TECHNICAL DEVELOPMENT REPORT NO. 342

BIRD-IMPACT TESTS OF THE BOEING MODEL 707 AIRPLANE EYEBROW WINDOW

FOR LIMITED DISTRIBUTION

by

John Summers, Jr.
Roy K. Hackbarth

Aircraft Division

April 1958

CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT CENTER
INDIANAPOLIS, INDIANA

BIRD-IMPACT TESTS OF THE BOEING MODEL 707 AIRPLANE EYEBROW WINDOW

INTRODUCTION

Additional tests involving the impact of bird carcasses on the eyebrow window of the Boeing Model 707 airplane were conducted at the Civil Aeronautics Administration Technical Development Center, Indianapolis, Indiana, during the period May 15 to May 29, 1957. The results of 14 tests conducted previously on the over-all windshield canopy, including the eyebrow window, during the period July 12 to July 26, 1956, are described in Technical Development Report No. 301.[1] The purpose of these additional tests was to help develop an eyebrow window which, when struck by a four-pound bird carcass, would prevent penetration and would minimize the danger to the pilots from flying window fragments. The tests were conducted with the assistance of Mr. Robert L. Peterson of the Boeing Airplane Company.

EYEBROW-WINDOW INSTALLATION

The eyebrow window was mounted in a welded steel jig assembly furnished by the Boeing Airplane Co. The jig was fabricated to represent the relative position of the pilot's eyebrow window exactly as it is installed in the Boeing 707 airplane. Inboard, outboard, and bottom sills, plus the top sill intercostal, were mounted as shown in Fig. 1. The top sill intercostal is shown in Fig. 2. These sills were fabricated and attached to the jig assembly in Tests Nos. 15 and 16 in accordance with the original Boeing 707 design, modified as a result of tests conducted during the period July 12 to July 26, 1956. During Tests Nos. 17 through 26, the sill construction and attachment were modified as indicated in Table I.

The eyebrow window is fastened directly to the sill structure by bolts which pass through the edge of the window as shown in Fig. 3. The window is mounted from the inside and retaining nuts bear against a washer plate. The window, mounted in the jig assembly, is shown in Fig. 4.

The windows tested were manufactured by the Pittsburgh Plate Glass Co. and the Libbey-Owens-Ford Co. Windows manufactured by the Pittsburgh

[1] John Sommers, Jr., "Bird-Impact Tests of the Boeing Model 707 Airplane Windshield," CAA Technical Development Report No. 301, February 1957.

Plate Glass Co. incorporated the electrically operated and controlled NESA heating unit. Structural details of the eyebrow window panels tested are indicated in Table I and Fig. 3. Boeing drawing numbers pertaining to the original eyebrow window design and to that of Test No. 26 are given in Table I.

TEST PROCEDURE

Freshly killed chicken carcasses were propelled at the test structure by means of a compressed air gun. The chicken carcasses were placed in a cloth sack, backed up by a Styrofoam plug 6 inches in diameter and 6 inches long. The use of the Styrofoam plug improved muzzle velocity control of the chicken carcass. The Styrofoam plug in turn was backed up by a thin, 6-inch-diameter, cellulose acetate disc to increase the strength of the plug. All this was placed inside the sack. The sack then was sewn shut. This arrangement gave the appearance of a projectile approximately 14 inches long and 6 inches in diameter. The combined weight of the chicken, Styrofoam plug, cellulose acetate disc, and cloth sack was 4 pounds, plus or minus 2 ounces. The weight of the plug, disc, and sack is approximately 5 ounces.

The jig assembly used in these tests was fastened securely to a temporary wood structure which was built up from, and securely fastened to, existing fixed structure of the test cell at the end of the gun barrel. The back of the jig was supported by wood members which slanted downward from the jig to the floor structure of the test cell. This mounting arrangement is shown in Fig. 5. The jig assembly was positioned so that the bird carcass would strike the geometric center of the window. This was accomplished by sighting through the gun barrel at the target point.

The following arrangements were used to evaluate glass fragmentation by visual inspection: During Tests Nos. 15 through 17, a freshly killed and plucked chicken carcass was placed on the floor of the jig assembly at the approximate relative location of the pilot's head, during Tests Nos. 20 through 24, one sheet of laminated cardboard packing was placed on the jig floor and one against the vertical back of the jig, during Tests Nos. 18 and 19, clay molded to the shape of a dome was placed on the floor of the jig to simulate the top of a pilot's head; during Test No. 26, two Styrofoam boards, each 2 inches thick, were placed behind the window, one in a horizontal position resting on the jig floor and one in a vertical position resting against the jig back. A high-speed camera was focused on the inner face of the window during each test. The high-speed photographs comprised the only evaluation method used during Test No. 25.

Projectile velocity measurements were determined by the projectile breaking two pairs of fine steel wires positioned between the gun nozzle and the target. One pair of these wires was connected to an electronic chronograph and the other pair to a recording oscillograph. A third method of determining the projectile velocity, using a high-speed camera, was employed primarily as a check on the other two methods. The chronograph failed to operate correctly during Tests Nos. 19 and 20, and the oscillograph failed to operate correctly during Test No. 17.

The projectile velocities, given under "Test Results," are averages of the readings obtained from the chronograph and oscillograph with the exception of Tests Nos. 17, 19, and 20, in which cases the velocities were obtained from the one measurement available plus verification by the high-speed photographs. Temperatures of the glass-vinyl lamination of the window were determined by averaging readings obtained from the thermocouples mounted on the inner and outer faces of the window. Temperatures at the center of the window were obtained for Tests Nos. 15 and 16, and temperatures at the center and edges of the windows were obtained for Tests Nos. 17 through 26. The thermocouples at the edge of the window were mounted on the outer and inner window surfaces within 1 1/2 inches of the sills.

Windows manufactured by the Pittsburgh Plate Glass Co. were heated to desired temperatures by applying required voltage to the NESA heating units and by positioning heat lamps near the outer and inner surfaces of the window. Windows manufactured by the Libbey-Owens-Ford Co. were heated to desired temperatures by the use of heat lamps only.

TEST RESULTS

The results of the impact tests are as follows

*Test No.	Date	Carcass Velocity (mph)	Outside-Air Temperature (°F)	Window-Edge Temperature (°F)	Center-of-Window Temperature (°F)
15	5/15/57	438	70	--	97

Bird-carcass penetration was experienced as the window failed along the upper, outboard, and lower sills. Details of the window failure are shown in Figs. 6, 7, 8, and 9. Both the outer vinyl layer, which incorporated a metal insert, and the inner vinyl layer tore out around all outboard sill

*Test numbers continued from Technical Development Report No. 301.

bolts and five bottom sill bolts. The outer vinyl layer sheared along the metal insert 5 inches along the top sill. The outer layer of vinyl pulled loose from the insert 2 inches outboard along the top sill and along the entire outboard sill. The inner layer of vinyl pulled loose along the top, outboard, and lower sills. Most of the 1/8-inch-thick inner face of glass adhered to the inner vinyl layer. The inner vinyl layer split open and allowed 1/4-inch-thick full-tempered glass fragments to spray into the "cockpit area," with enough energy to break the skin of the plucked chicken carcass. The upper, outboard, and lower sills bent inward slightly. Washer strips were not used because of the clearance problem with the edge of 1/8-inch-thick inner face glass. The window-bolt hole-edge distance was insufficient due to the clearance problem and this was the main cause of failure.

Test No.	Date	Carcass Velocity (mph)	Outside-Air Temperature (°F)	Window-Edge Temperature (°F)	Center-of-Window Temperature (°F)
16	5/16/57	430	52	--	107

Part of the carcass penetrated the window due to shearing of the vinyl, as shown in Figs. 10, 11, 12, and 13. No window-edge pullout was experienced. The bond between the Plex inner face and inner layer of vinyl caused the vinyl and Plex to fail in the same manner. Most of the 1/4-inch-thick full-tempered glass fragments entered the "cockpit area," but the velocity of the fragments was noticeably lower than that experienced with the original Boeing 707 eyebrow window. It is believed that the vinyl temperature around the window edge was low due to the transfer of heat from the vinyl into the adjacent sill structure which was relatively cold. The outside temperature was 52° F. Upper and lower sills were bent inward slightly.

Test No.	Date	Carcass Velocity (mph)	Outside-Air Temperature (°F)	Window-Edge Temperature (°F)	Center-of-Window Temperature (°F)
17	5/17/57	384	--	90	120

The window tested was of the original design consisting of 1/8-inch-thick semitempered glass, 5/16-inch-thick, 21 parts plasticized vinyl and 1/4-inch-thick full-tempered glass. There was slight penetration by the bird carcass through an opening at the top sill, as shown in Figs. 14, 15, 16, and 17. The hydraulic action of the carcass in passing between the window and upper sill forced the window edge downward, with the result that the vinyl and metal insert pulled loose from the top sill bolts. A chicken carcass, used to simulate the pilot's head, suffered several severe lacerations due to flying glass, as shown in Fig. 18.

Test No.	Date	Carcass Velocity (mph)	Outside-Air Temperature (°F)	Window-Edge Temperature (°F)	Center-of-Window Temperature (°F)
18	5/18/57	402	80	--	122

Part of the carcass penetrated the window as the window edge pulled loose from the bolts along the top sill and outboard sill, as shown in Figs. 19, 20, 21, and 22. The inner vinyl-Plex-55 laminated layers tore open at two places and allowed the 1/4-inch-thick full-tempered glass fragments to be propelled against a clay dome which simulated the top of the pilot's head. The glass fragments either imbedded themselves or left impressions in the clay to a depth of 3/32-inch. A view of the clay dome following the test is shown in Fig. 23.

Test No.	Date	Carcass Velocity (mph)	Outside-Air Temperature (°F)	Window-Edge Temperature (°F)	Center-of-Window Temperature (°F)
19	5/20/57	412	65	75	120

Part of the carcass penetrated the window as both vinyl interlayers sheared along the outboard sill, bottom sill, and outboard from the inboard sill as shown in Figs. 24, 25, 26, and 27. Twenty per cent of the inner face of the Plex-55 tore loose from the inner vinyl layer. Two pieces of acrylic imbedded themselves in the clay dome used to simulate the top of the pilot's head. The clay dome was pitted from several pieces of glass or acrylic. This is shown in Fig. 28. The top sill bent downward approximately 1 inch. Failure indicates that the vinyl adjacent to the sills was below optimum temperature.

Test No.	Date	Carcass Velocity (mph)	Outside-Air Temperature (°F)	Window-Edge Temperature (°F)	Center-of-Window Temperature (°F)
20	5/21/57	405	--	105	110

Part of the carcass penetrated the window as both vinyl interlayers sheared along the top sill and the window edge tore out around the bolts along the outboard sill, as shown in Figs. 29, 30, 31, and 32. All four sills bent inward under the force of the impact. Most of the 1/4-inch-thick full-tempered glass fragments were contained between the two layers of vinyl. The 1/8-inch-thick inner face of semitempered glass adhered almost entirely to the inner layer of vinyl. The glass pattern on cardboard sheets placed behind the window indicates that one group of fine glass particles passed over the position of the pilot's head with high velocity, and one group struck the position of the pilot's head. The cardboard sheets are shown in Fig. 33.

Test No.	Date	Carcass Velocity (mph)	Outside-Air Temperature (°F)	Window-Edge Temperature (°F)	Center-of-Window Temperature (°F)
21	5/22/57	414	80	98	105

Penetration by part of the carcass was experienced as both vinyl interlayers and inserts pulled loose from bolts along the top and outboard sills, as shown in Figs. 34, 35, 36, and 37. Both metal inserts cracked approximately at the center of the top and outboard sills. Approximately 60 per cent of the Plex-55 departed from the inner layer of vinyl. This amount of delamination was considerably more than that which occurred in Test No. 19, the only other test in which delamination of Plex-55 for the vinyl interlayer was experienced. The vinyl interlayers confined most of the 1/4-inch-thick full-tempered glass fragments with only a few nuggets escaping into the cockpit area. Two Plex-55 fragments, approximately 4 inches long, knifed into the cardboard sheets, shown in Fig. 38, which were placed behind the window. One fragment passed over the pilot's head and the other struck in the vicinity of the pilot's head. All of the sills bent inward and the two 3/16-inch-diameter rivets, shown as D and E in Fig. 2, failed in tension. The window of this test was cold soaked at a temperature of -65° F. for 8 hours. prior to being impact tested. This may have weakened the bond between the Plex-55 and vinyl, thereby resulting in the high degree of delamination of Plex-55 from the vinyl interlayer. There was no indication of any delamination of the Plex-55 from the vinyl prior to the test.

Test No.	Date	Carcass Velocity (mph)	Outside-Air Temperature (°F)	Window-Edge Temperature (°F)	Center-of-Window Temperature (°F)
21	5/23/57	408	--	97	106

The carcass did not penetrate the window. The condition of the window is shown in Figs. 39, 40, 41, and 42. Two 1/4-inch-diameter bolts had been added at K, as shown in Fig. 1. All top sill bolts bent inward approximately 3/8-inch. Both metal inserts cracked at two bolt locations at the center of the top sill, but tearout did not occur. The inner layer of vinyl and inner-face Plex-55 remained bonded together and the vinyl and Plex-55 tore open as one unit. Particles of 1/4-inch-thick full-tempered glass were propelled at a high velocity and imbedded themselves in the cardboard sheets placed behind the window. Of the flying glass which was imbedded in the cardboard, approximately one-half was directed toward the position of the pilot's head. This is shown in Fig. 43.

Test No.	Date	Carcass Velocity (mph)	Outside-Air Temperature (°F)	Window-Edge Temperature (°F)	Center-of-Window Temperature (°F)
23	5/24/57	390	--	92	115

There was slight penetration of the window as part of the outboard sill sheared and the top sill assembly failed partially, as shown in Figs. 44, 45, 46, and 47. The outer vinyl-metal insert edge lamination tore out around four sill bolts. Along the inboard sill the outer vinyl-metal insert edge lamination partially failed around four bolts. The inner layer of vinyl partially sheared approximately 9 inches along the inboard sill continuing approximately 5 inches along the top sill. The 1/8-inch-thick semitempered glass inner face remained laminated to the inner layer of vinyl. The glass fragmentation hazard associated with the 1/4-inch-thick full-tempered and 1/8-inch-thick semitempered glass particles was slight, as shown in Fig. 48.

Test No.	Date	Carcass Velocity (mph)	Outside-Air Temperature (°F)	Window-Edge Temperature (°F)	Center-of-Window Temperature (°F)
24	5/25/57	390	80	90	94

An eyebrow window of original design was tested with a protective window, consisting of 1/8-inch-thick annealed glass inner face, 0.040-inch-thick vinyl interlayer with 21 parts plasticizer, and 1/4-inch-thick full-tempered glass outer face, mounted 4 inches below and parallel to the eyebrow window. Part of the carcass penetrated the outer window and the top attachment of the protective window failed as shown in Figs. 49, 50, 51, and 52. The vinyl of the eyebrow window sheared along top and bottom sills and the vinyl-metal laminated edge tore out around all outboard sill bolts. The protective window reduced the velocity and changed the direction of glass particles propelled from the outer window panel. The protective window shattered, with only a small amount of glass departing from the inner face. The protective window wedged in the steel jig, preventing it from full downward rotation. The fragmentation pattern on the cardboard showed that the flying glass would pass over the pilot's head or fall into his lap. This is shown in Fig. 53. The top sill bent downward considerably, with lesser bending of the bottom and outboard sills.

Test No.	Date	Carcass Velocity (mph)	Outside-Air Temperature (°F)	Window-Edge Temperature (°F)	Center-of-Window Temperature (°F)
25	5/26/57	442	--	102	Inner face 78 Outer face 115

Part of the carcass penetrated the window as the top sill intercostal failed and one-half of the outboard sill failed as shown in Figs. 54, 55, 56, and 57. The two 3/16-inch-diameter rivets and one 3/16-inch-diameter bolt, shown as C, D, and E of Fig. 2, failed and permitted the remaining portion of the top intercostal sill to deflect rearward and downward. Parts of the carcass which penetrated the window extruded through the structure between the top sill and the attached skin, and passed over the position of the pilot's head. The Plex-55 inner face crazed, but did not depart from the inner-layer vinyl. The inner vinyl-Plex-55 laminate tore at the center of impact and from the top outboard corner toward the center of the window. A few 1/4-inch-thick full-tempered glass particles escaped through the tears in the vinyl-acrylic and impinged upon the floor and vertical wall of the test jig, as determined from high-speed film. Glass fragmentation from this window was less severe than in any of the previous tests.

Test No.	Date	Carcass Velocity (mph)	Outside-Air Temperature (°F)	Window-Edge Temperature (°F)	Center-of-Window Temperature (°F)
26	5/29/57	448	--	98	112

Parts Nos. 7 and 9, Fig. 2, were omitted for this test. There was no penetration through the window or adjacent structure, but a small part of the bird carcass penetrated through a tear in the skin above the top sill, shown in Figs. 58 and 59. The tee-shaped extrusion portion of the top intercostal sill assembly parted from the assembly, as shown in Fig. 60, and was held only by the top skin and the window edge. The inner face of the Plex-55 remained laminated to the inner layer of vinyl. The vinyl-Plex-55 laminate tore for a length of 5 inches from the upper inboard corner diagonally toward the center of the window, as shown in Fig. 61. Some 1/4-inch-thick full-tempered glass particles escaped through the tear and penetrated the Styrofoam boards, predominately at two positions. One position was above and to the left of the pilot's head while the other was at the pilot's head level, but to the left. One small glass particle penetrated the Styrofoam board to a depth of 1/8-inch near the position of the pilot's head. In addition, there were several extremely small indentations in the Styrofoam board at the pilot's head position. The Styrofoam boards, after the test, are shown in Fig. 62.

CONCLUSIONS

The following conclusions are based upon an analysis of test results:

1. The Boeing 707 eyebrow window will resist the impact of a 4-pound bird with only a slight amount of penetration at 448 mph if a window design and supporting structure comparable to that utilized during Test No. 26 are used. Structural details of this combination are given in Table I.

2. Relative to flying glass, the window design utilizing vinyl 0.20-inch-thick with 21 parts plasticizer content, an 0.025-inch-thick 24-ST aluminum insert, and Plex-55 acrylic 0.0625-inch thick laminated successively to the inside face of the window, as used in Test No. 26, proved to be the least hazardous of any of the 12 windows tested. A study of the Styrofoam boards used as evaluation media in Test No. 26 indicated that the pilot was struck by only one particle of full-tempered glass which had any substantial degree of energy.

3. The minimum window temperature required for the Boeing 707 eyebrow window to develop maximum resistance to penetration as determined from these tests is 100° F. along the edges.

4. The use of a protective glass shield mounted 4 inches below the original Boeing 707 window, as used in Test No. 24, gives the pilot appreciable protection at 390 mph. However, the eyebrow window in its original design will not resist penetration at 440 mph, and no tests were conducted at this speed using the protective glass shield arrangement. The glass shield as mounted in Test No. 24 failed at the upper hinge point at 390 mph.

5. Three windows, utilizing a 1/8-inch-thick pane of semitempered glass laminated to the inner layer of vinyl having 41 parts plasticizer content, proved to be ineffective in preventing rearward accelerations of full-tempered glass particles because, at the temperature tested, the inner vinyl had practically no strength. It is believed that better results would have been obtained if the plasticizer content of the vinyl had been 31 parts or less; but even so, a fine spray of small sliver-like particles of glass could be expected from this window design.

TABLE I

SILL AND WINDOW CONSTRUCTION

TEST NO.	* WINDOW MANUFACTURER	INBOARD SILL		LOWER SILL		OUTBOARD SILL		INTERCOSTAL SILL	**INTERCOSTAL FABRICATION					*** INNER WINDOW CONSTRUCTION (SEE FIG. 3) PVB INNER LAYER		INNER FACE		INNER INSERT
		SILL CONSTRUCTION (SEE FIGS 1 AND 2)																
		THICK.	MATERIAL	THICK	MATERIAL	THICK	MATERIAL	THICK A	B	C	D	E	F	THICK G	PLASTICIZER CONTENT	THICK. H	MATERIAL	THICK. I 24S-T3 MATERIAL
ORIGINAL BOEING DESIGN (COMPARISON)		.160	75S-T6	.160	75S-T6	160	75S-T6	156	1/4 RIVET	3/16 BOLT	3/16 BOLT	3/16 BOLT	1/4 RIVET	NONE		NONE		NONE
15	LOF	.160	75S-T6	160	75S-T6	.160	75S-T6	156	1/4 RIVET	3/16 BOLT	3/16 BOLT	3/16 BOLT	1/4 RIVET	0.10	41 PARTS	125	ST.GLASS	NONE
16	PPG	160	75S-T6	.160	75S-T6	.160	75S-T6	156	1/4 RIVET	3/16 BOLT	3/16 BOLT	3/16 BOLT	1/4 RIVET	0 10	21 PARTS	.0625	PLEX-55	.025
17	PPG	.160	75S-T6	.160	75S-T6	160	75S-T6	.156	3/16 BOLT	3/16 BOLT	3/16 BOLT	3/16 BOLT	3/16 BOLT	NONE		NONE		NONE
18	PPG	160	75S-T6	.160	75S-T6	.160	75S-T6	.156	3/16 BOLT	3/16 BOLT	3/16 BOLT	3/16 BOLT	3/16 BOLT	0.10	21 PARTS	.0625	PLEX-55	.025
19	PPG	.160	75S-T6	.160	75S-T6	.160	75S-T6	.080	3/16 BOLT	3/16 BOLT	3/16 BOLT	3/16 BOLT	3/16 BOLT	0 10	21 PARTS	0625	PLEX-55	.025
20	LOF	.102	75S-T6	.102	75S-T6	102	75S-T6	.092	3/16 BOLT	3/16 BOLT	3/16 BOLT	3/16 BOLT	3/16 BOLT	0.10	41 PARTS	125	ST GLASS	.025
21	PPG	102	75S-T6	.102	75S-T6	.081	24S-T3	.080	3/16 BOLT	3/16 BOLT	3/16 RIVET	3/16 RIVET	3/16 BOLT	0 10	21 PARTS	0625	PLEX-55	.025
22	PPG	081	24S-T3	081	24S-T3	.081	24S-T3	.090	3/16 BOLT	3/16 BOLT	3/16 RIVET	3/16 RIVET	3/16 BOLT	0 10	21 PARTS	0625	PLEX-55	.025
23	LOF	.081	24S-T3	081	24S-T3	.081	24S-T3	.090	3/16 BOLT	3/16 BOLT	3/16 RIVET	3/16 RIVET	3/16 BOLT	0 125	41 PARTS	125	ST GLASS	.025
24	PPG	.102	75S-T6	102	75S-T6	.081	24S-T3	[illegible]	3/16 BOLT	3/16 BOLT	3/16 RIVET	3/16 RIVET	3/16 BOLT	NONE		NONE		NONE
25	PPG	.102	75S-T6	.102	75S-T6	.102	75S-T6	.090	3/16 BOLT	3/16 BOLT	3/16 RIVET	3/16 RIVET	3/16 BOLT	0.20	31 PARTS	.0625	PLEX-55	.025
26	PPG	.102	75S-T6	102	75S-T6	102	75S-T6	.090	NONE	3/16 RIVET	3/16 BOLT	3/16 BOLT	NONE	0 20	21 PARTS	.0625	PLEX-55	.025

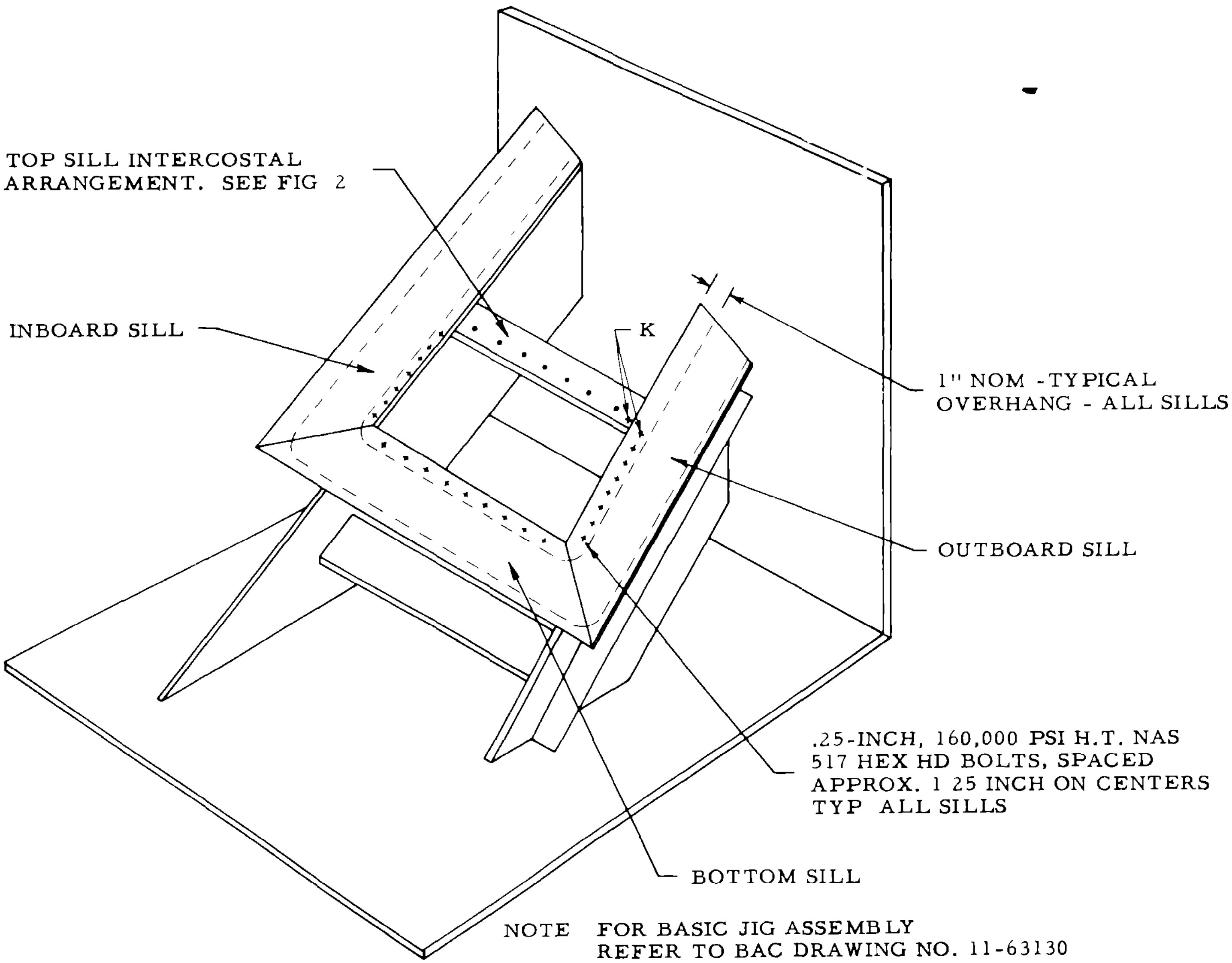
NOTE

1. ORIGINAL DESIGN - REFER TO BAC DRAWING NO 5-89357, SHT 1A AND 2A
2. DESIGN OF TEST NO. 26 - REFER TO BAC DRAWING NO 5-89357, SHT 1A AND 2A-REV B
3. THERE ARE NO SPECIFIC DRAWING NUMBERS FOR THE PANELS OF TESTS NOS 15 THROUGH 25
4. ALL THICKNESSES ARE GIVEN IN INCHES

* PPG - PITTSBURGH PLATE GLASS CO
LOF - LIBBY-OWENS-FORD GLASS CO

** BOLTS ARE 125,000 PSI HT HEX HD
RIVETS ARE A-17S.

*** THIS PERTAINS ONLY TO THAT PART OF THE WINDOW CONSTRUCTION COVERED BY NOTE 2 OF FIG. 3.



NOTE FOR BASIC JIG ASSEMBLY
REFER TO BAC DRAWING NO. 11-63130

TWO .25-INCH, 160,000 PSI H.T. NAS 517 HEX HD BOLTS
WERE ADDED IN TESTS NOS. 22, 23, 24, 25, AND 26 AT K.

FIG 1 TEST JIG ASSEMBLY

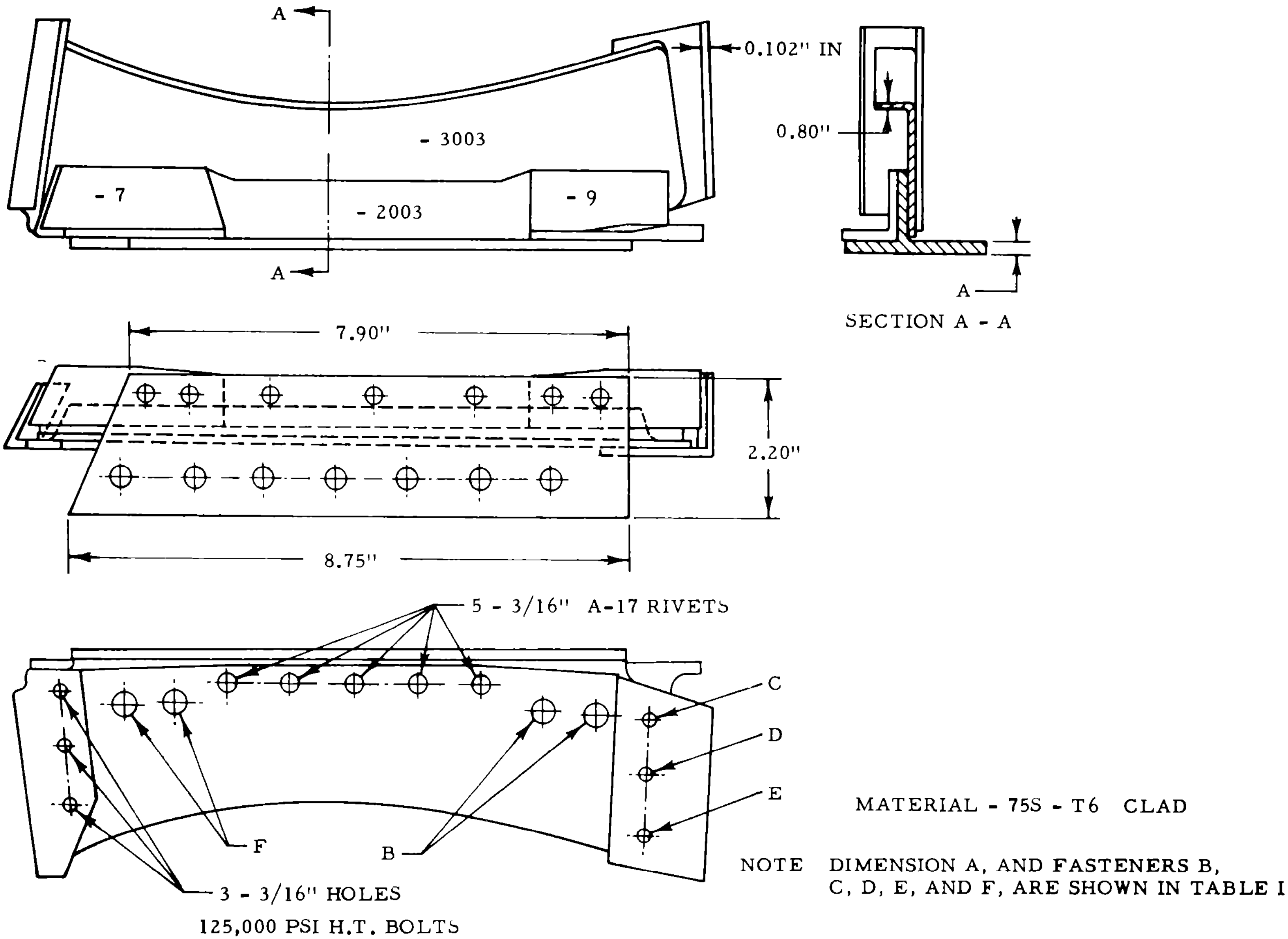


FIG. 2 TOP SILL INTERCOSTAL ASSEMBLY NO. 5 - 71779

CAA TECHNICAL
DEVELOPMENT CENTER
INDIANAPOLIS INDIANA

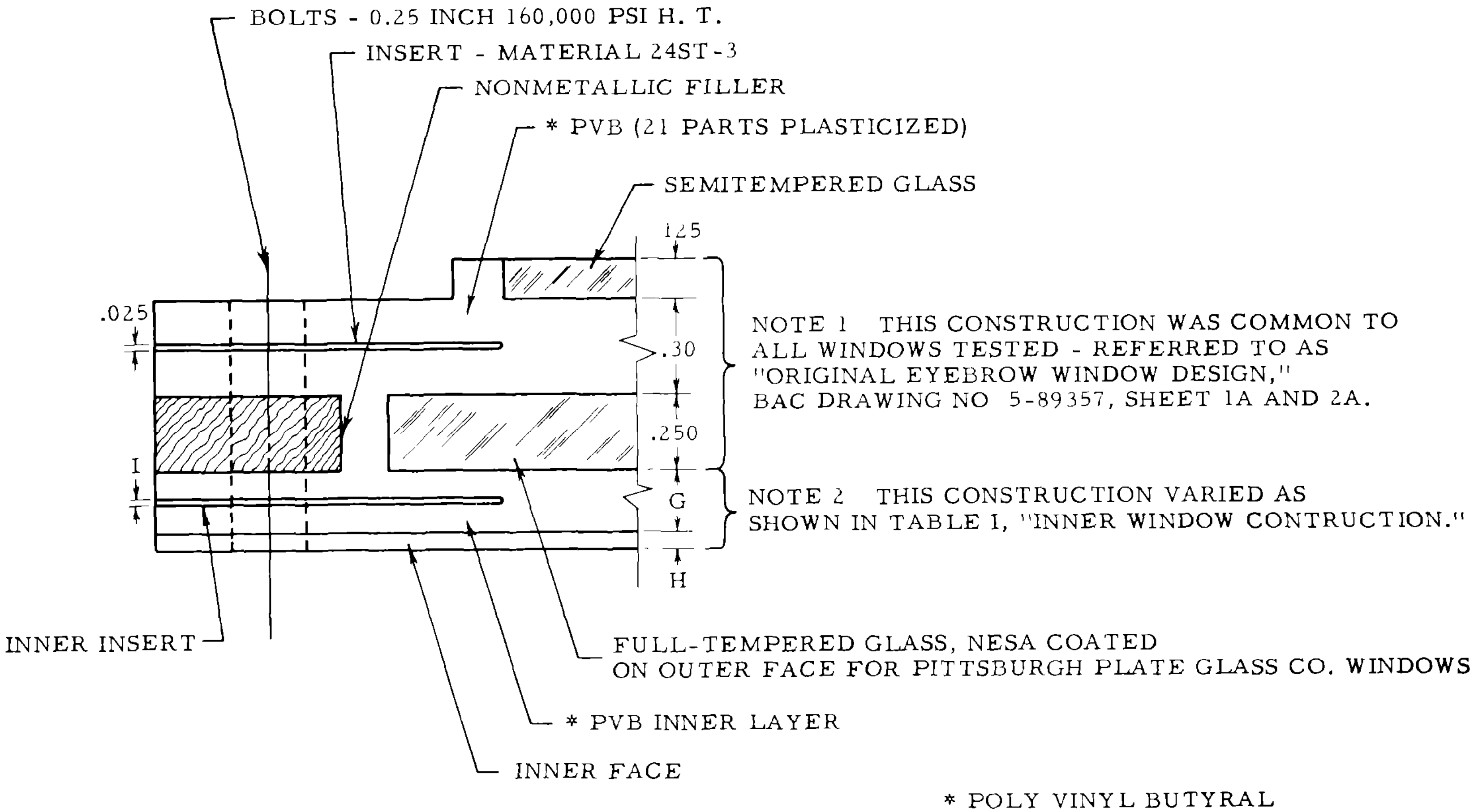


FIG. 3 TYPICAL WINDOW CONSTRUCTION

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS INDIANA

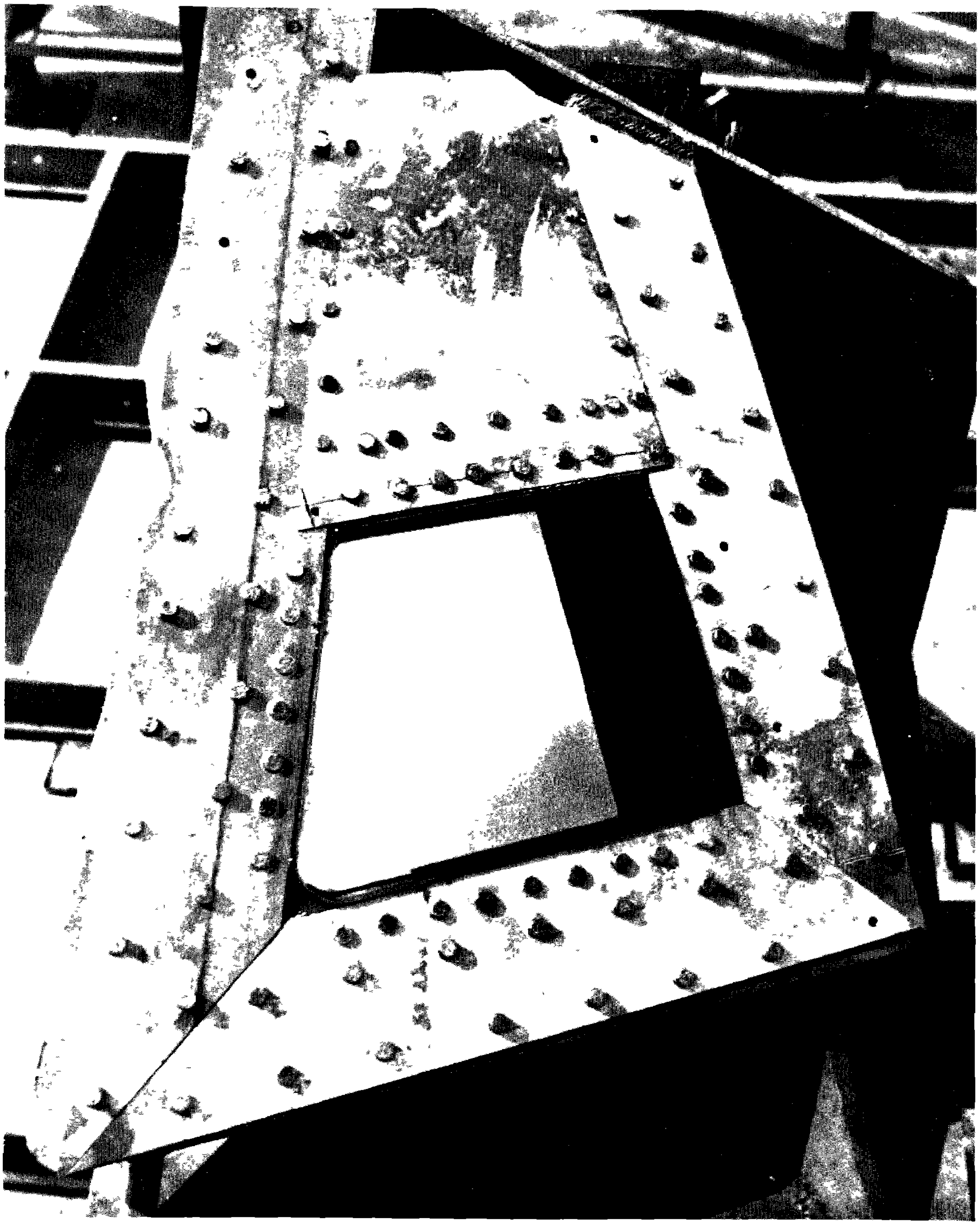
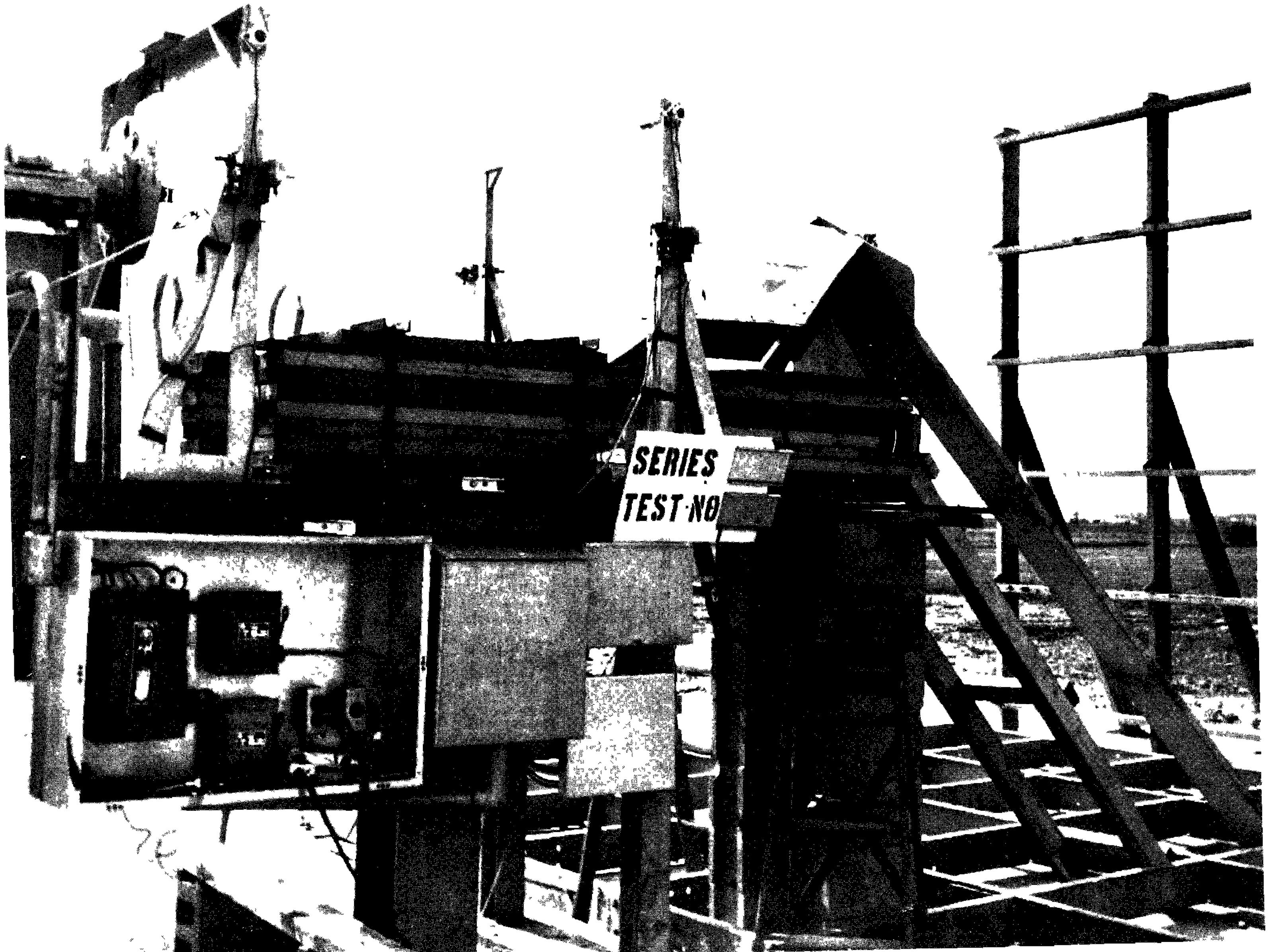


FIG. 4 WINDOW TEST JIG

CAA TECHNICAL
DEVELOPMENT CENTER
INDIANAPOLIS, INDIANA



CAA TECHNICAL
DEVELOPMENT CENTER
INDIANAPOLIS INDIANA

FIG. 6 TEST NO. 15. PROJECTILE VELOCITY 438 MPH

FIG. 7 TEST NO. 15. PROJECTILE VELOCITY 438 MPH

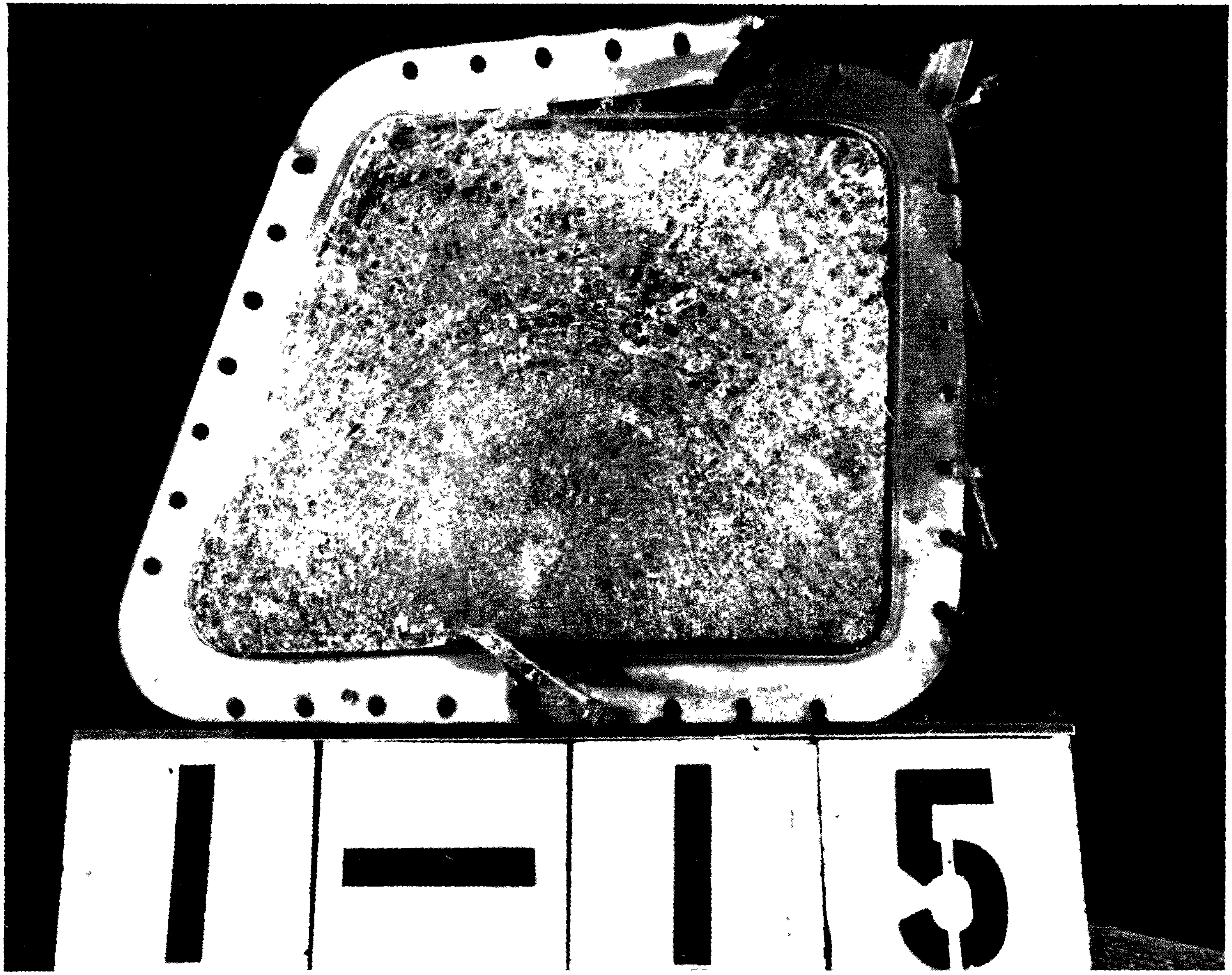


FIG. 8 TEST NO. 15. PROJECTILE VELOCITY 438 MPH

FIG. 9 TEST NO. 15. PROJECTILE VELOCITY 438 MPH

FIG. 16 TEST NO. 16 PROJECTILE VELOCITY [illegible]0 MPH

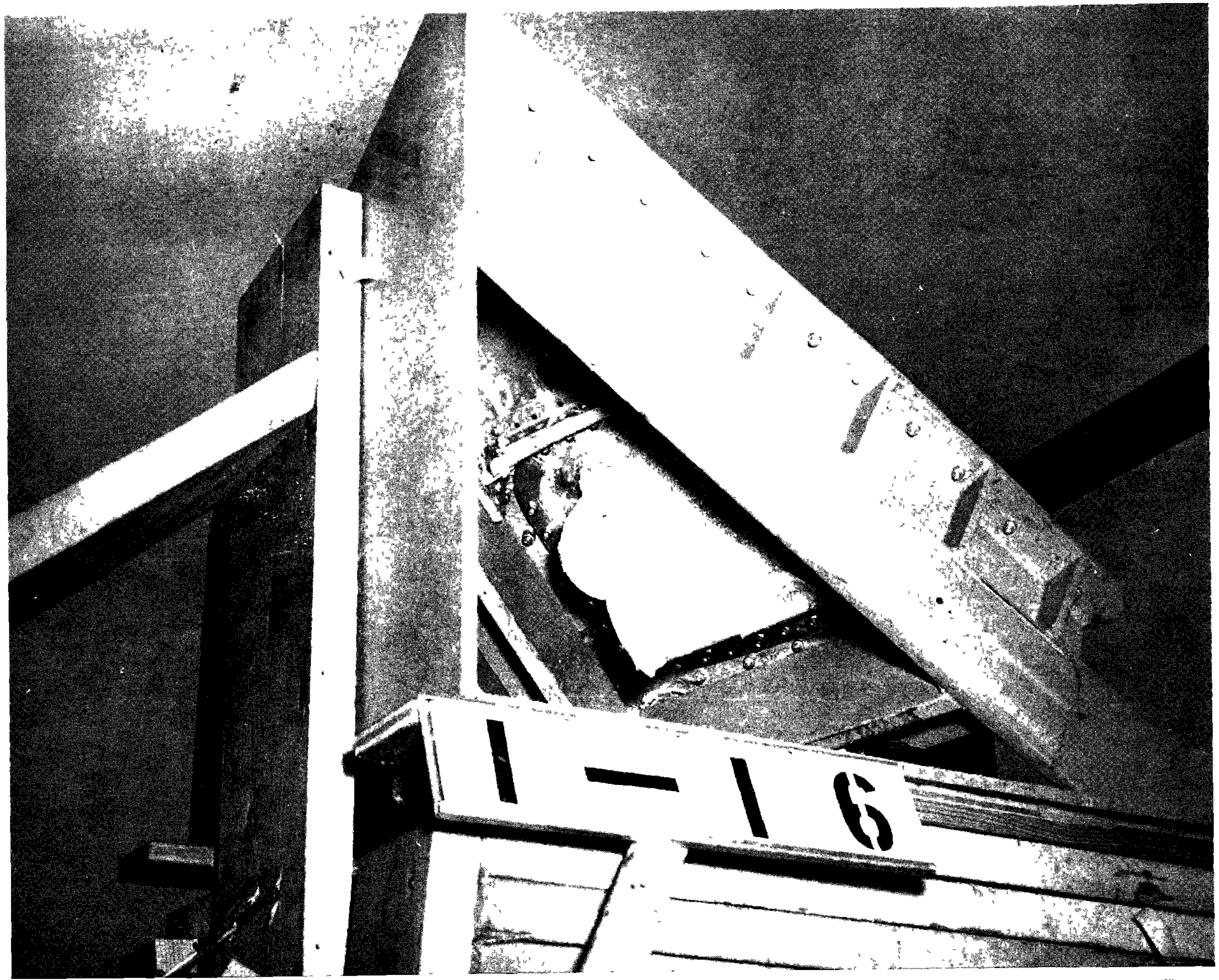


FIG 11 TEST NO. 16 PROJECTILE VELOCITY 430 MPH

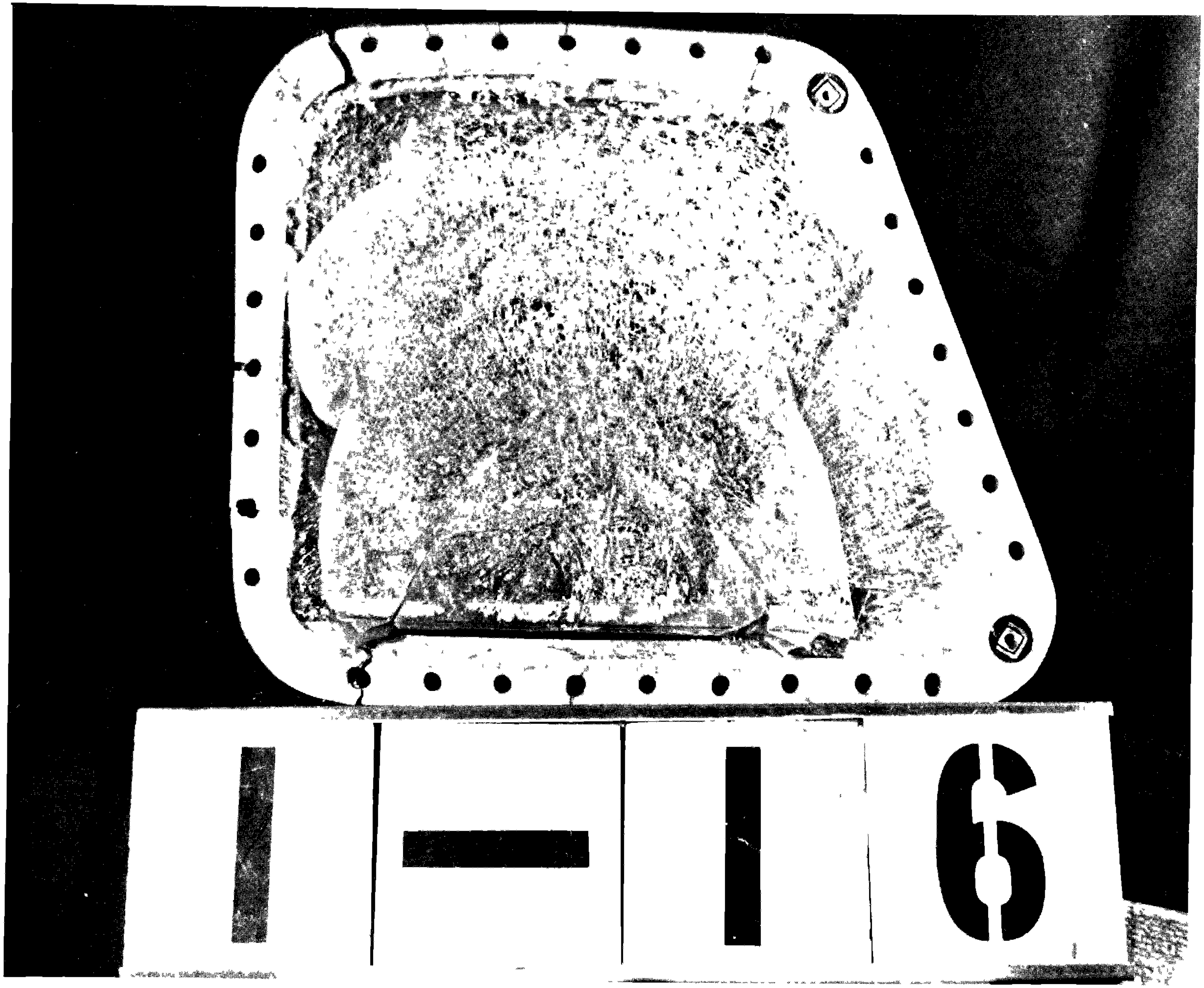


FIG. 12 TEST NO. 16. PROJECTILE VELOCITY 450 MPH

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS, INDIANA

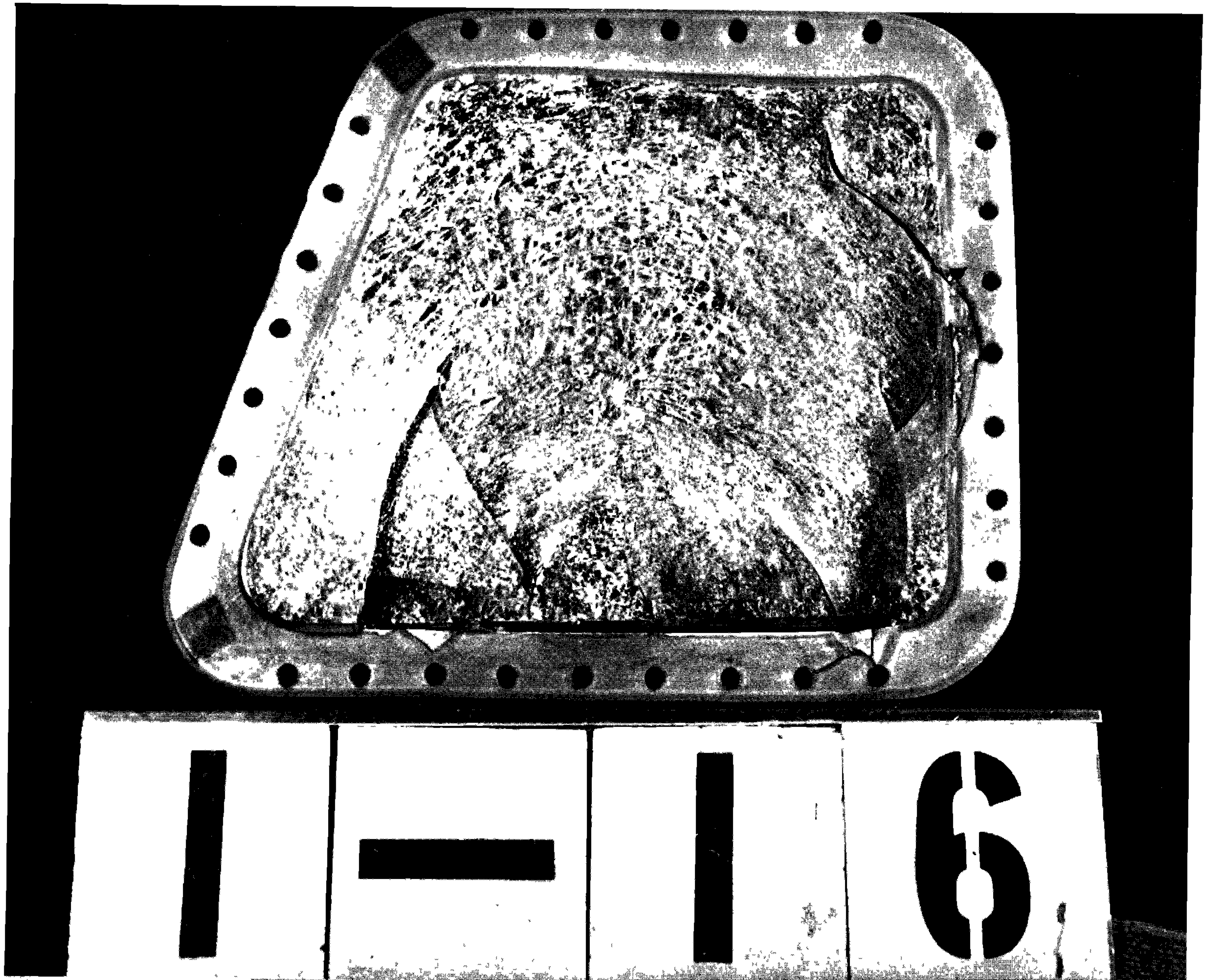


FIG. 13 TEST NO. 16. PROJECTILE VELOCITY 430 MPH

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS, INDIANA

FIG 14 TEST NO. 17. PROJECTILE VELOCITY 384 MPH

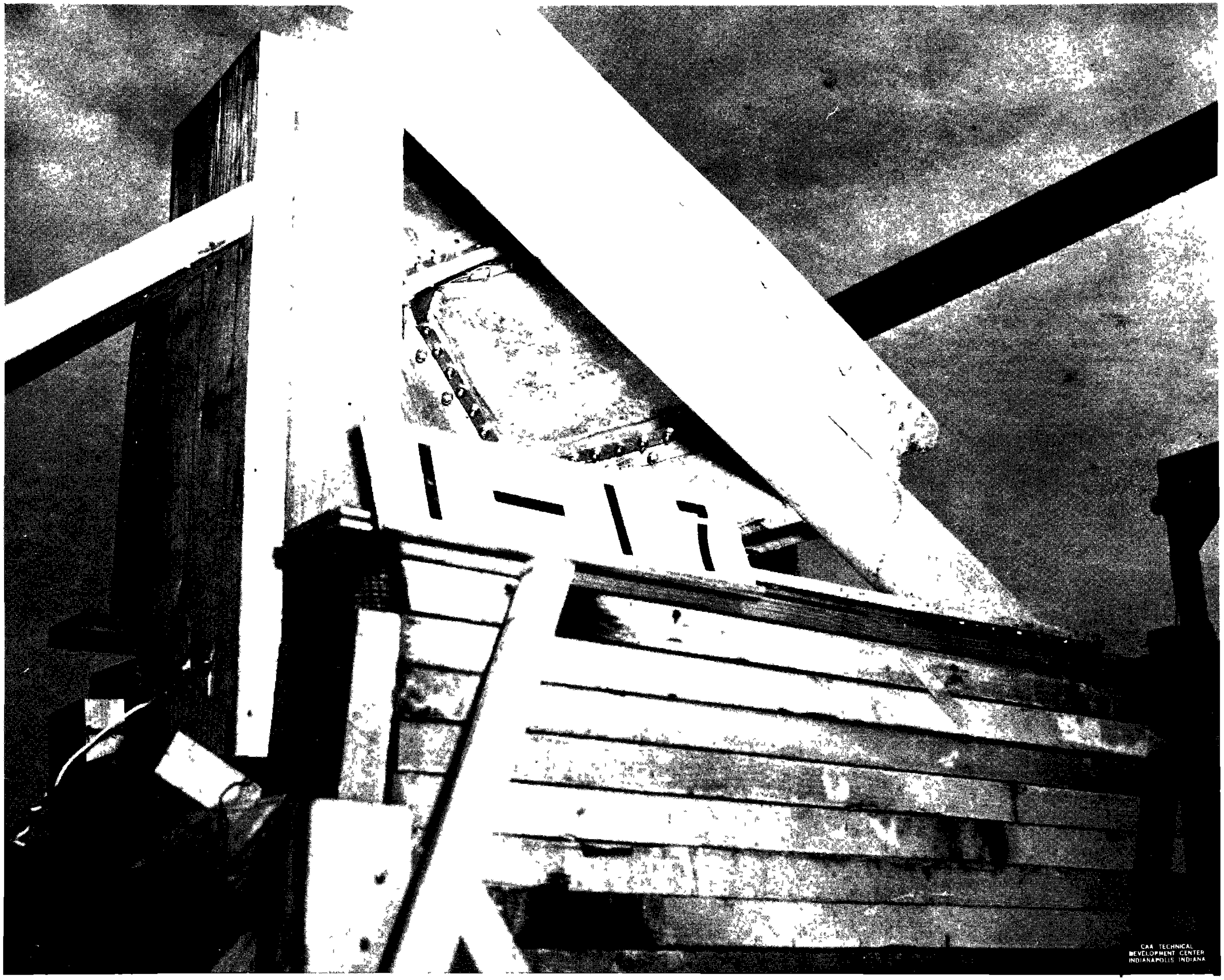


FIG 15 TEST NO. 17. PROJECTILE VELOCITY 384 MPH

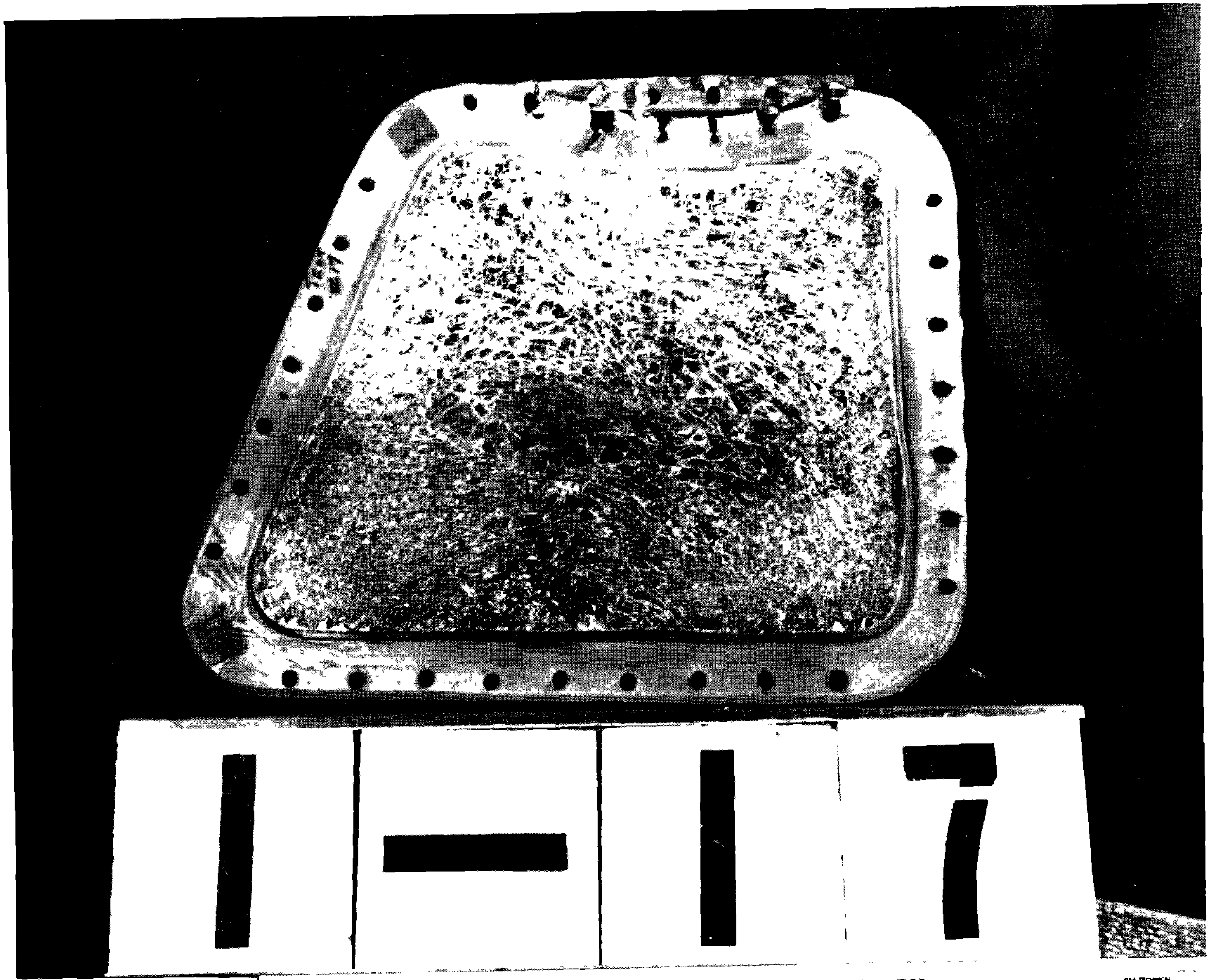


FIG. 16 TEST NO. 17. PROJECTILE VELOCITY 384 MPH

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS, INDIANA

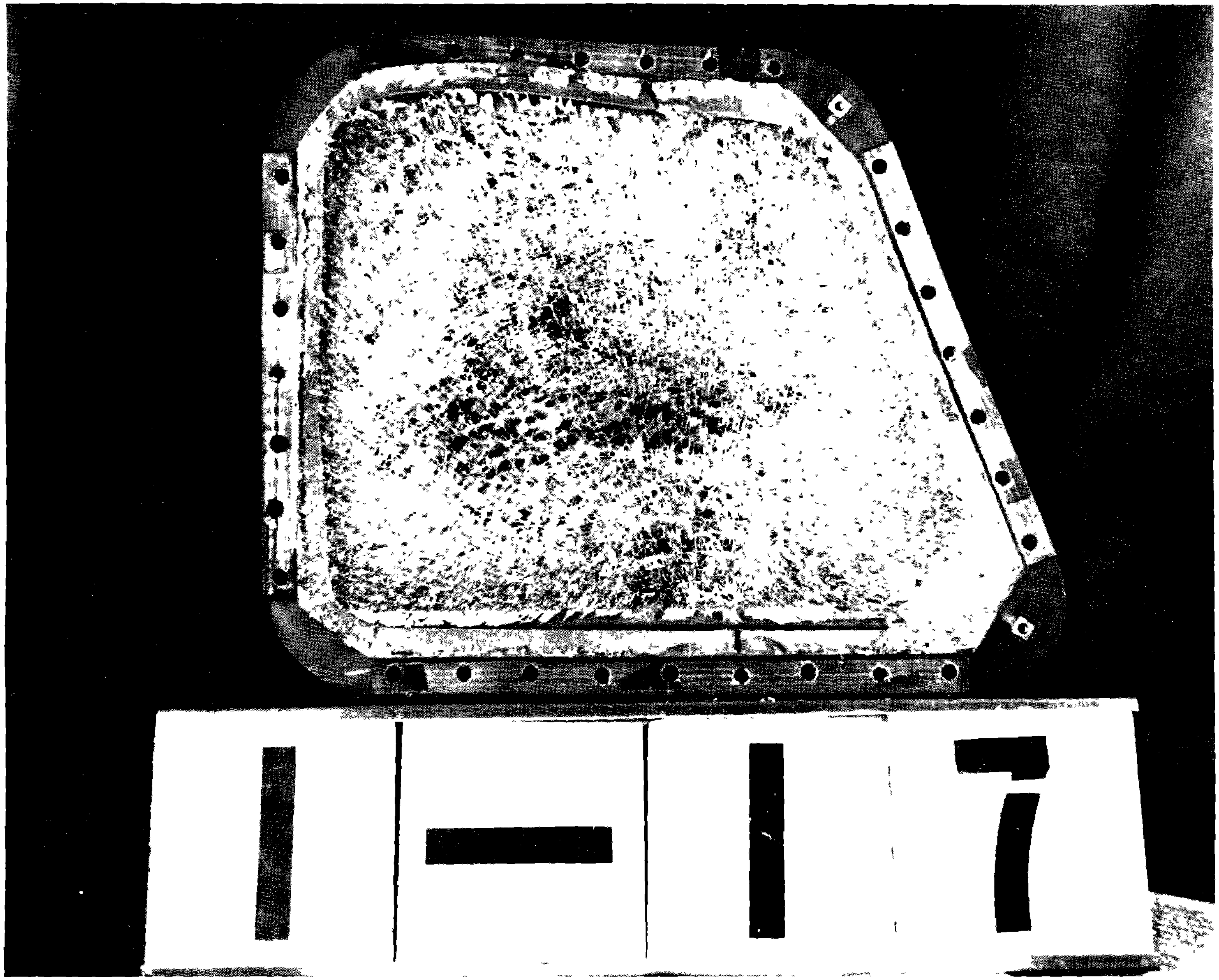


FIG 17 TEST NO 17. PROJECTILE VELOCITY 384 MPH

FIG. 18 TEST NO. 17. PROJECTILE VELOCITY 384 MPH

FIG. 19 TEST NO. 18. PROJECTILE VELOCITY 402 MPH

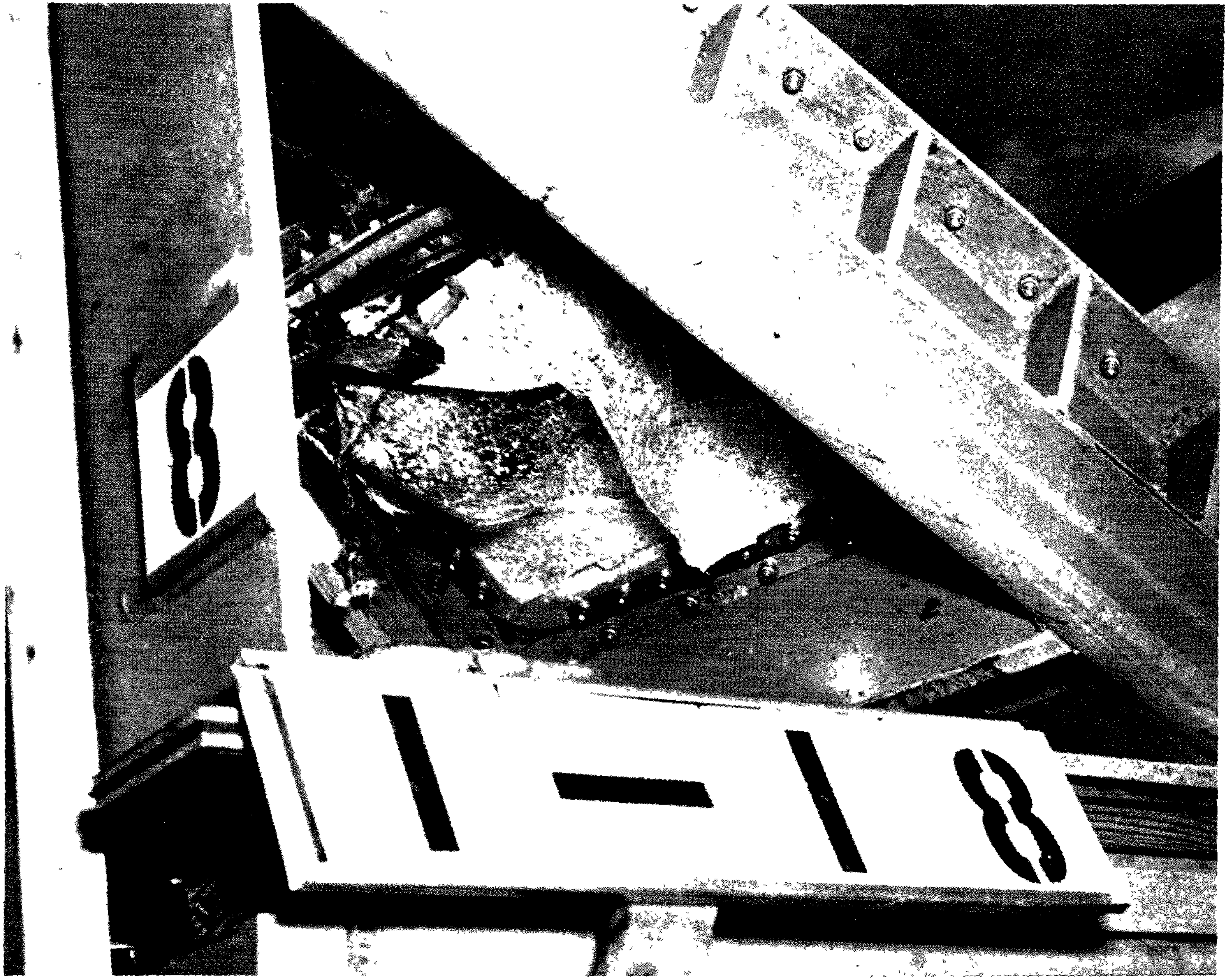


FIG. 20 TEST NO. 18. PROJECTILE VELOCITY 402 MPH

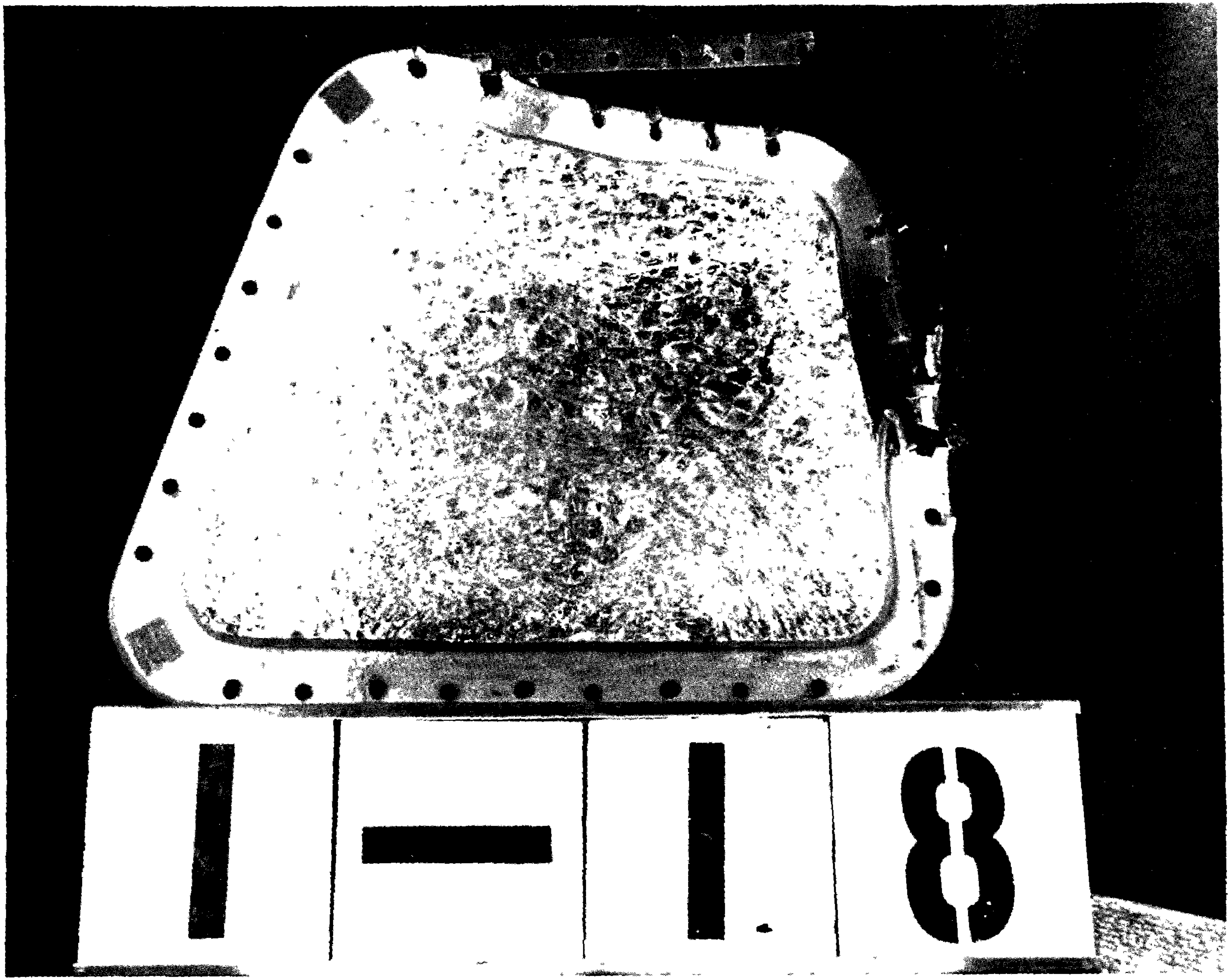


FIG. 21 TEST NO. 18. PROJECTILE VELOCITY 402 MPH

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS, INDIANA

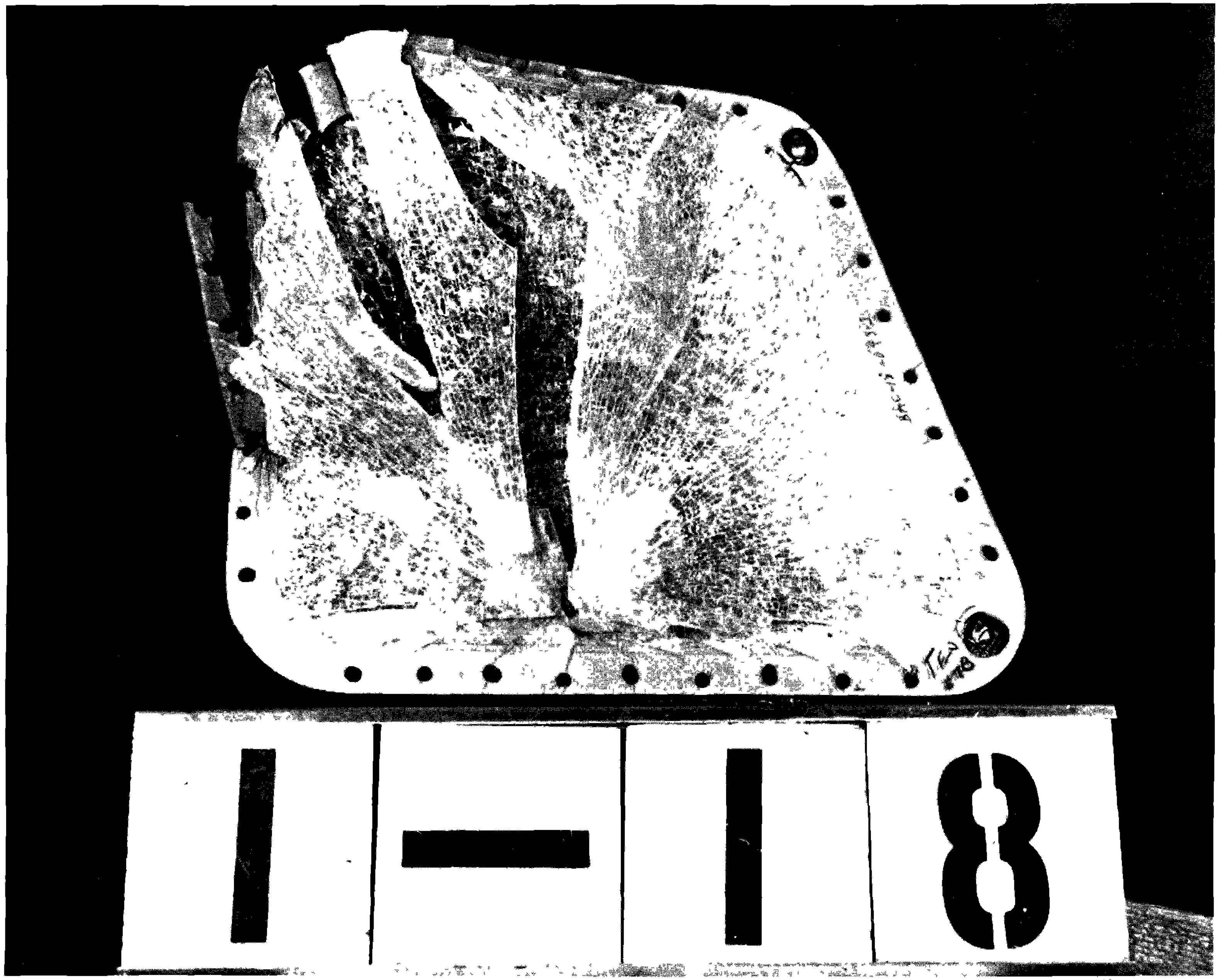


FIG. 22 TEST NO. 18. PROJECTILE VELOCITY 402 MPH

FIG. 23 TEST NO. 18. PROJECTILE VELOCITY 402 MPH

CAA TECHNICAL
DEVELOPMENT CENTER
INDIANAPOLIS, INDIANA

FIG. 24 TEST NO. 19. PROJECTILE VELOCITY 412 MPH

FIG. 25 TEST NO. 19. PROJECTILE VELOCITY 412 MPH

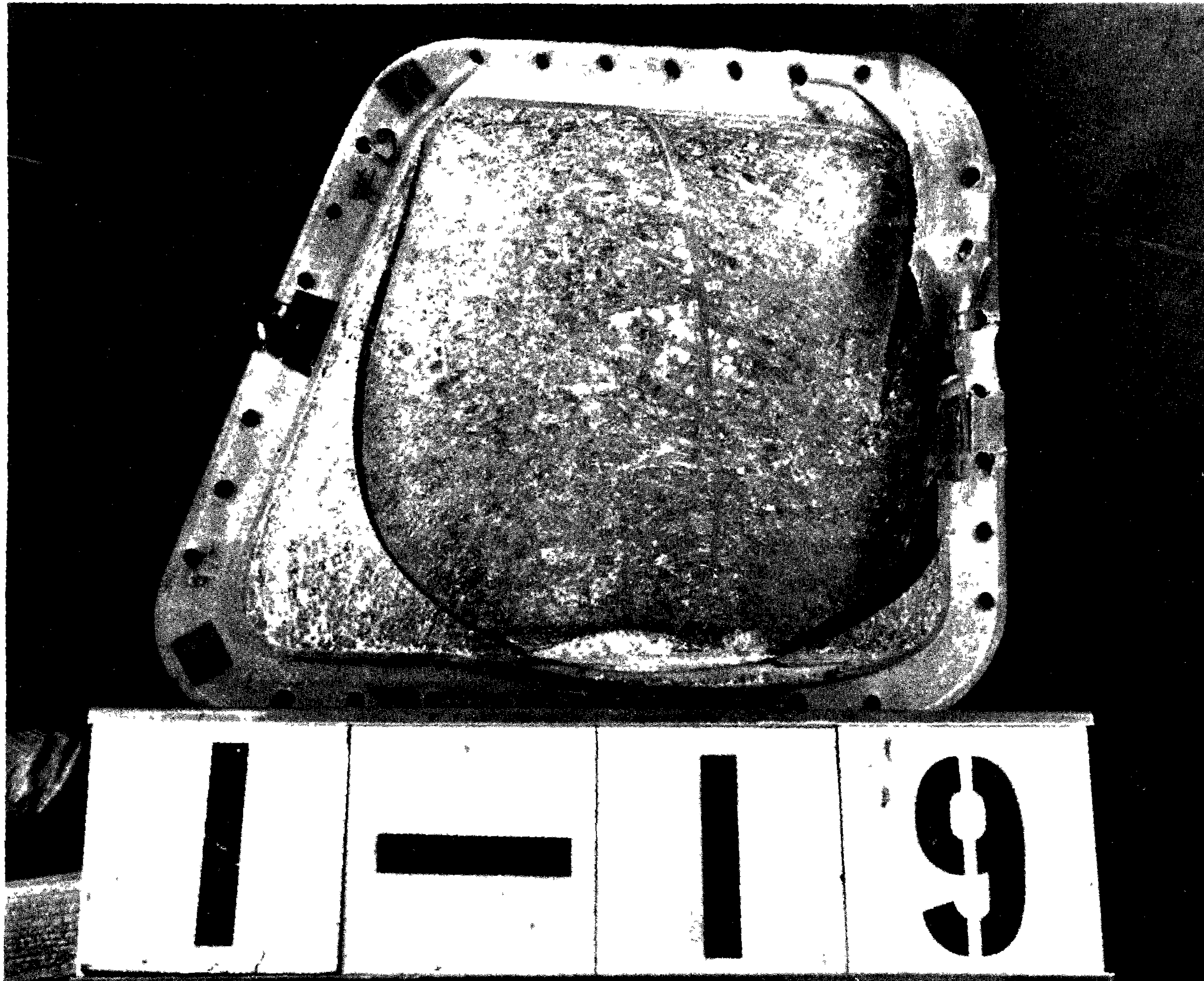


FIG. 26 TEST NO. 19. PROJECTILE VELOCITY 412 MPH

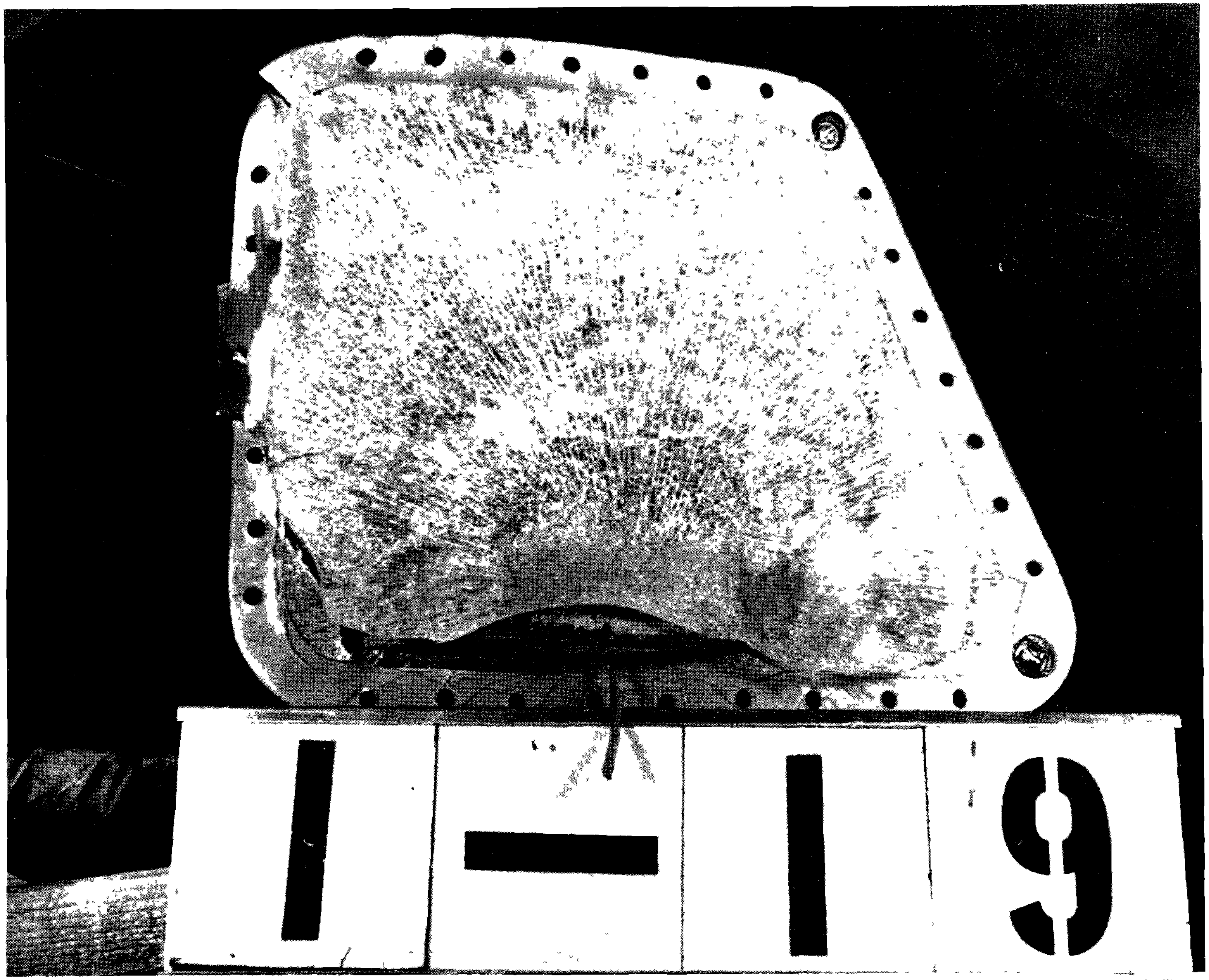


FIG. 27 TEST NO. 19. PROJECTILE VELOCITY 412 MPH

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS, INDIANA

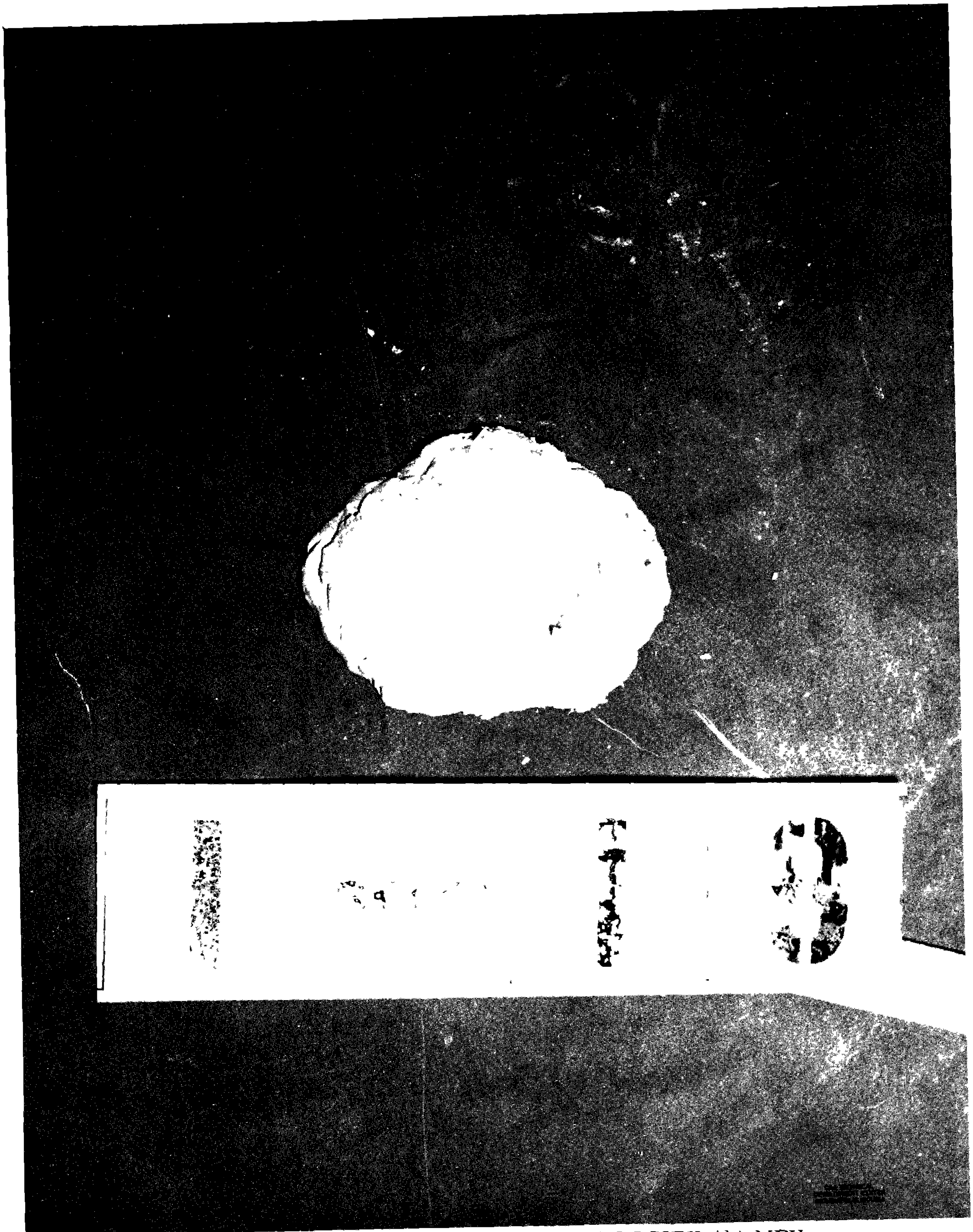


FIG 28 TEST NO. 19. PROJECTILE VELOCITY 412 MPH

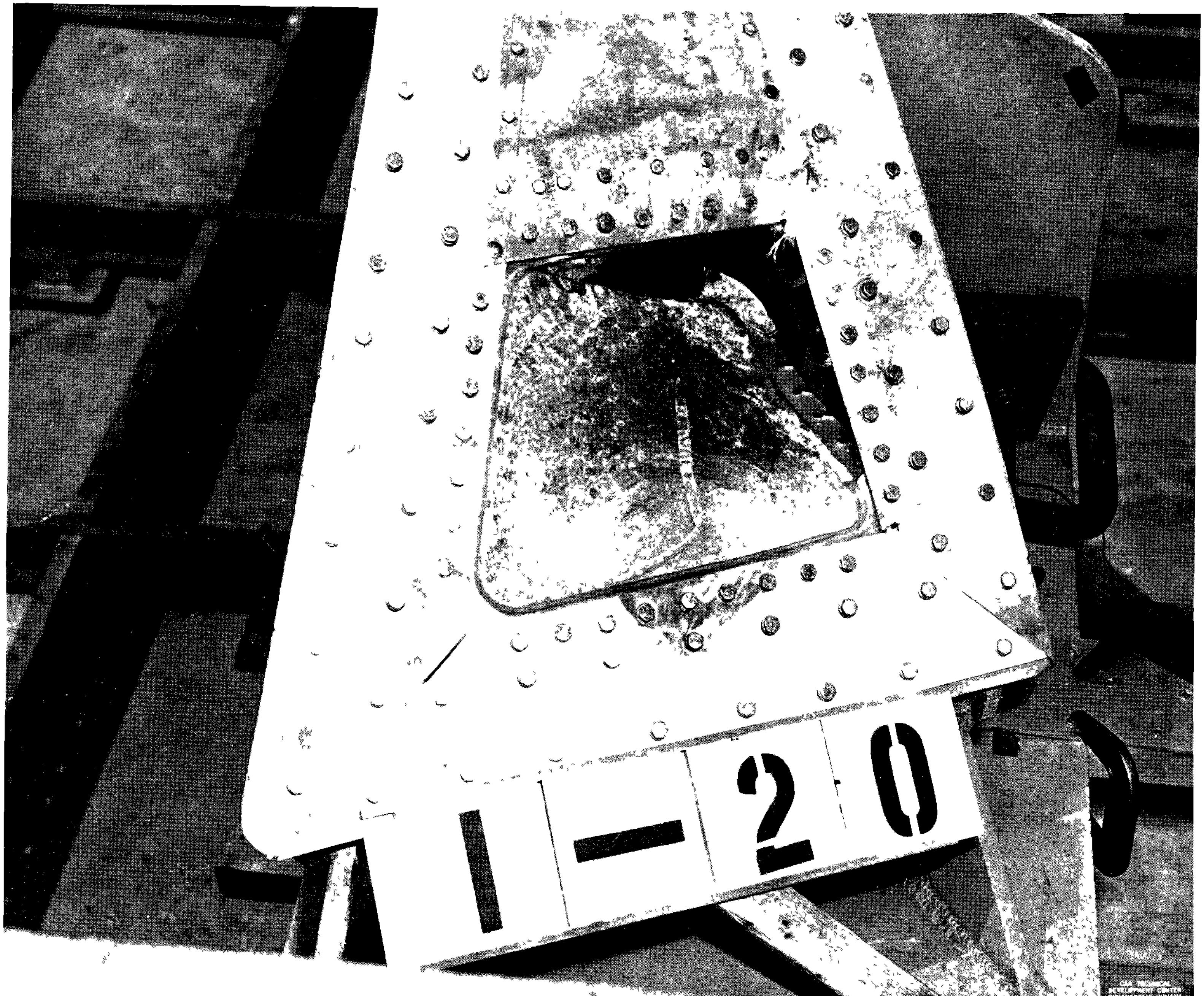


FIG 29 TEST NO. 20 PROJECTILE VELOCITY 405 MPH

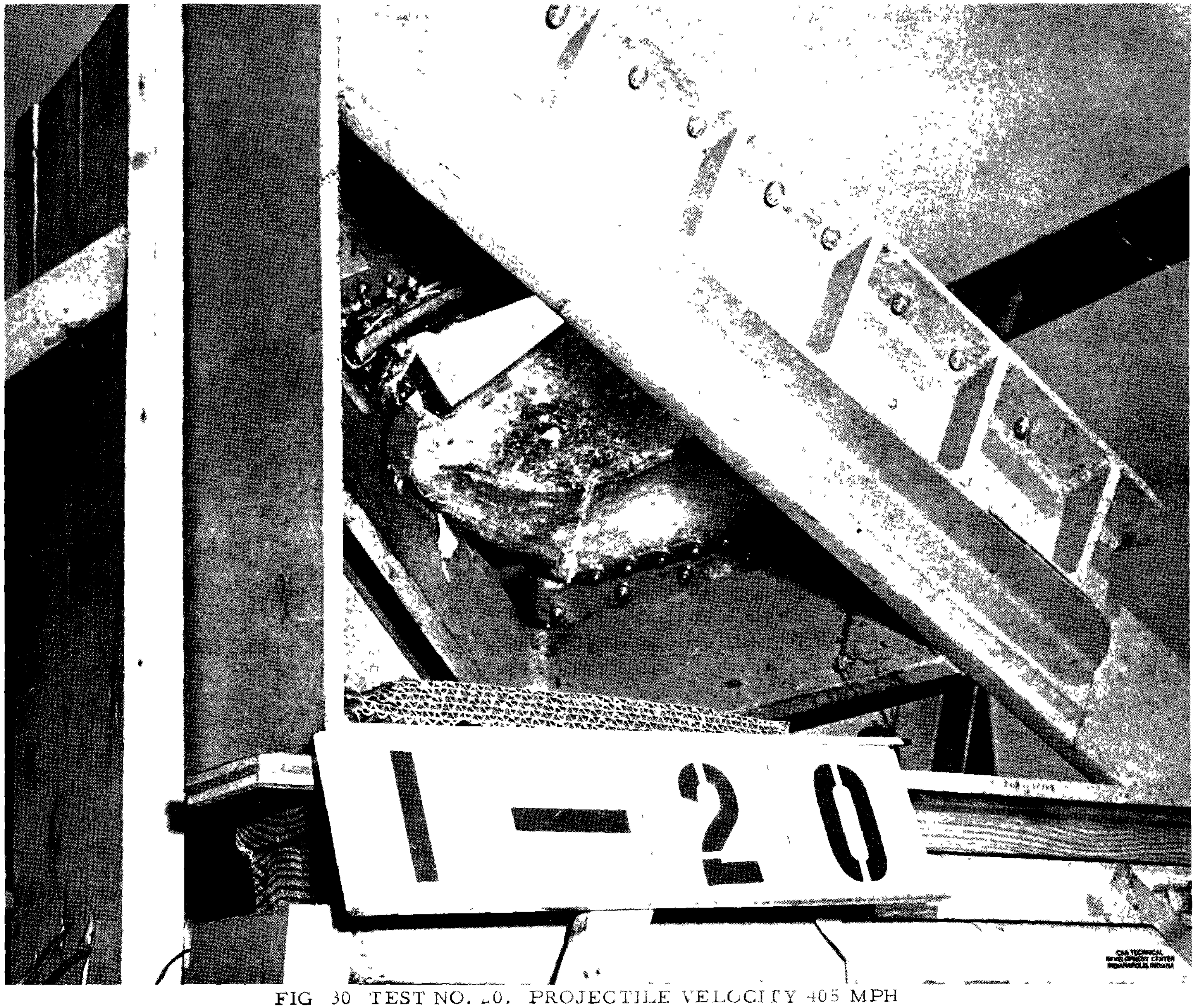


FIG 30 TEST NO. 20. PROJECTILE VELOCITY 405 MPH

FIG. 31. TEST NO. 20. PROJECTILE VELOCITY 405 MPH

FIG. 32 TEST NO. 20. PROJECTILE VELOCITY 405 MPH

FIG. 33 TEST NO. 20. PROJECTILE VELOCITY 405 MPH

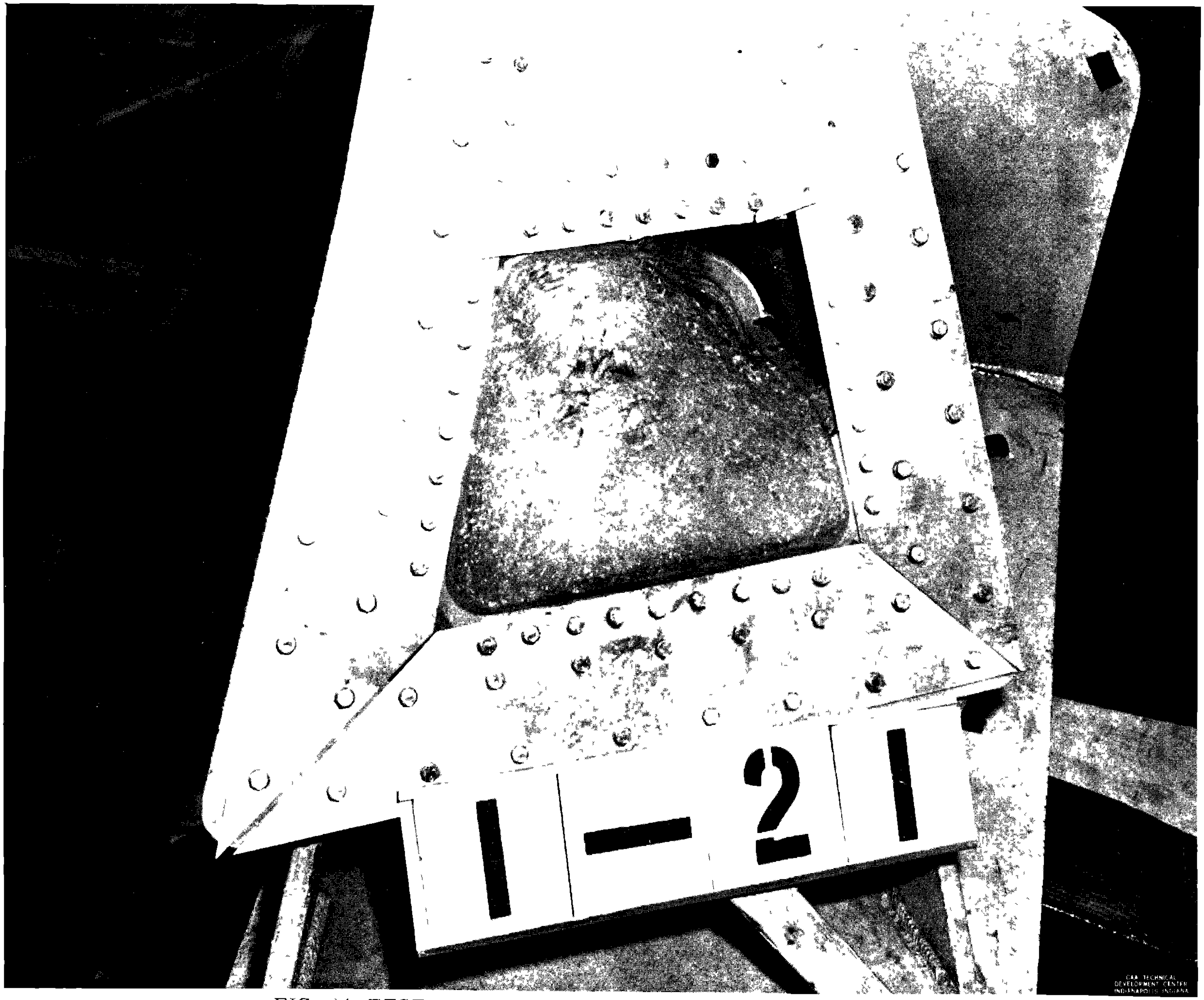


FIG. 34 TEST NO. 21. PROJECTILE VELOCITY 414 MPH

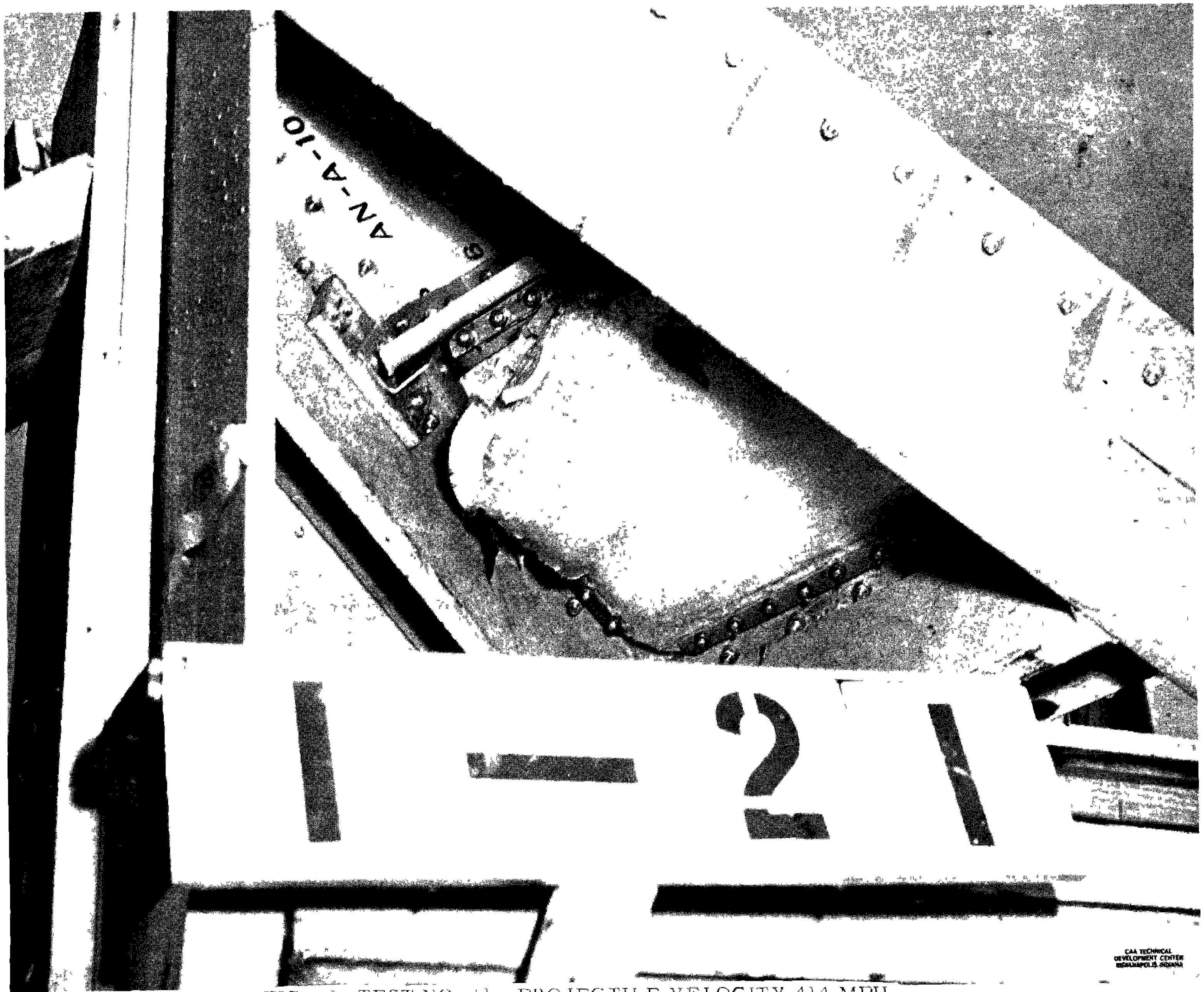


FIG [illegible] TEST NO. 11. PROJECTILE VELOCITY 414 MPH

FIG. 36 TEST NO. 21. PROJECTILE VELOCITY 414 MPH

FIG 57 TEST NO [illegible] PROJECTILE VELOCITY [illegible] MPH

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS INDIANA

FIG. 30 TEST NO 21. PROJECTILE VELOCITY 414 MPH

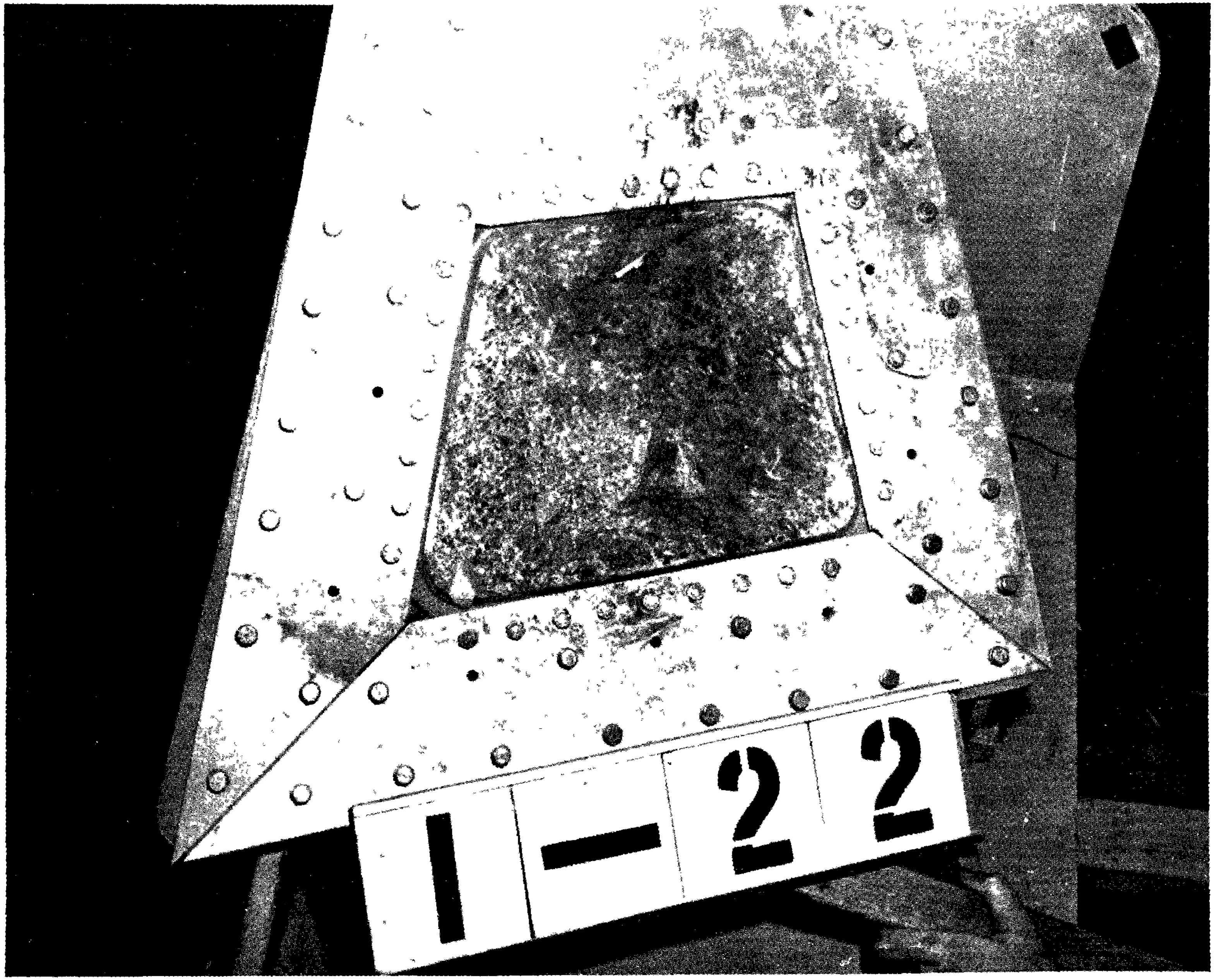


FIG. 39 TEST NO. 22. PROJECTILE VELOCITY 408 MPH

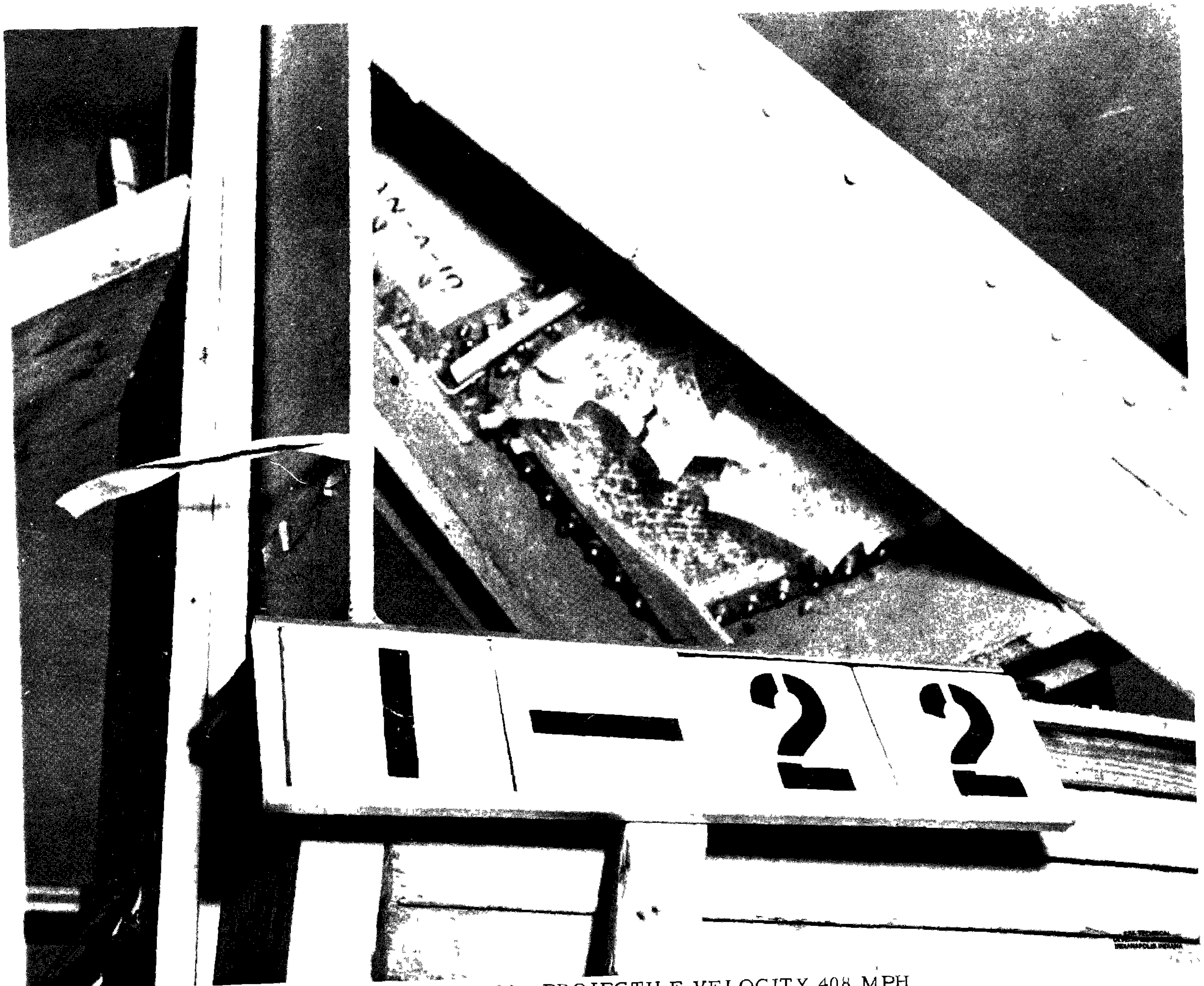


FIG. 40 TEST NO. 22. PROJECTILE VELOCITY 408 MPH

FIG 41 TEST NO 22. PROJECTILE VELOCITY 408 MPH

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS INDIANA

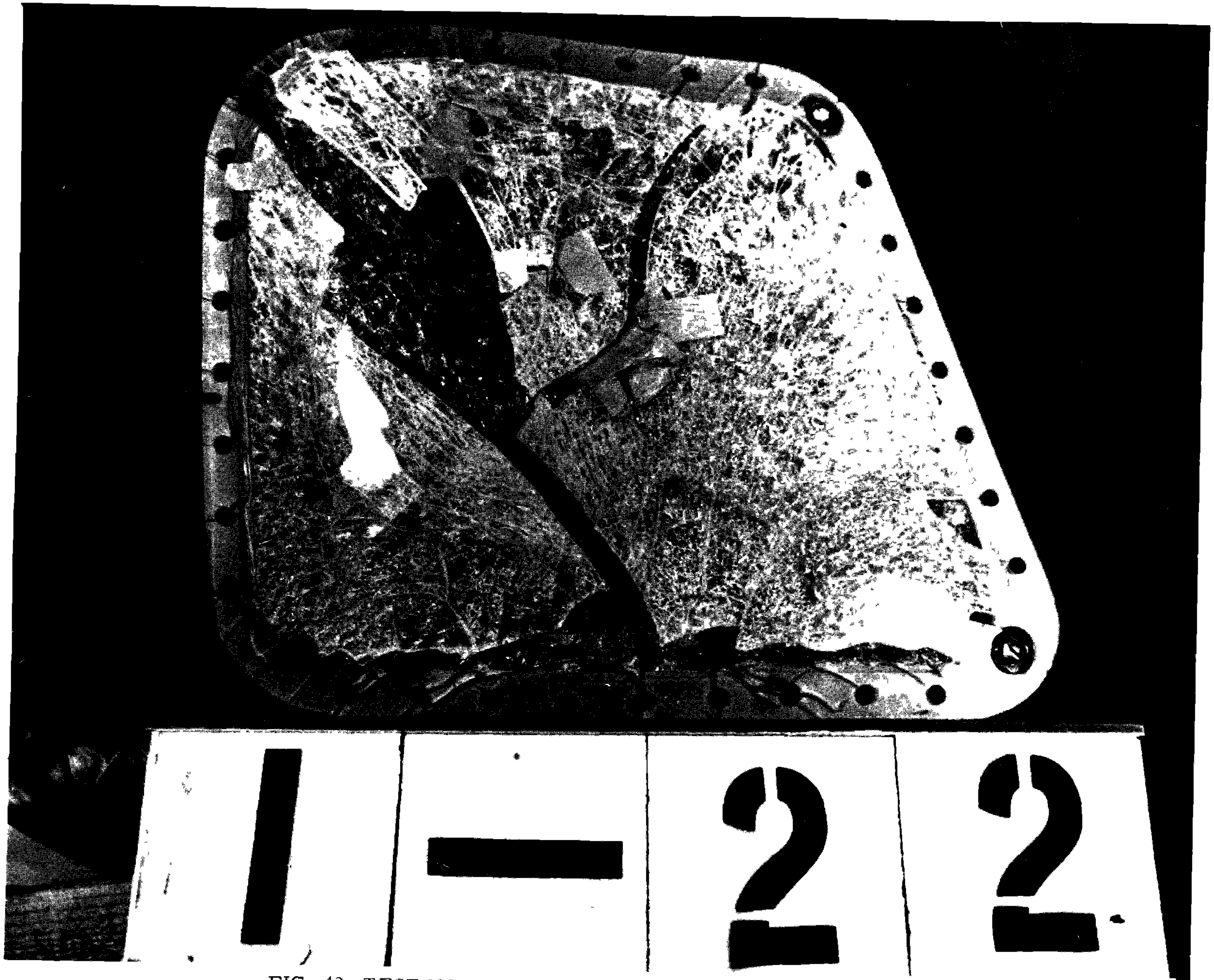


FIG. 42 TEST NO. 22. PROJECTILE VELOCITY 408 MPH

FIG. 43 TEST NO. 22. PROJECTILE VELOCITY 408 MPH

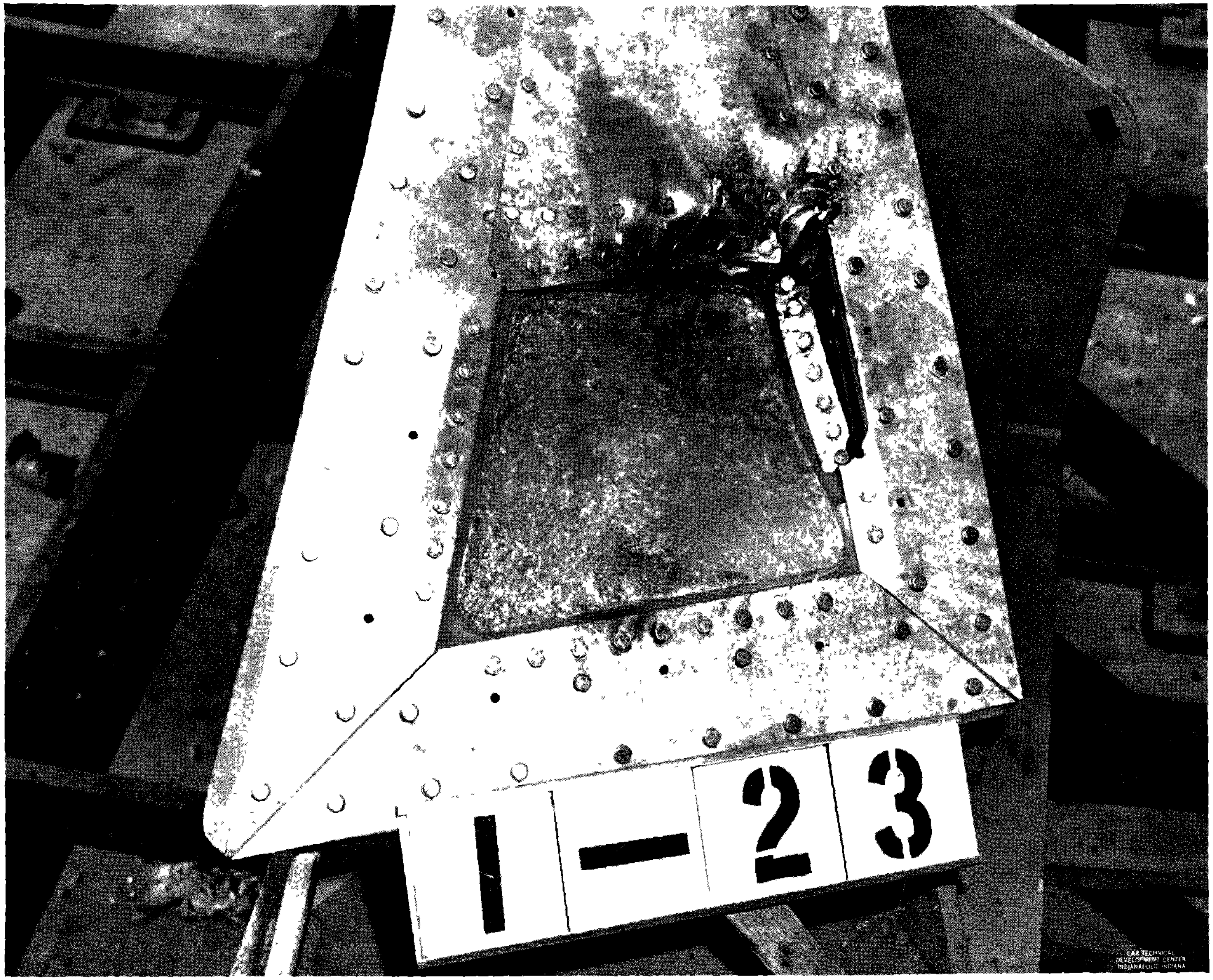


FIG. 44 TEST NO. 23. PROJECTILE VELOCITY 390 MPH .

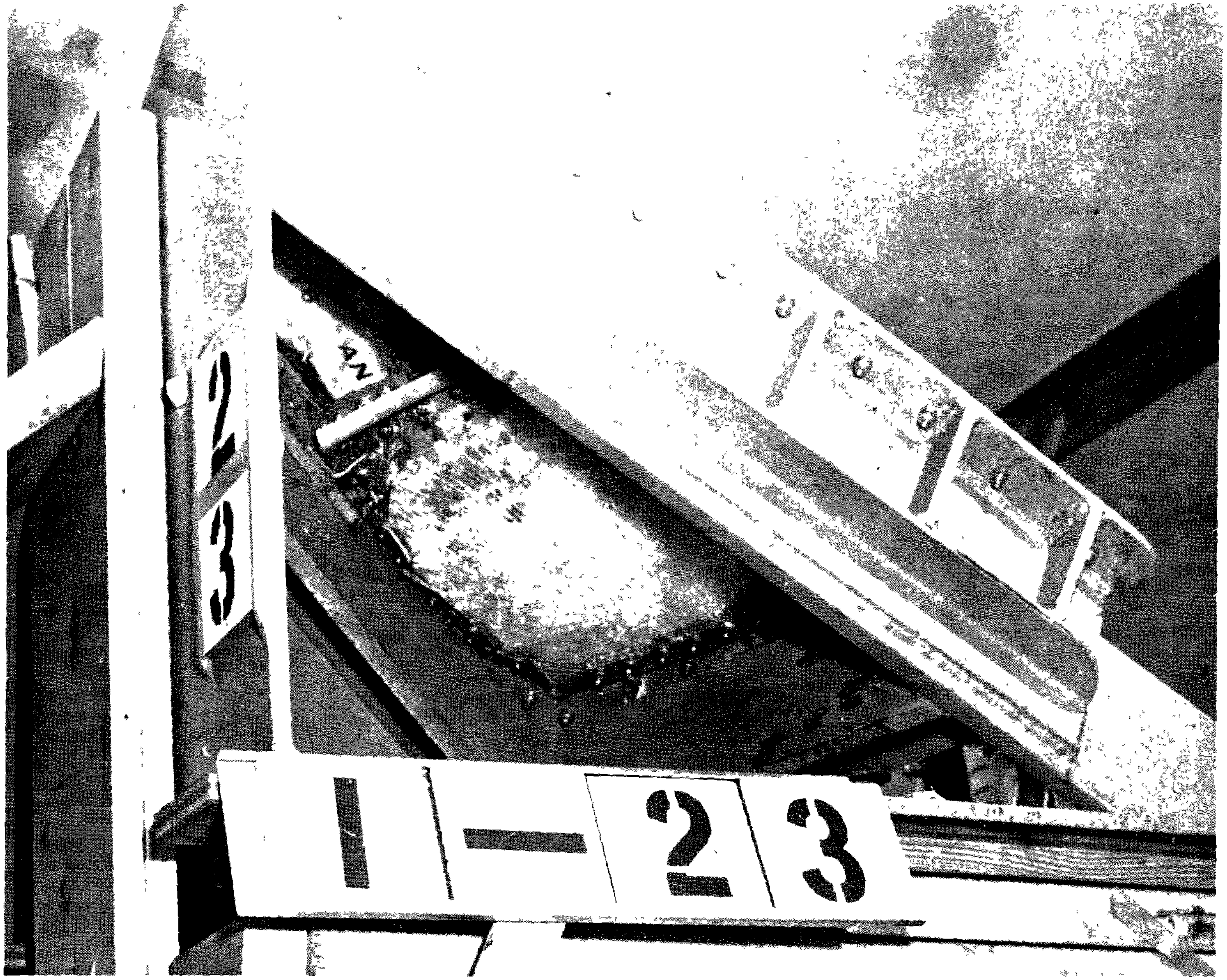


FIG. 45 TEST NO 23. PROJECTILE VELOCITY 390 MPH

FIG. 46 TEST NO. 23. PROJECTILE VELOCITY 390 MPH

FIG. [illegible] TEST 2[illegible]O PROJECTILE VELOCITY [illegible] M.PH.

CAA TECHNICAL
DEVELOPMENT CENTER
INDIANAPOLIS INDIANA

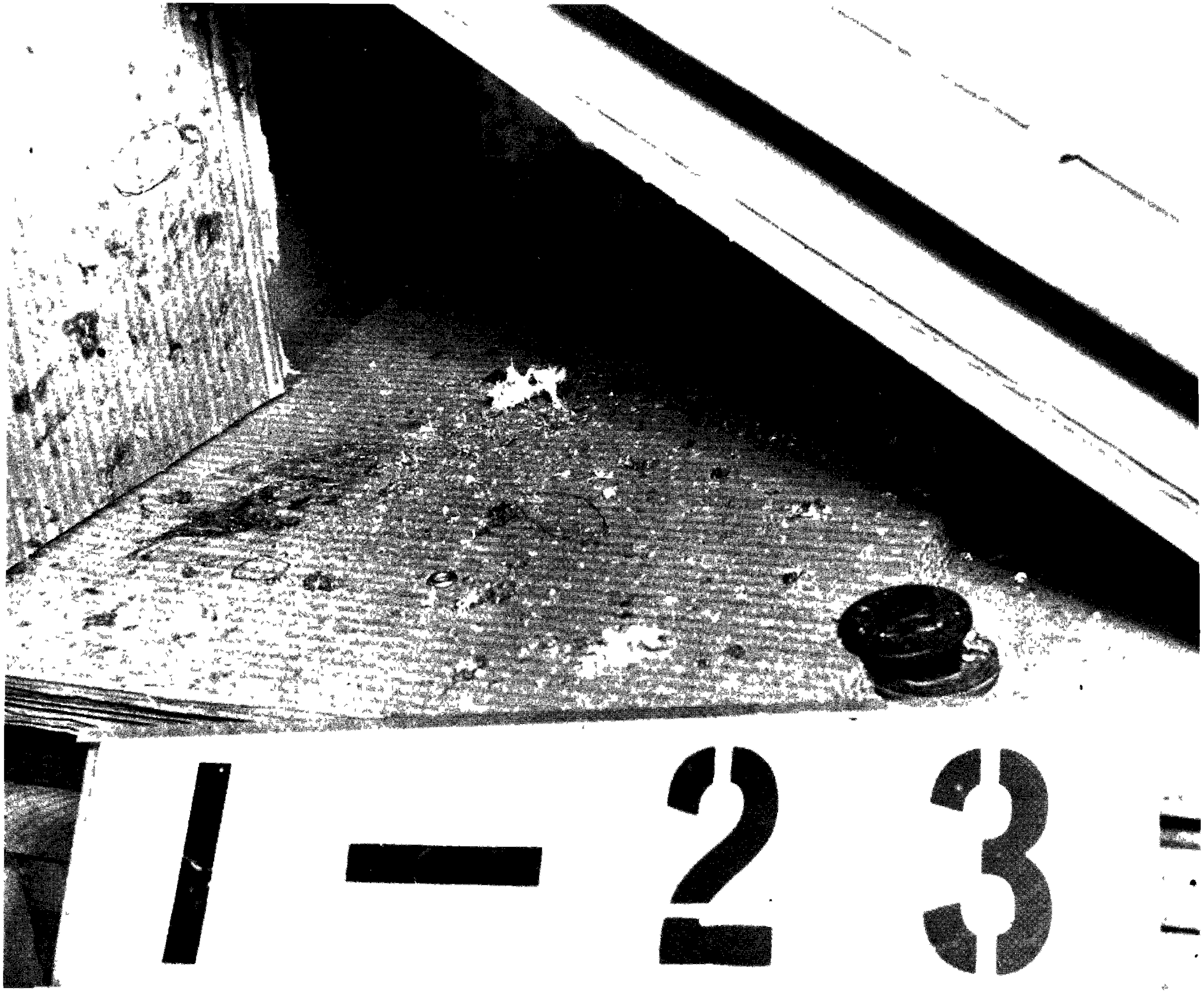


FIG. 48 TEST NO. 23. PROJECTILE VELOCITY 390 MPH

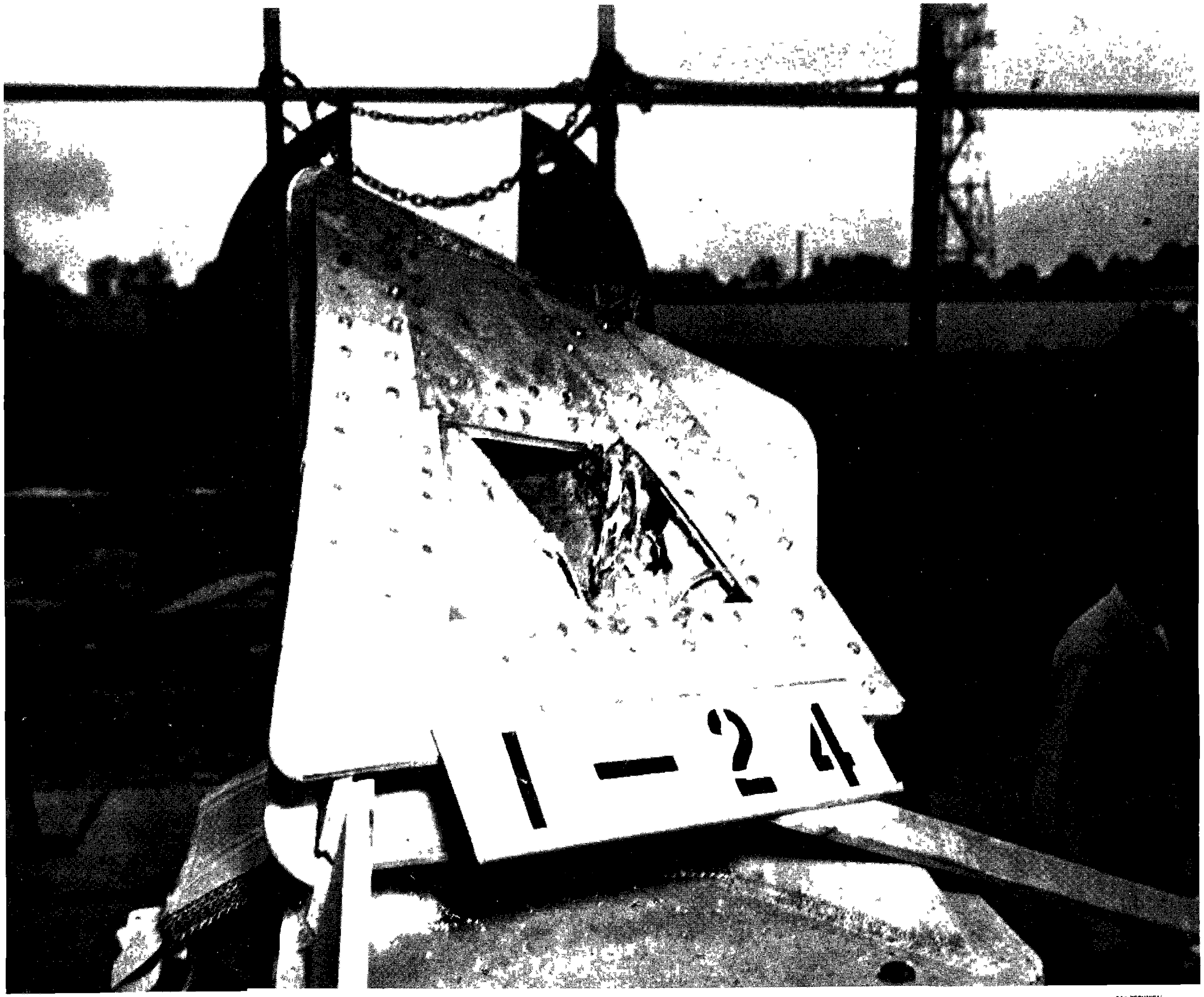
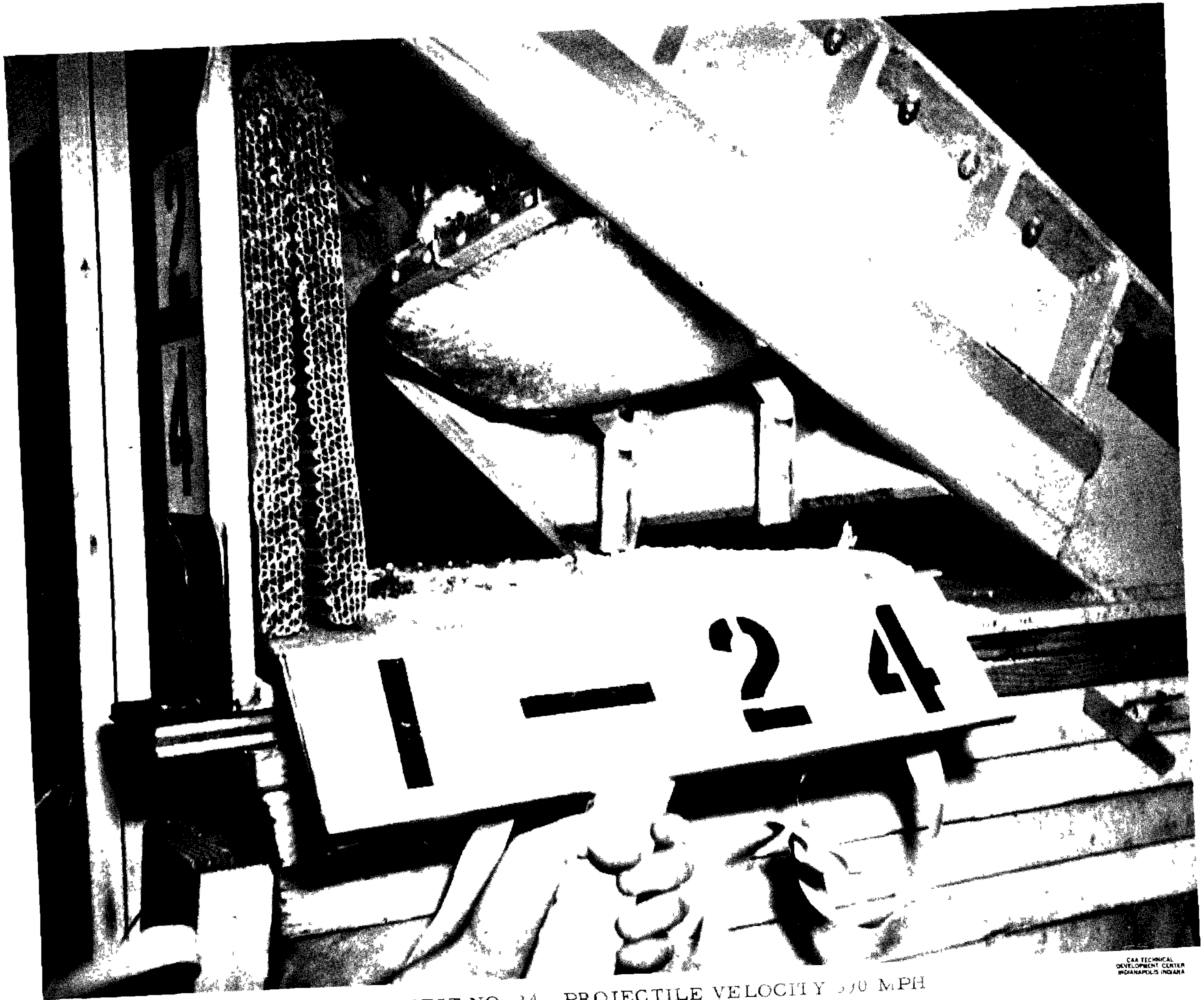


FIG. 47 TEST NO. [illegible] PROJECTILE VELOCITY 590 MPH



CAA TECHNICAL
DEVELOPMENT CENTER
INDIANAPOLIS INDIANA

FIG 50 TEST NO 24. PROJECTILE VELOCITY [illegible]0 MPH

CAA TECHNICAL
DEVELOPMENT CENTER
INDIANAPOLIS INDIANA

FIG. 5[illegible] TEST NO. 24. PROJECTILE VELOCITY 390 MPH

FIG [illegible] TEST NO. [illegible] PROJECTILE VELOCITY [illegible] MPH

CAA TECHNICAL
DEVELOPMENT CENTER
INDIANAPOLIS INDIANA

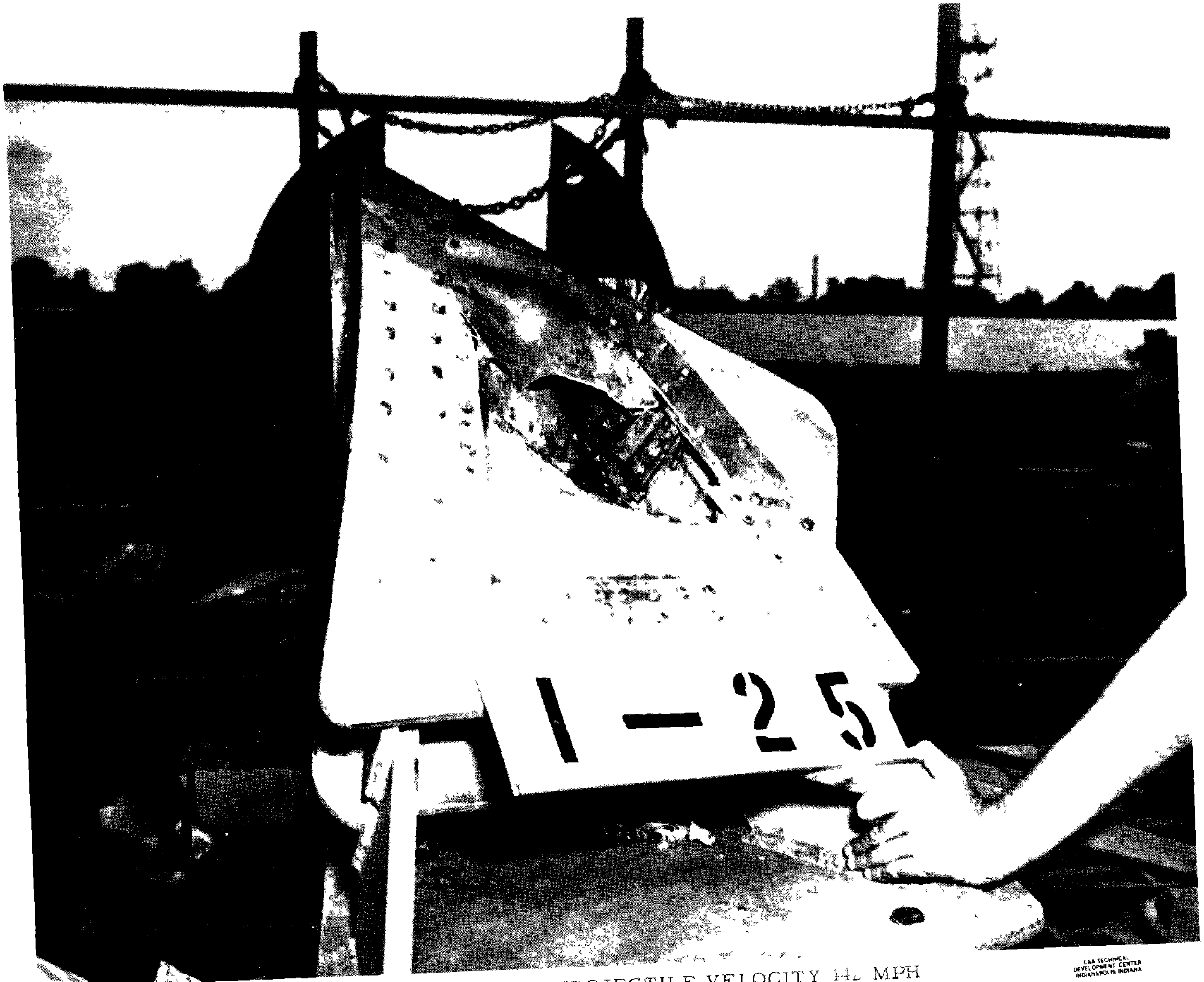


FIG. 54 TEST NO. 25. PROJECTILE VELOCITY 142 MPH

FIG 55 TEST NO 25. PROJECTILE VELOCITY 442 MPH

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS INDIANA

FIG. 56 TEST NO. 25. PROJECTILE VELOCITY 442 MPH

FIG. 57 TEST NO. 25. PROJECTILE VELOCITY 442 MPH

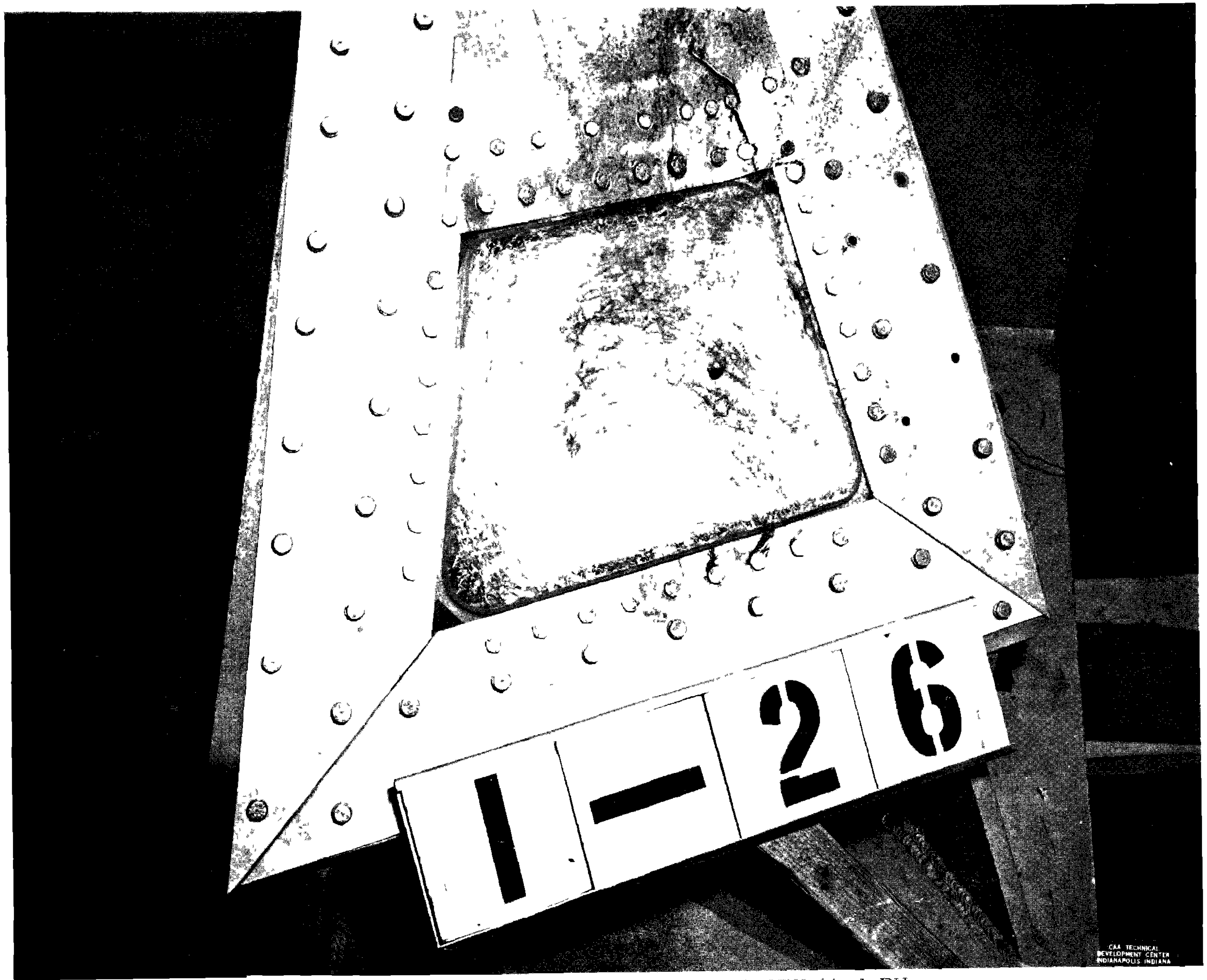


FIG. 56 TEST NO. [illegible]. PROJECTILE VELOCITY 448 MPH

FIG 59 TEST NO. 26. PROJECTILE VELOCITY 448 MPH

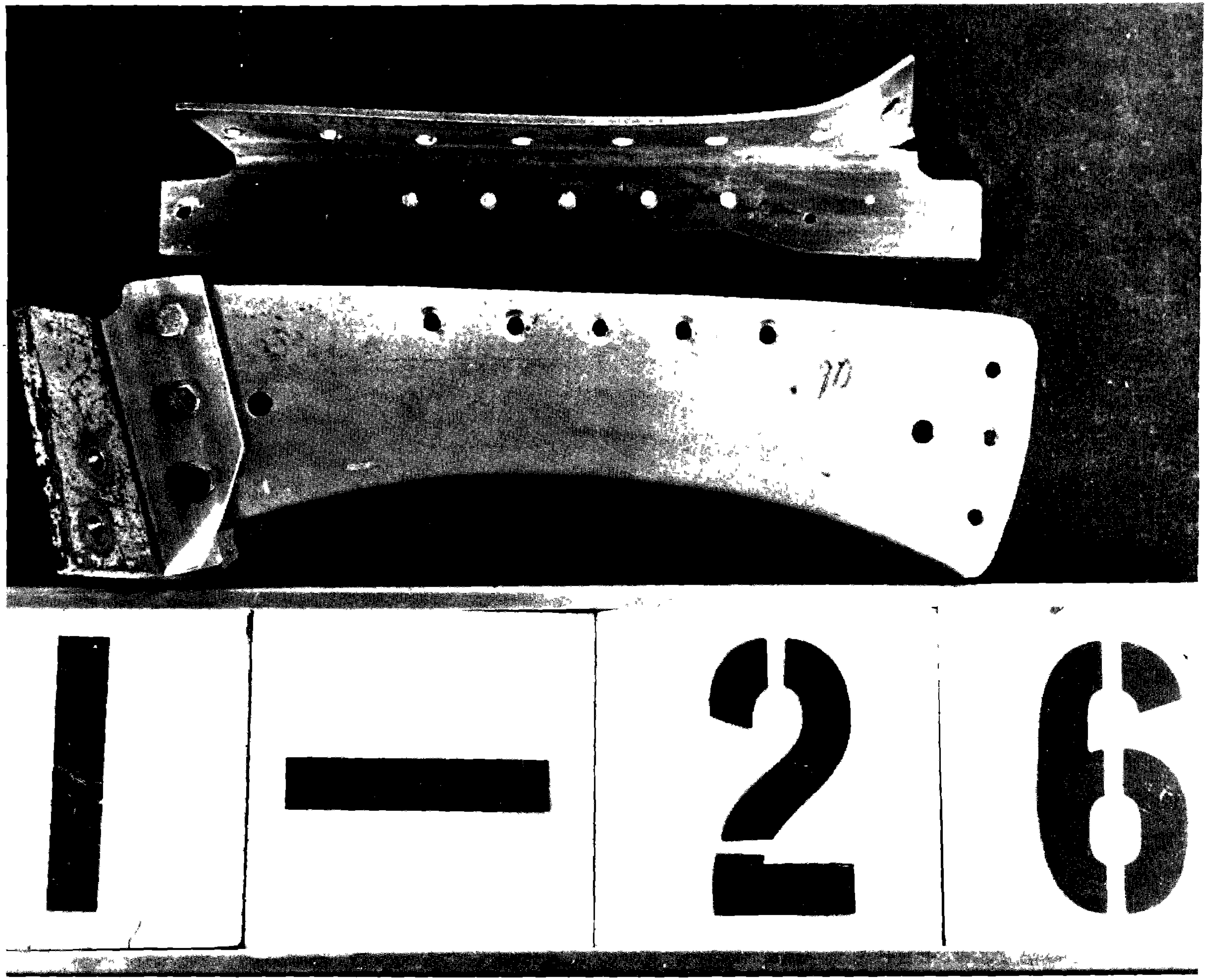


FIG. 60 TEST NO. 26. PROJECTILE VELOCITY 448 MPH

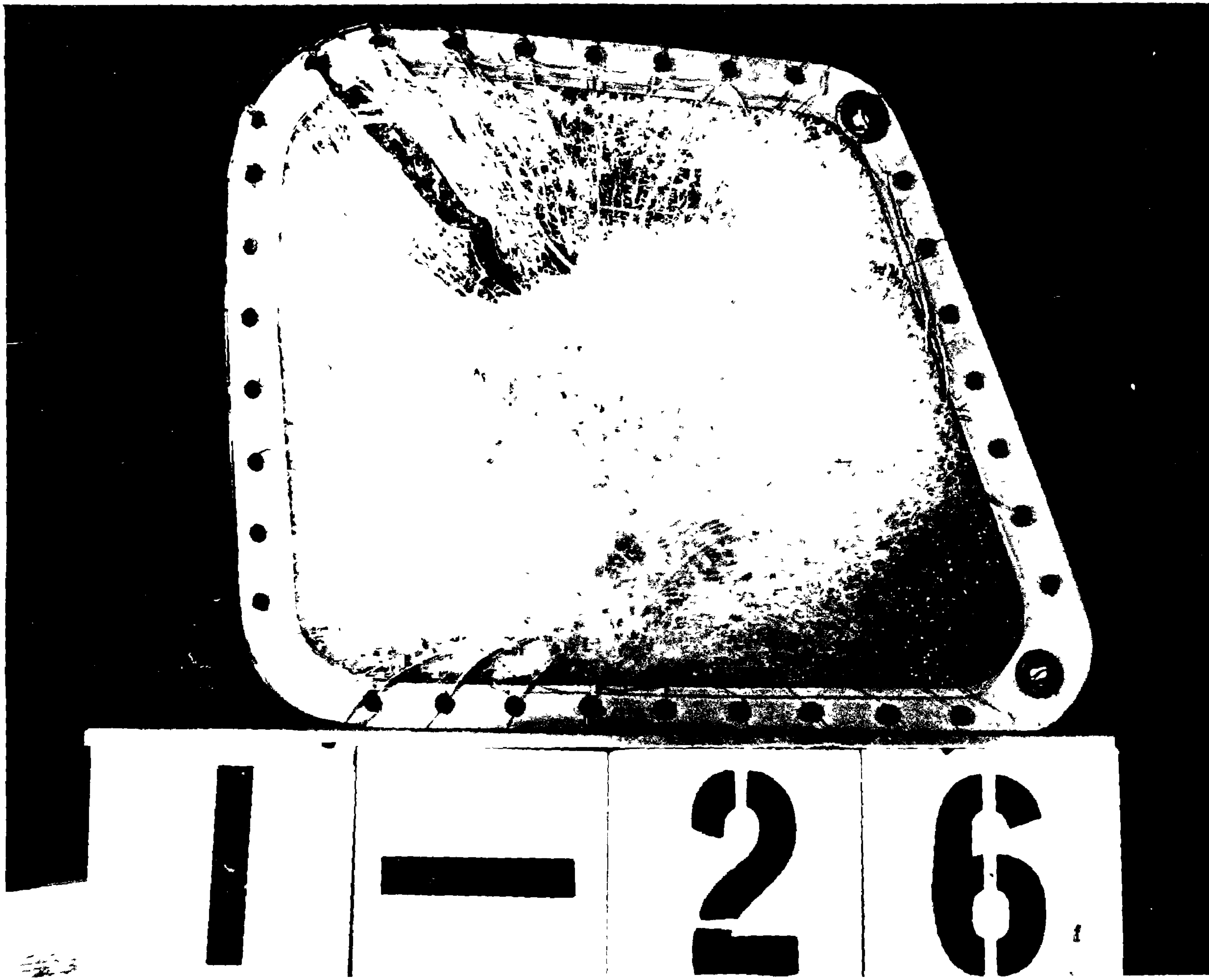


FIG 61 TEST NO 26 PROJECTILE VELOCITY 448 MPH

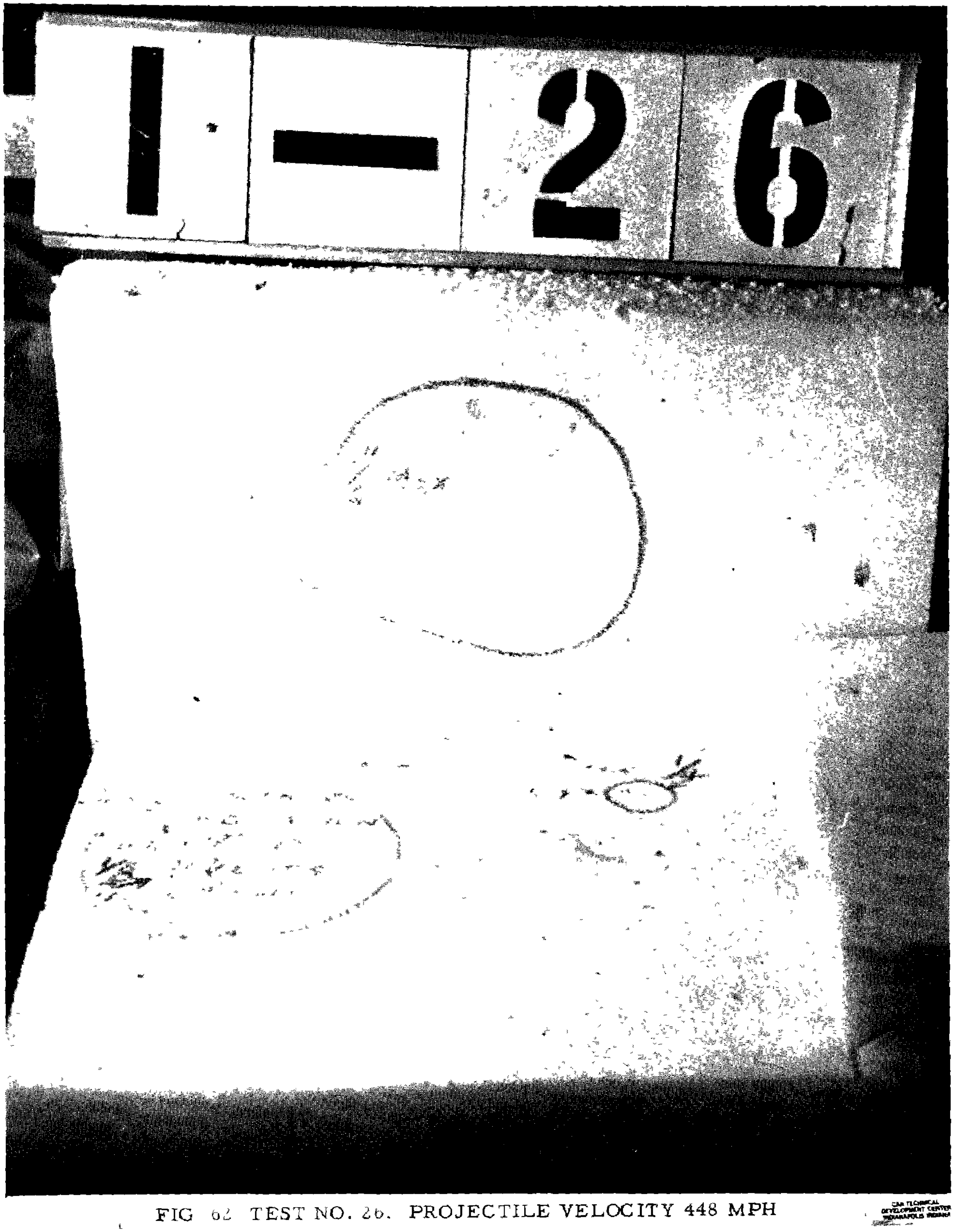


FIG 62 TEST NO. 26. PROJECTILE VELOCITY 448 MPH