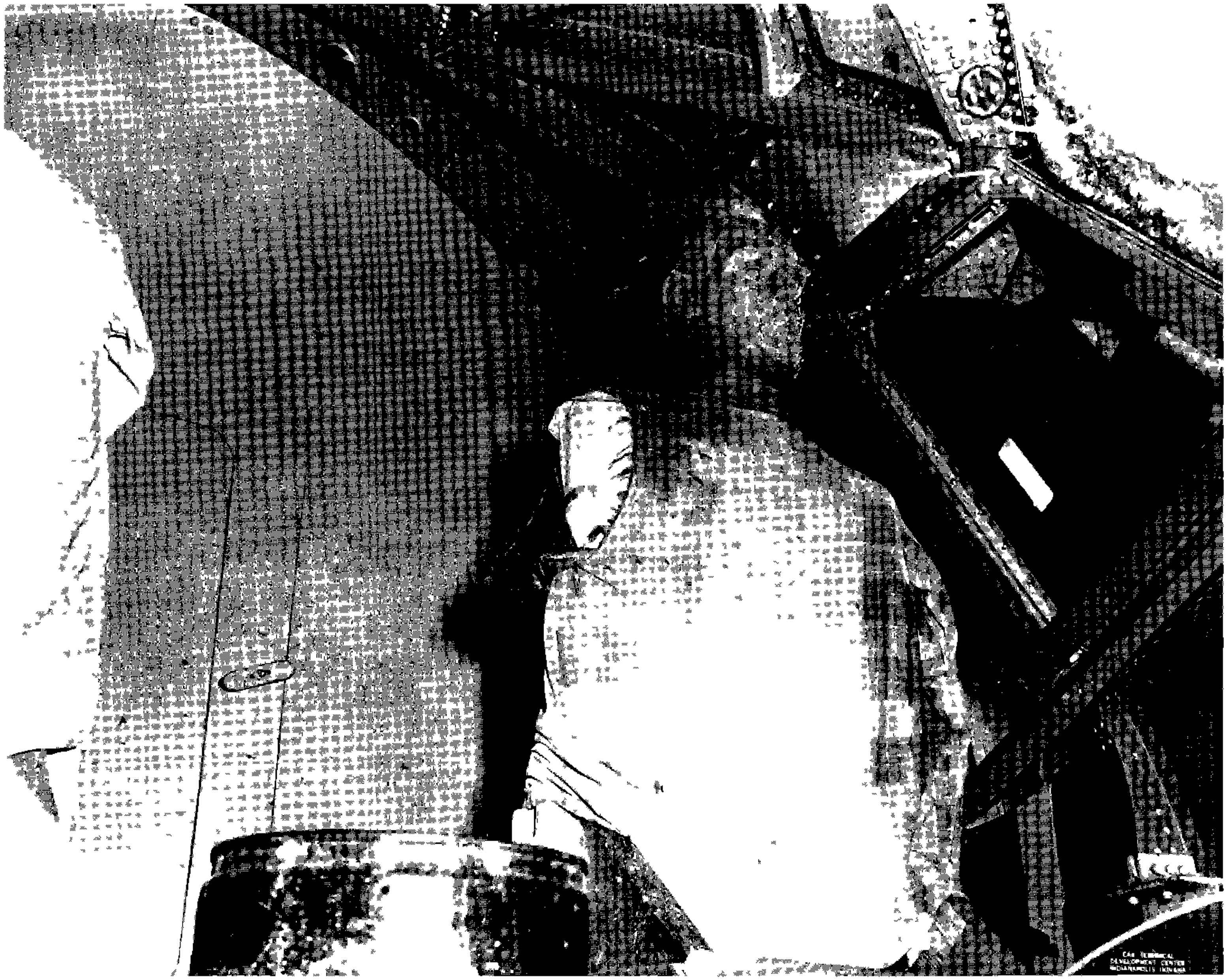


FIG 17 - TEST NO 7 - 7/17/56 - BIRD-CARCASS VELOCITY 380 mph

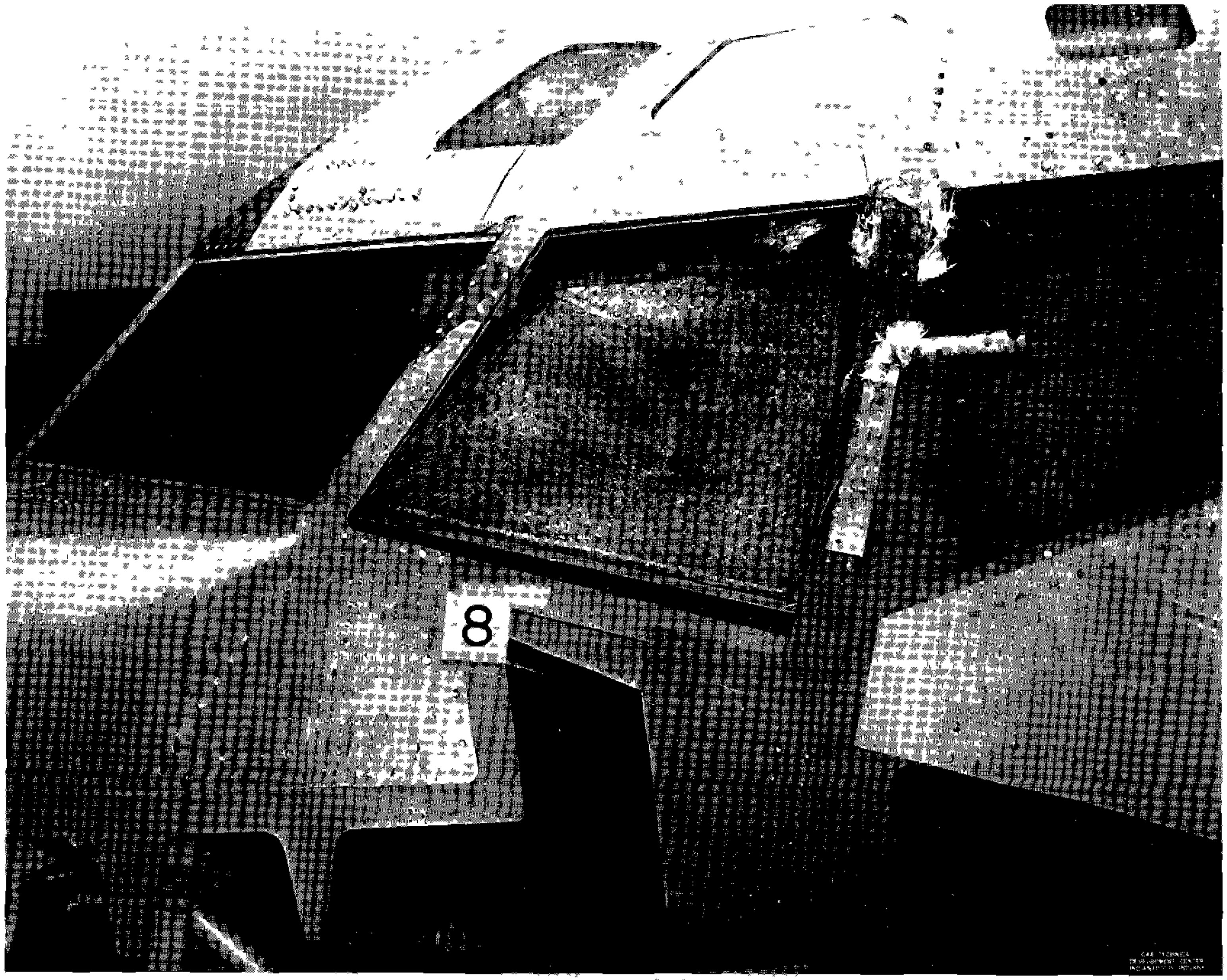


FIG. 18 - TEST NO. 8 - 7/18/56 - BIRD-CARCASS VELOCITY 378 mph

FIG. 19 - TEST NO. 8 - 7/18/56 - BIRD-CARCASS VELOCITY 378 mph

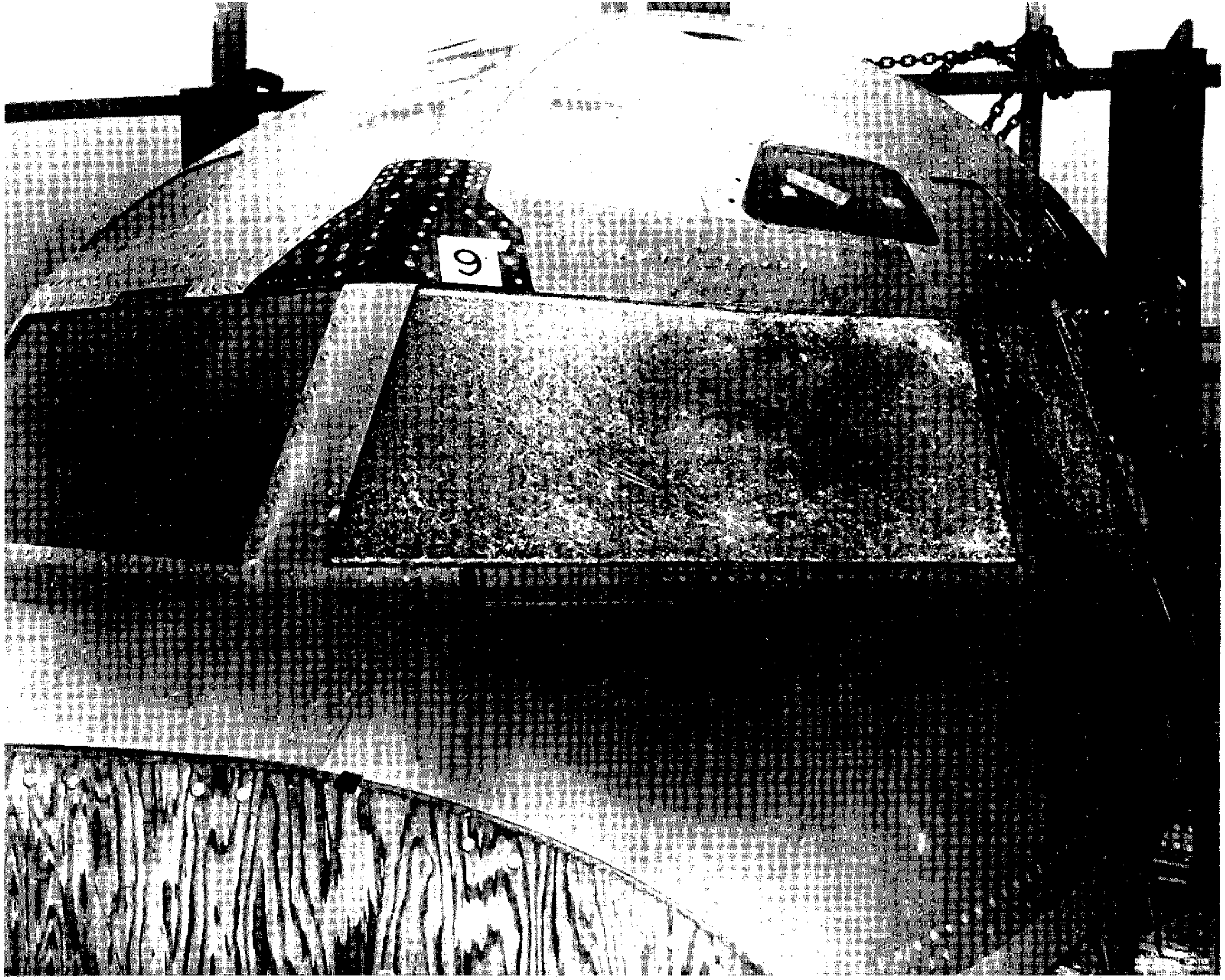


FIG. 20 - TEST NO. 9 - 7/18/56 - BIRD-CARCASS VELOCITY 400 mph

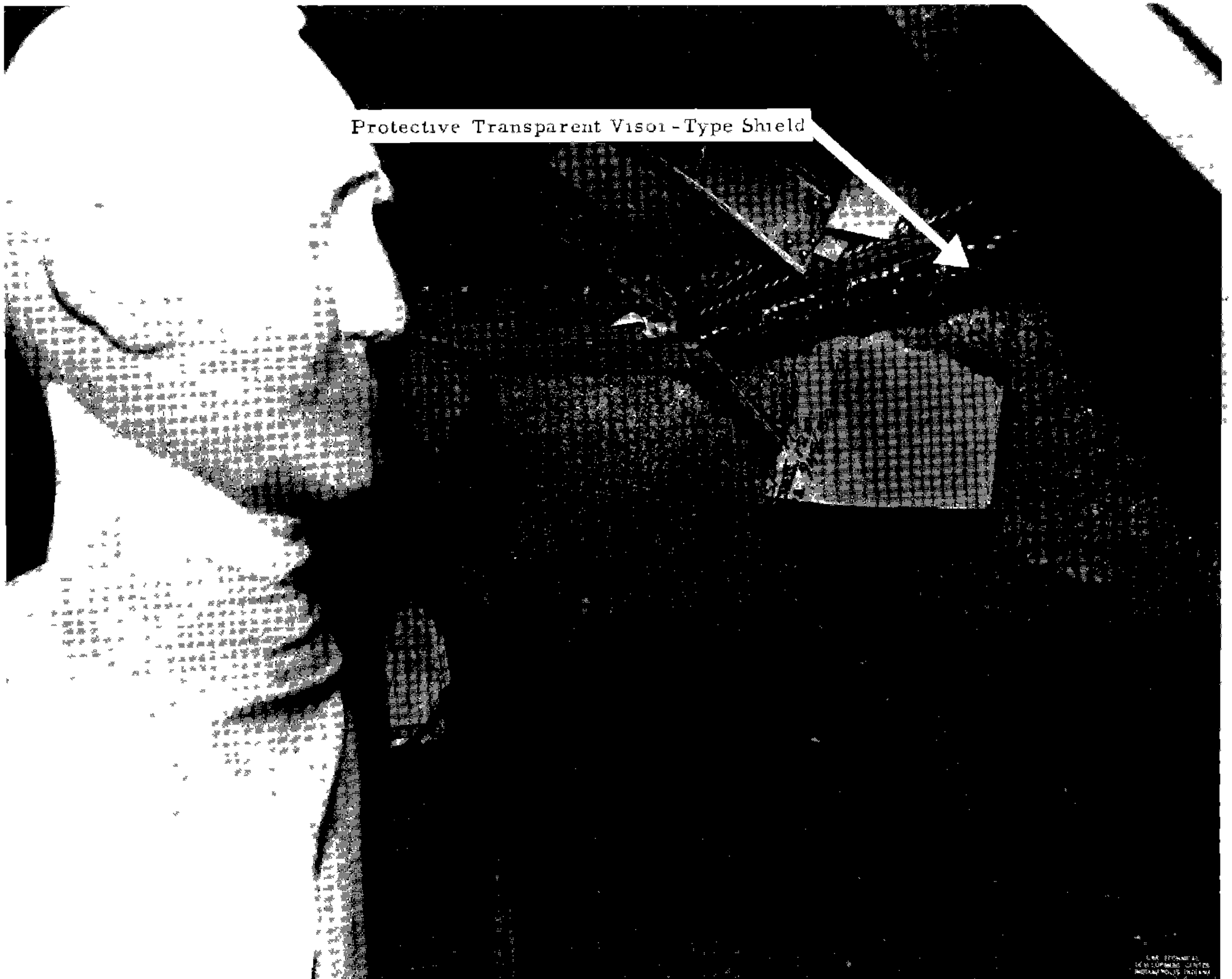


FIG 21 - TEST NO. 9 - 7/18/56 - BIRD-CARCASS VELOCITY 400 mph

FIG 22 - TEST NO. 10 - 7/19/56 - BIRD-CARCASS VELOCITY 460 mph

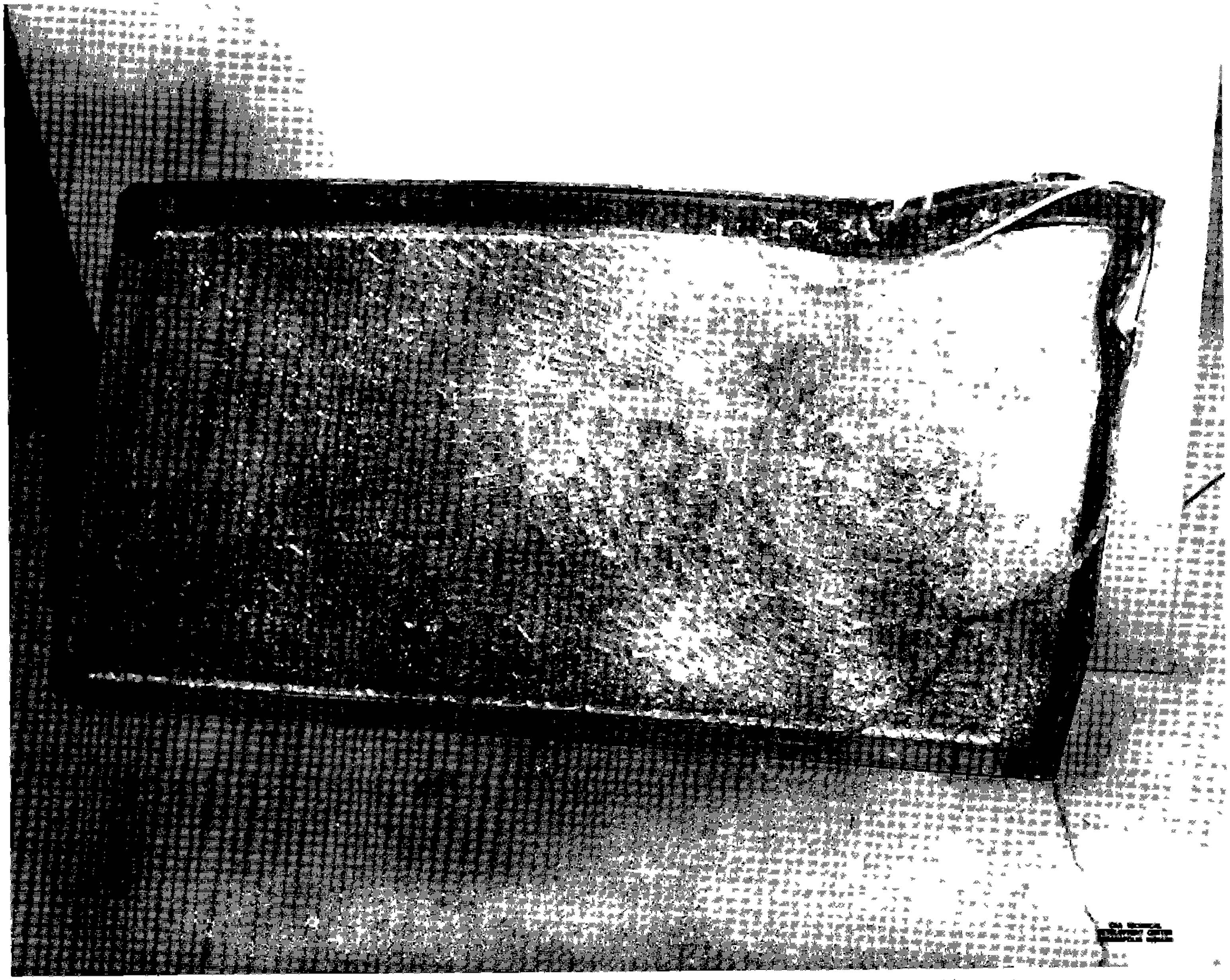


FIG 23 - TEST NO 10 - 7/19/56 - BIRD-CARCASS VELOCITY 460 mph

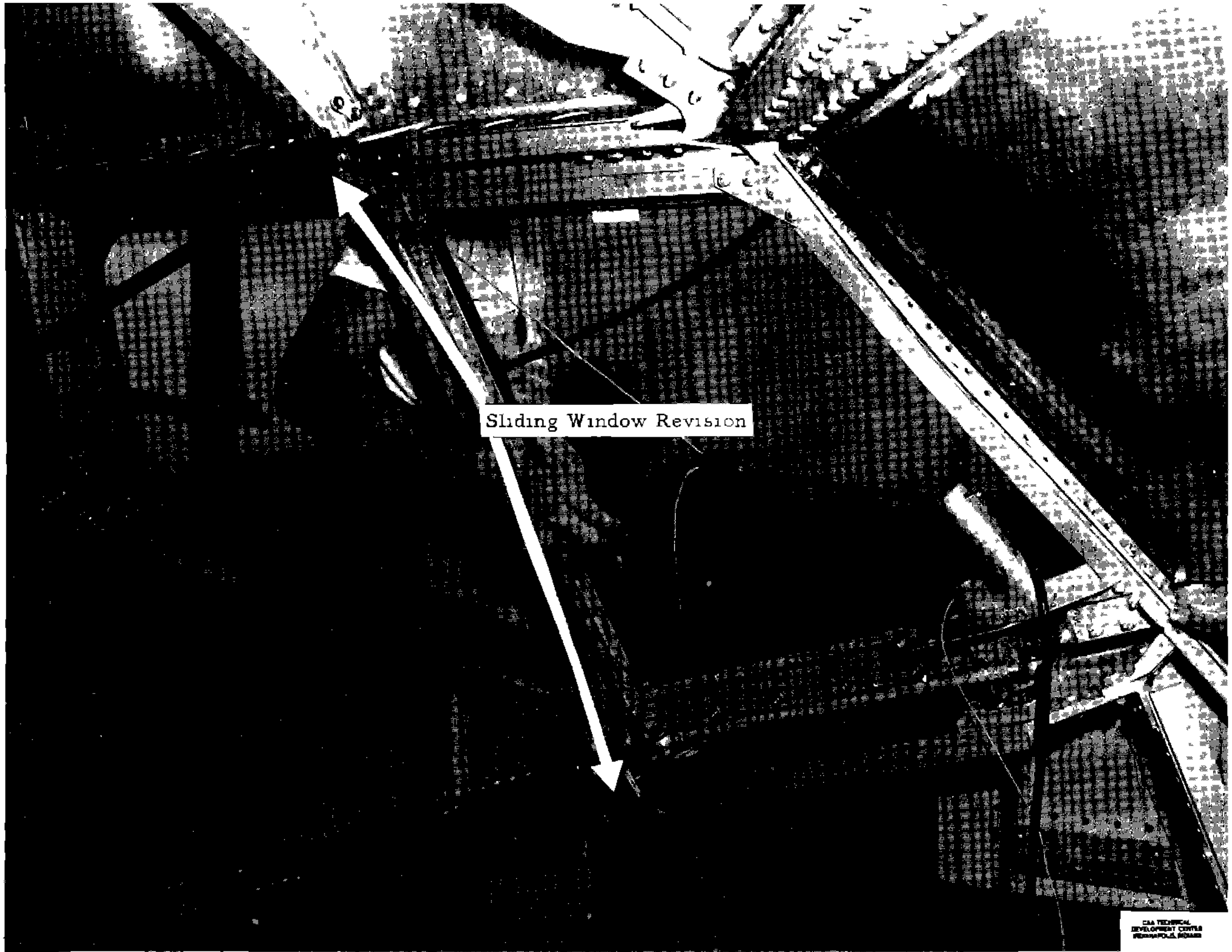


FIG. 24 - PRIOR TEST NO. 11 - REVISED SIDE-WINDOW RETAINING ARRANGEMENT

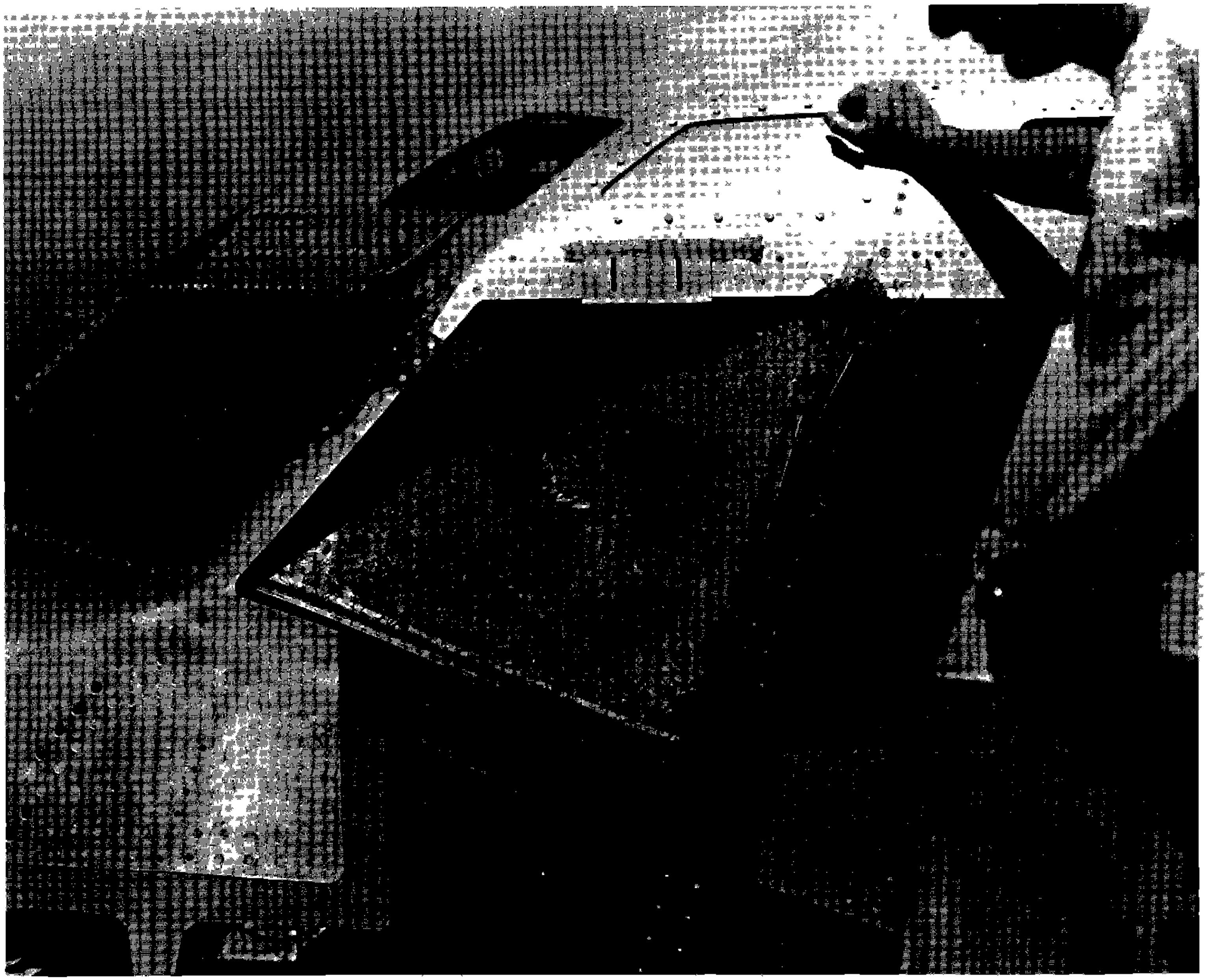


FIG 25 - TEST NO 11 - 7/20/56 - BIRD-CARCASS VELOCITY 420 mph

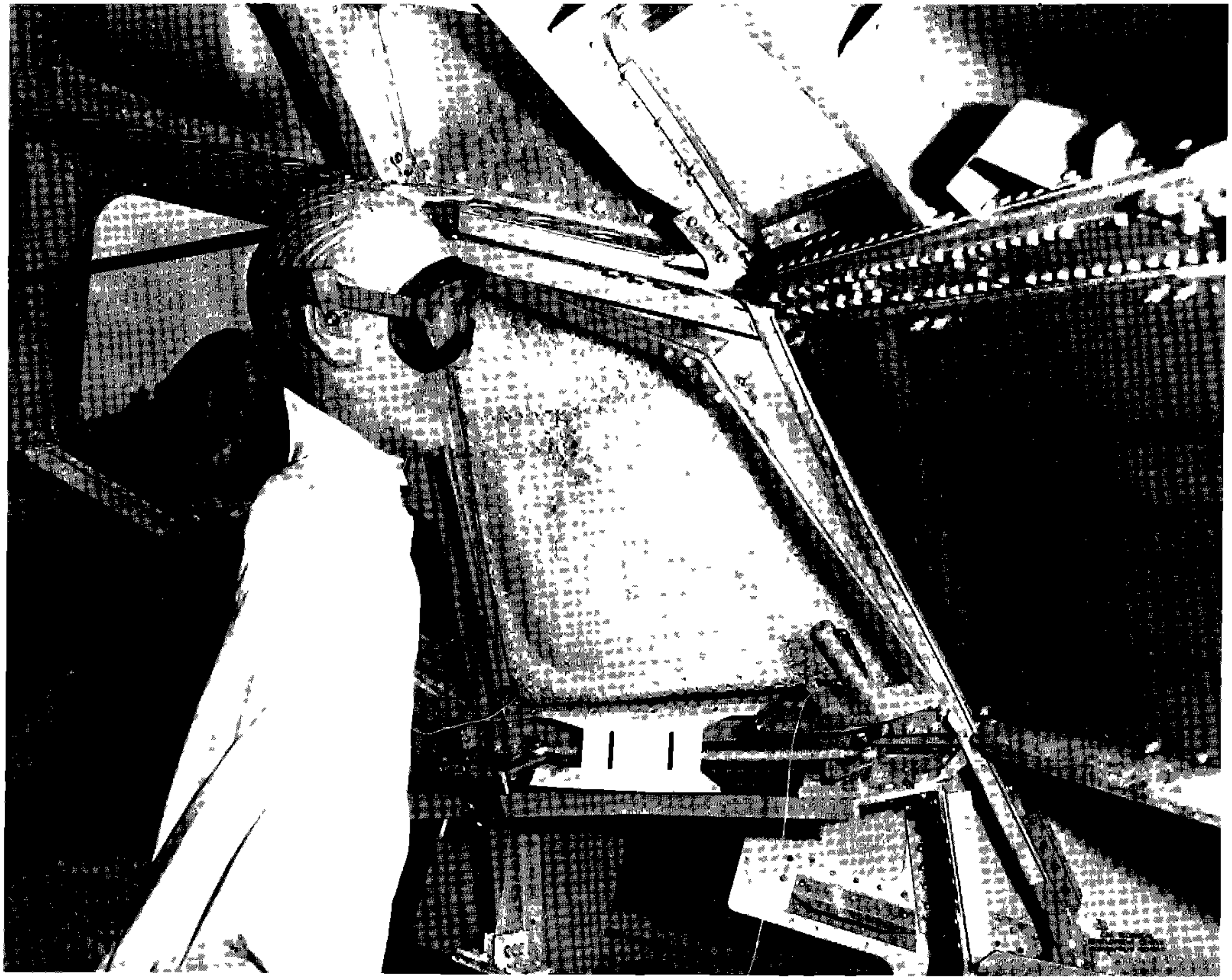


FIG 20 - TEST NO 11 - 7/20/56 - BIRD-CARCASS VELOCITY 420 mph

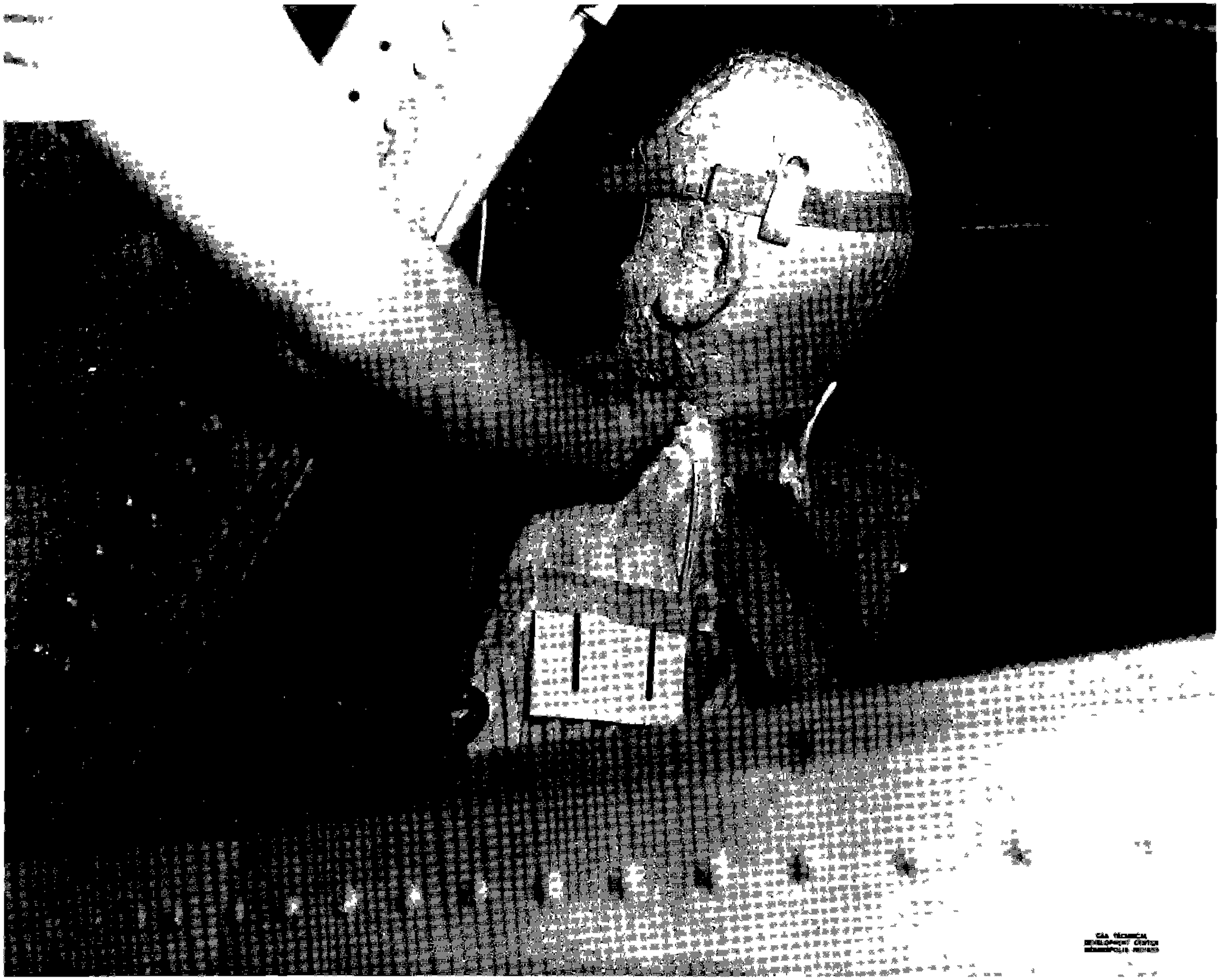


FIG 27 - TEST NO 11 - 7/20/56 - BIRD-CARCASS VELOCITY 420 mph

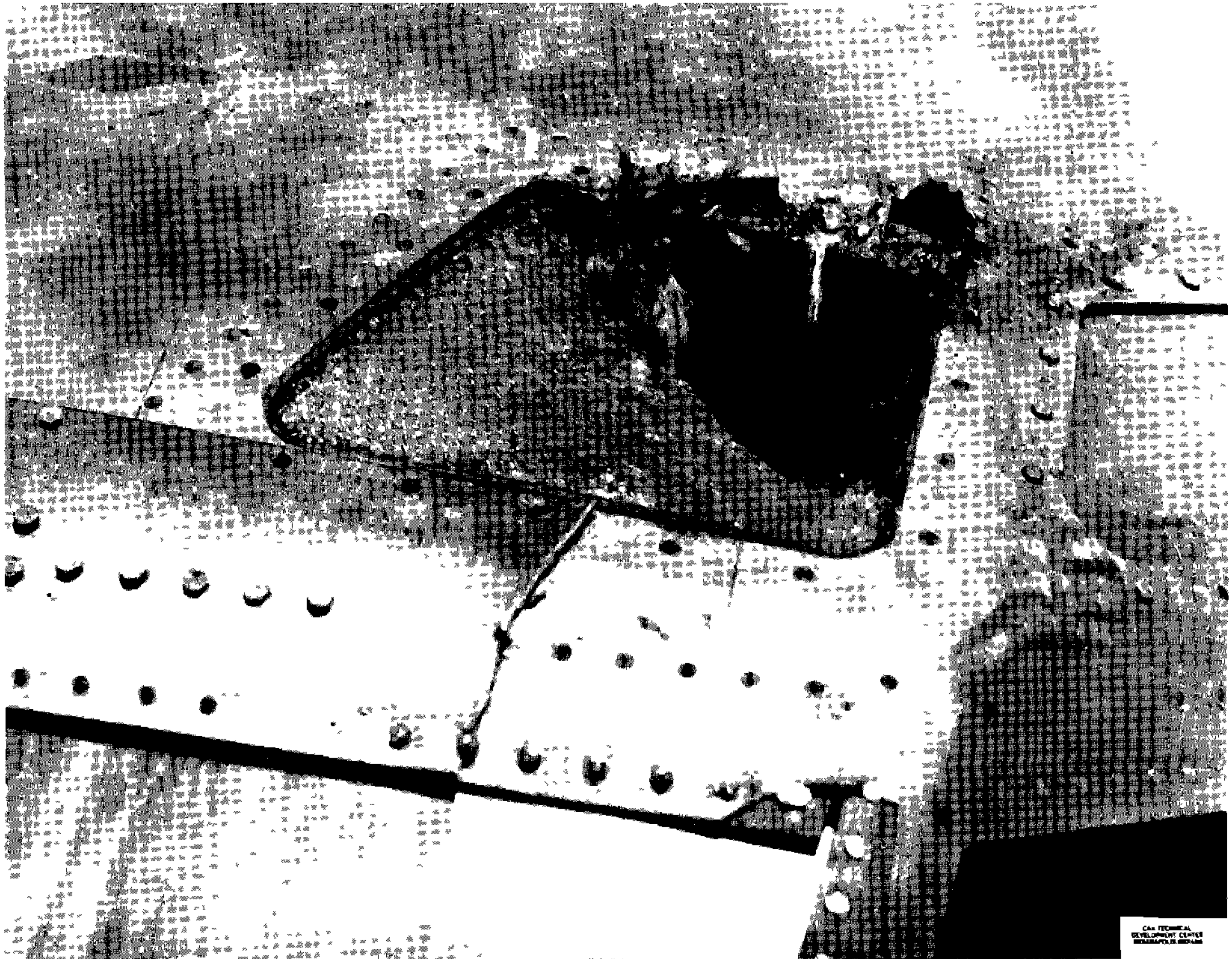


FIG. 28 - TEST NO. 12 - 7/21/56 - BIRD-CARCASS VELOCITY 393 mph

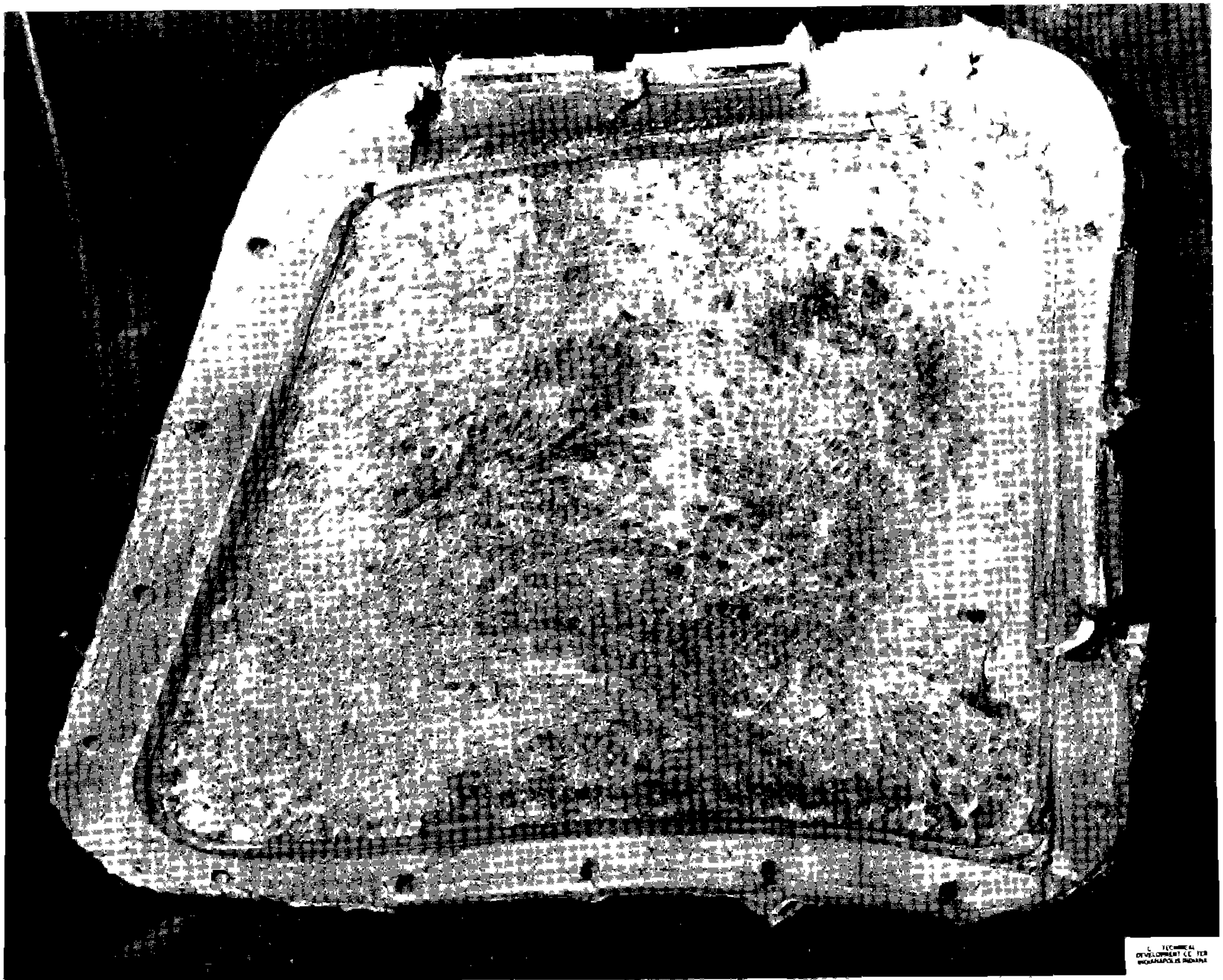


FIG. 29 - TEST NO 12 - 7/21/56 - BIRD-CARCASS VELOCITY 393 mph

FIG. 50 - TEST NO. 12 - 7/21/56 - BIRD-CARCASS VELOCITY 393 mph

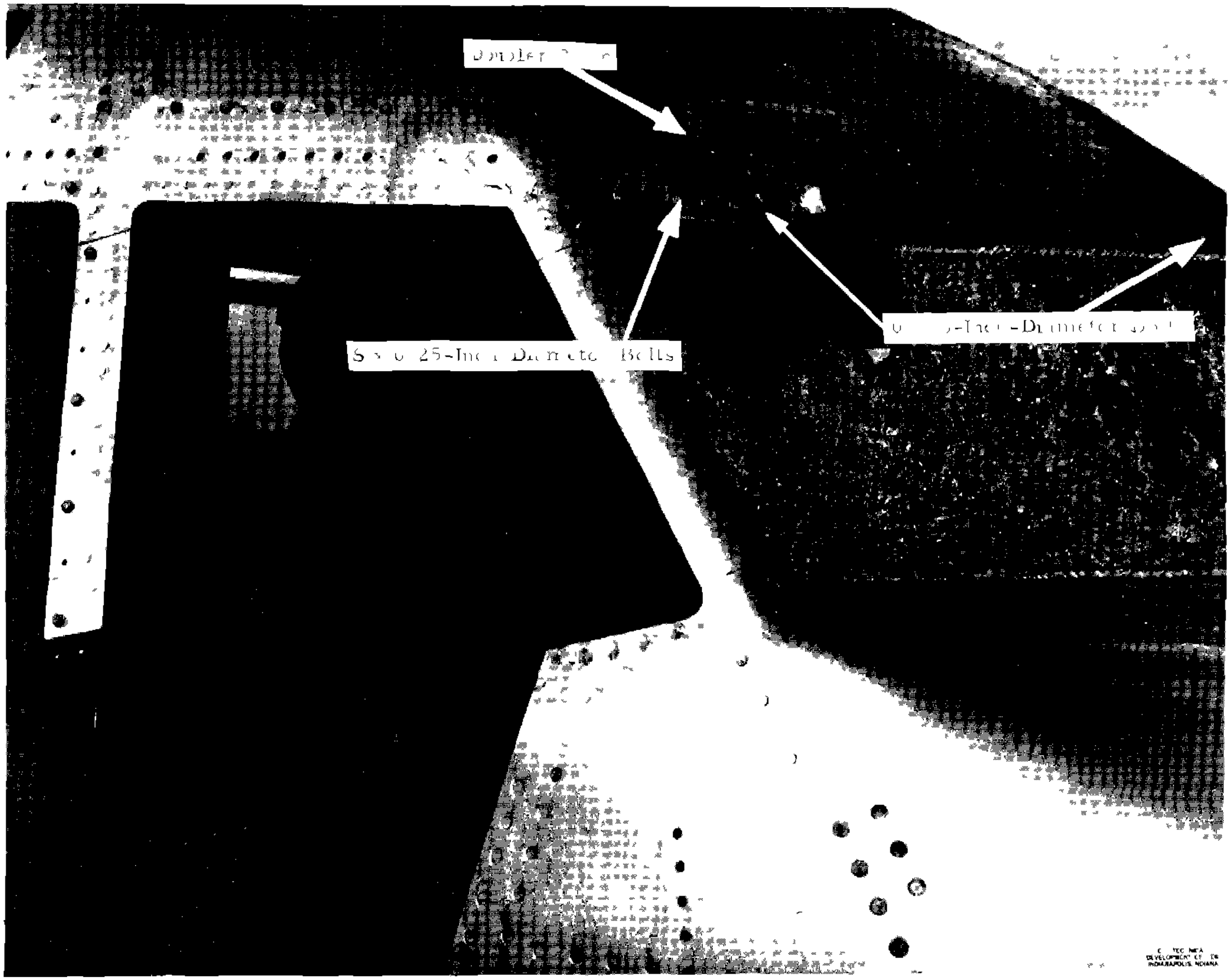


FIG 51 - TEST NO 13 - 7/21/56 - BIRD-CARCASS VELOCITY 450 mph

FIG. 32 - TEST NO. 13 - 7/21/56 - BIRD-CARCASS VELOCITY 450 mph

FIG 33 - TEST NO 13 - 7/21/56 - BIRD-CARCASS VELOCITY 450 mph

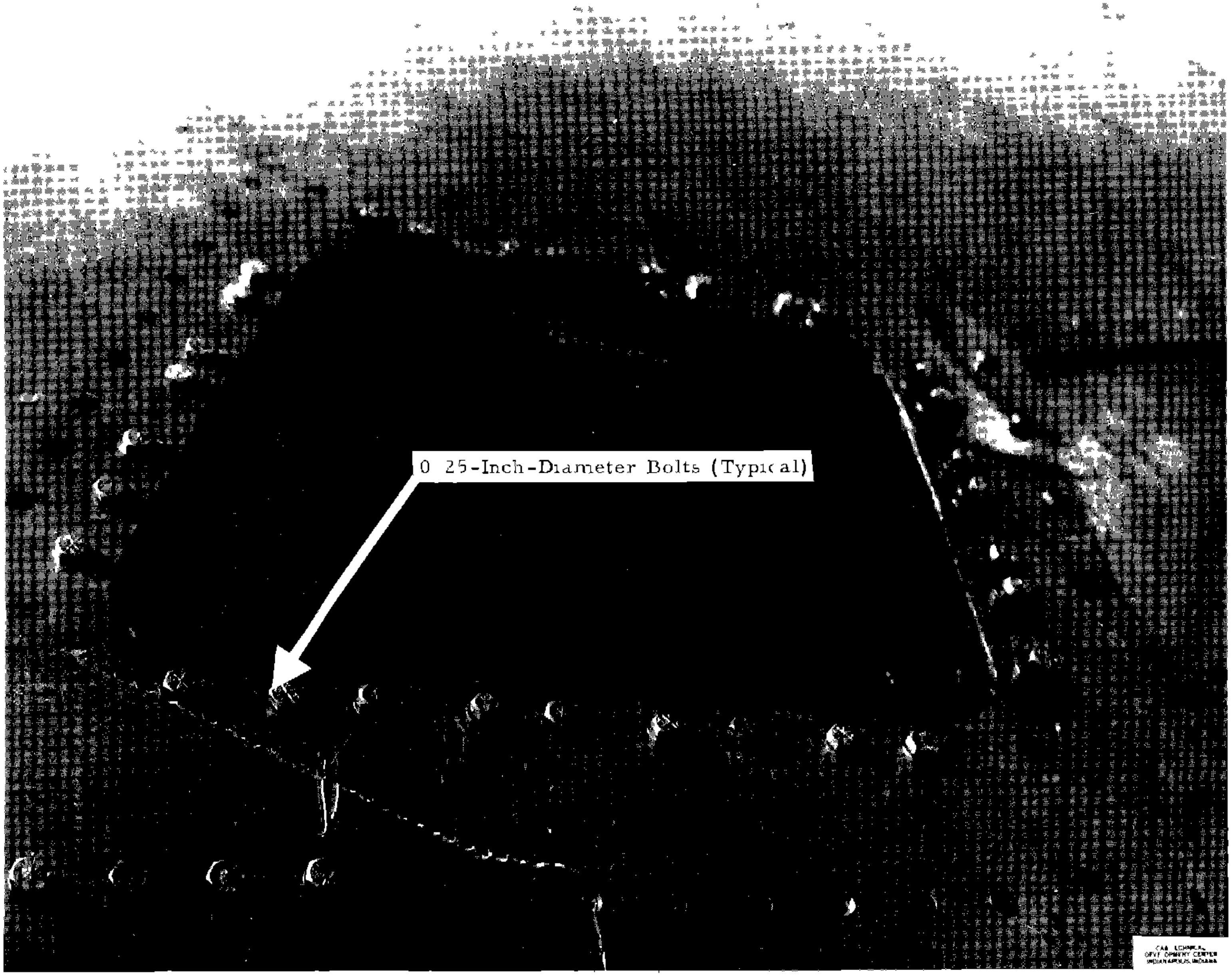


FIG 34 - PRIOR TEST NO 14 - REVISED EYEBROW-WINDOW ARRANGEMENT

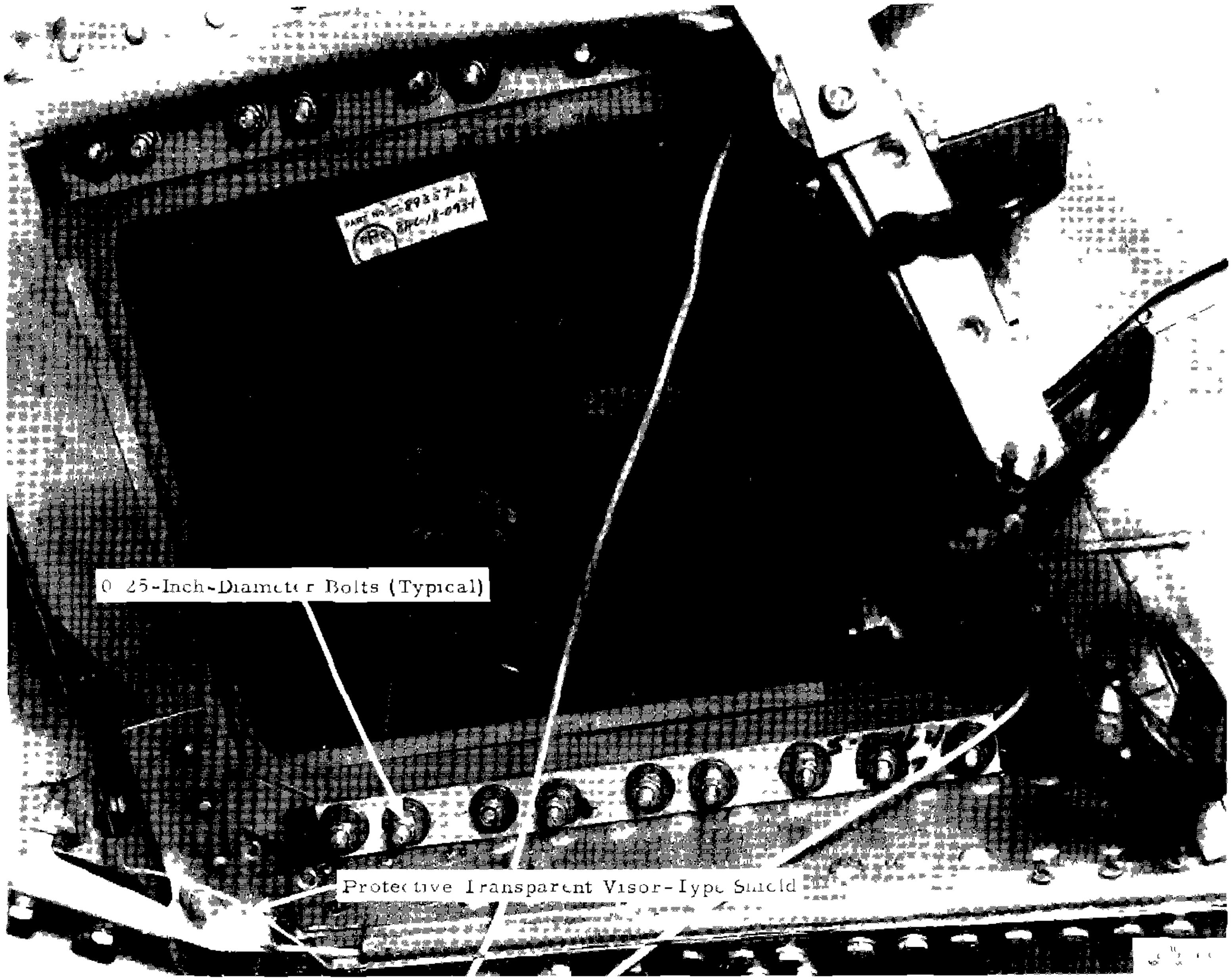


FIG 35 - PRIOR TEST NO 14 - REVISED EYEBROW-WINDOW ARRANGEMENT

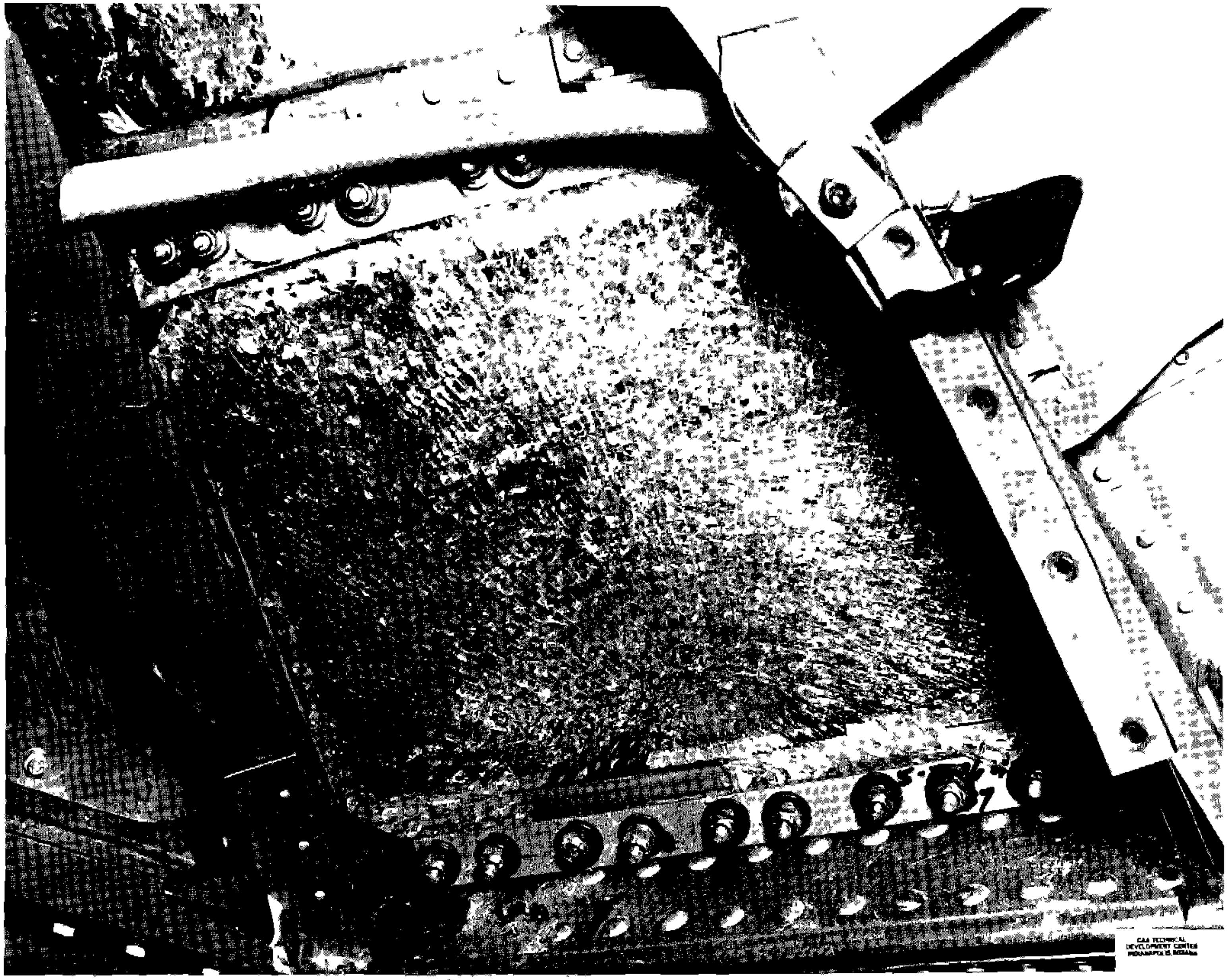


FIG. 36 - TEST NO. 14 - 7/22/56 - BIRD-CARCASS VELOCITY 405 mph

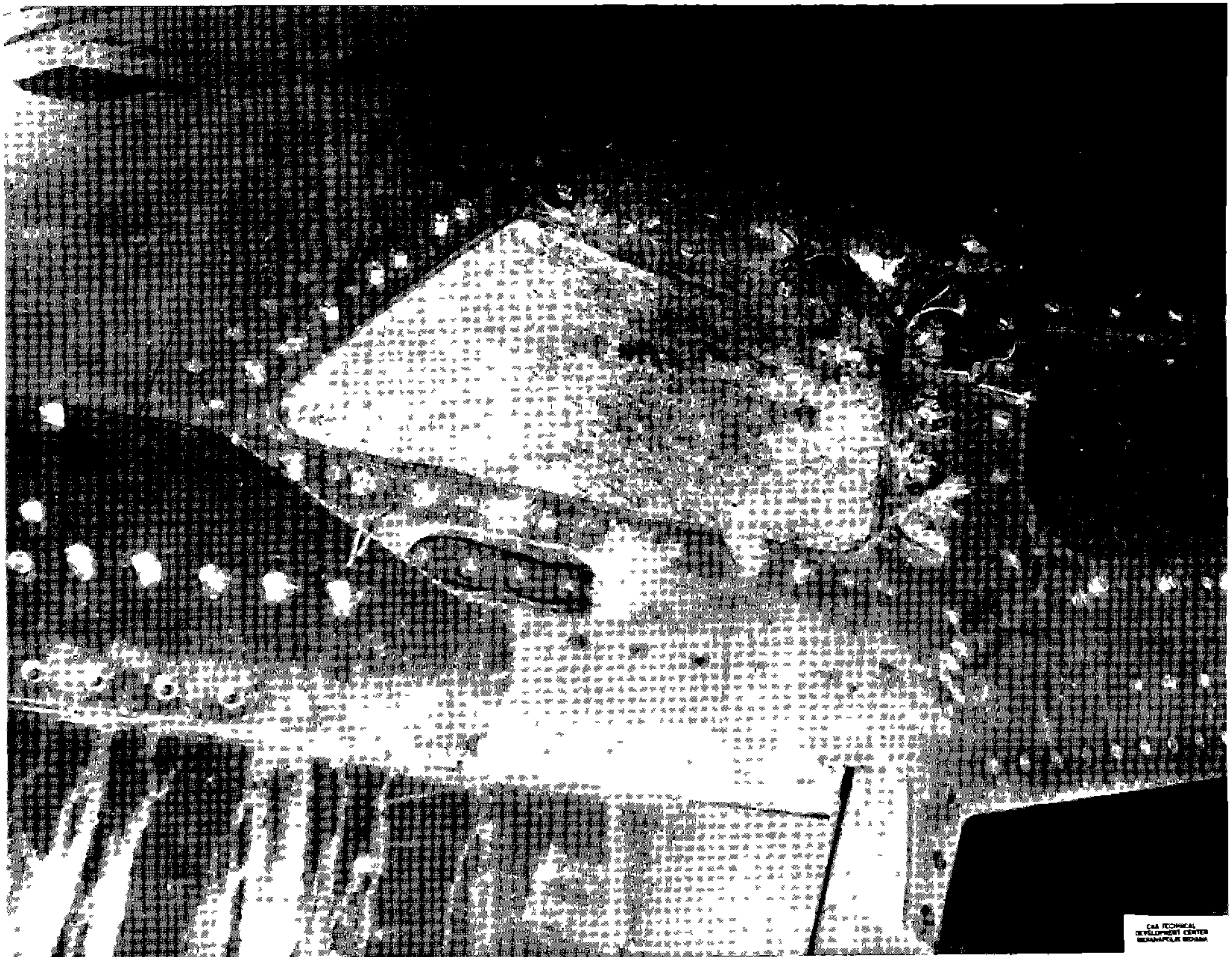


FIG. 37 - TEST NO. 14 - 7/22/56 - BIRD-CARCASS VELOCITY 405 mph

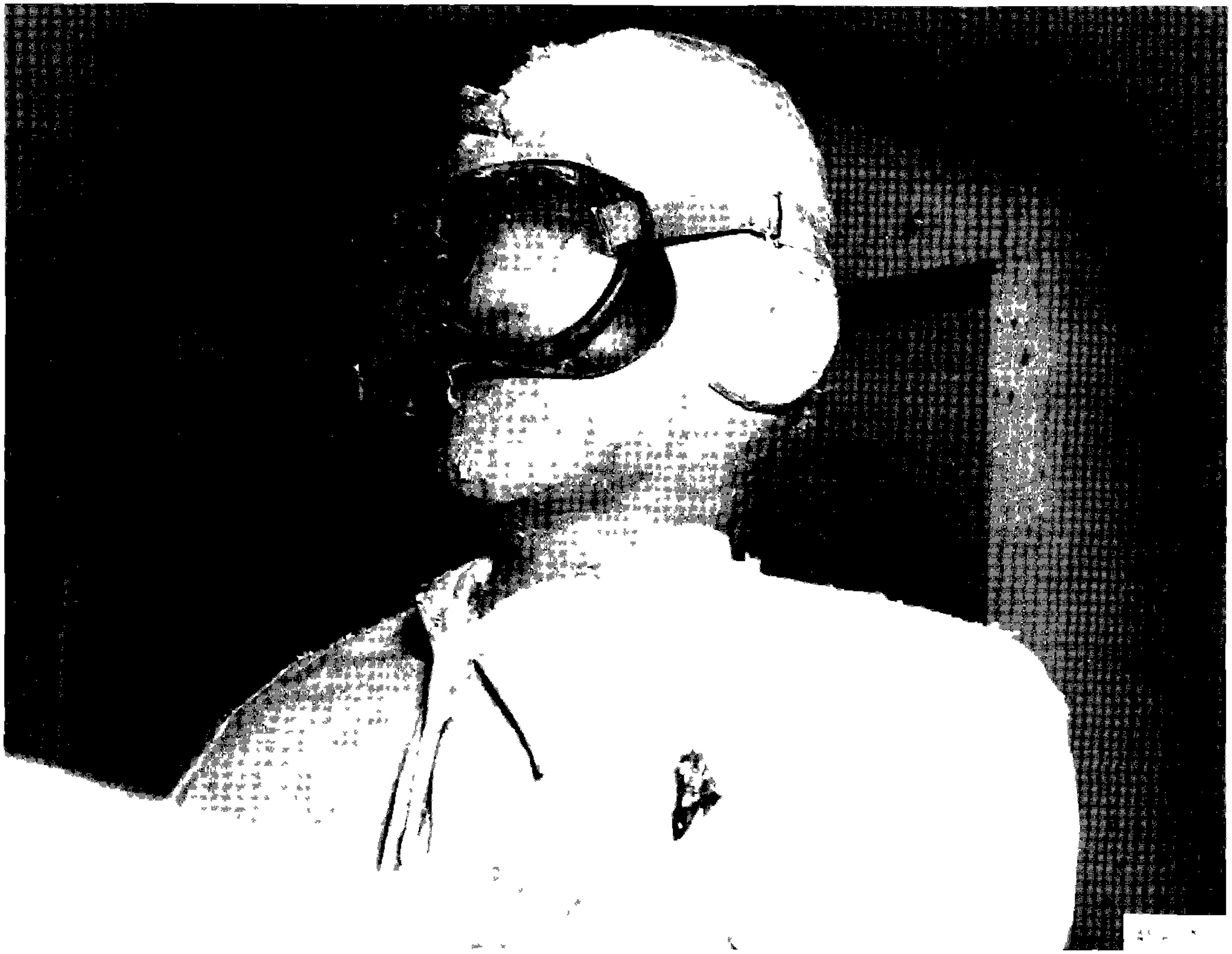


FIG. 58 - TEST NO. 14 - 7/22/56 - BIRD-CARCASS VELOCITY [illegible] mph