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FIELD REPAIR OF AH-1G HELICOPTER WINDOW CUTTING ASSEMBLIES

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SUMMARY

The United States Army AH-1G helicopter utilizes explosively actuated window cutting assemblies to provide emergency crew ground-egress. Inspections, that revealed large gaps between the explosive cord and the stretched acrylic windows, raised the concern of severance reliability for a fleet of several hundred aircraft. Needed were determinations of gap limits and a repair method for excessive gaps. Room temperature vulcanizing silicone compound (RTV) was installed in the gaps, using a simple, field process, to couple the explosive energy to the acrylic. Functional tests revealed that gaps to 0.100 inch without RTV were acceptable; RTV-filled gaps of up to 0.250 inch achieved fully functional severance.

INTRODUCTION

The United States Army AH-1G (Cobra) helicopter gunship uses explosive cords, called window cutting assemblies, mounted around the inside periphery of the 0.187-inch thick, stretched acrylic windows, to create openings for emergency ground-egress of the two-member crew. In March 1981 a test program was conducted to establish an allowable gap of 0.100 inch between the explosive cord and the acrylic to assure reliable severance. However, in March 1983, during inspection of a portion of the fleet of several hundred aircraft, it was discovered that the explosive cords were separated from the acrylic by a gap greater than 0.100 inch, which would have reduced or prevented the fracturing of the acrylic when the window cutting assemblies were functioned. A simple, permanent, field repair method was needed to allow rapid refurbishment of the fleet to maintain flight status.

The explosive cords are mounted in flexible, black, silicone-rubber extrusions (see fig. 1), which in turn are housed by plastic frames, mounted to either the airframe on the two windows or to the two door frames. The explosive cords are silver or lead-sheathed and contain 2.5 grains/foot hexanitrostilbene-II. The silicone rubber was extruded into an approximately 1-inch wide triangular cross section, which contains a large air cavity to dissipate the explosive pressures propagating inboard into the aircraft. The extrusion also contains bulbous areas on either side of the explosive cord to prevent contamination of the explosive cord-to-acrylic interface after the assembly has been mounted against the acrylic. The plastic frames are General Electric materials, EKE-450 or Lexan polycarbonates.

A 1981 inspection of 29 door assemblies revealed considerable uniformity, but a 1983 inspection of 15 aircraft revealed explosive cord-to-acrylic gaps that considerably exceeded the allowable 0.100 inch. The 29 door assemblies had gaps that averaged 0.054 inch with a standard deviation of 0.023 inch (25 measurements per door); the maximum gap of 0.200 inch occurred on only one unit. The 15-aircraft inspection revealed that at least one window or door from each aircraft (two windows and two doors per aircraft) had gaps that exceeded 0.100 inch. A total of 34 percent of all window cutting assemblies contained gaps that exceeded 0.100 inch, 17 percent contained gaps that exceeded 0.200 inch, and 3 percent contained gaps that exceeded 0.250 inch. The 0.250-inch gaps were less than 6 inches in length. The cause or causes of the gap between the explosive cord and the acrylic were unknown; speculations included the possibility of mismatches between the curvatures of the windows and doors and those of the window cutting assembly frames, as well as window cutting assembly frame distortions caused by age, heat, and solar radiation. However, considering the importance for crew survivability, an immediate repair had to be implemented to assure the flight status of several hundred aircraft.

The specific goals for the window cutting assembly repair were:

1. An inspection method was needed that would be easy to use, nondestructive and minimize judgment error.

2. The repair should be simple, requiring minimal training and equipment or tooling.

3. The repair should be accomplished in the field without the removal of components from the aircraft.

4. The repair should be permanent with an expected lifetime of 25 years.

5. The repair should prevent further displacement of the explosive cord, even if the window cutting assembly frame continues to warp.

6. The repair should allow subsequent removal and replacement of the acrylic panels without damage to the window cutting assembly.

The approach selected for the window cutting assembly repair was to fill the gaps that exceeded 0.100 inch with room temperature vulcanizing silicone compound (RTV), MIL A 46106. The RTV is injected as a smooth paste, which cures by water absorption from ambient air to a rubbery consistency. Furthermore, the RTV bonds to any surface to which it contacts. The principle of operation of the repaired window cutting assembly would be that the RTV would couple the explosive pressure wave into the acrylic to eliminate the effect of air gaps.

The objective of this program was to evaluate the RTV repair of AH-1G window cutting assemblies in terms of meeting the above goals.

PROCEDURES

The experimental effort was divided into three areas: inspection, tests to determine the allowable air gap between the explosive cord and acrylic, and tests to demonstrate RTV repair of gaps that exceed the allowable limit.

Inspection

In an attempt to scope the relative magnitude of the problem of explosive cord-to-acrylic separation, a 15-aircraft inspection (60 windows and doors) was conducted. The nondestructive inspections used an optical method and a tool that was developed for this effort. The optical method was a lens system that was focused on the surface of the explosive cord, and then the fixed lenses were displaced to refocus on a piece of paper pressed against the surface of the acrylic, opposite the explosive cord. The displacement of the lenses was the cord-to-acrylic gap. The inspection tool, shown in figure 2, provided a go/no-go approach. The flattened leg (the flattened area against the acrylic with the 1-inch leg perpendicular to the surface) was slipped between the acrylic and rubber extrusion; this shape allowed the bulbous areas of the rubber extrusion to be pushed aside without damage. The 1-inch leg was then rotated against the acrylic to place the 0.100-inch blade across the explosive cord-to-acrylic gap. A second inspector viewed the tool through the acrylic to determine if contact had been made with the explosive cord. Other tools with different blade widths could be used to establish any gap size.

Allowable Air Gap Tests

To determine the allowable limit of the air gap between the window cutting assembly's explosive cord and the acrylic, three full-scale door assembly tests were conducted with constant gaps between the explosive cord and the acrylic of 0.100, 0.150, and 0.200 inch, respectively, around the entire periphery. The gaps were achieved by using washers between the acrylic and frame on the mounting bolts.

RTV Repair Tests

A series of four tests were conducted, using door assemblies, to determine the approach for installation of RTV in gaps between the window cutting assembly's explosive cord and acrylic, while demonstrating functional severability. The variables to be assessed were: (1) maximum gap between the explosive cord and the acrylic that can be filled with RTV, (2) the width of the RTV covering the explosive cord, and (3) the proximity of the door frame to the explosive cord. These variables would affect the delivery of the explosive energy into the acrylic to induce fracture. All test firings were conducted with the door assemblies lying with the outboard side down on a wooden frame that supported both ends of the assembly.

For the first three tests, the acrylics were removed, test gaps were set, using washers on the acrylic-to-frame mounting bolts, the RTV was spread on the explosive cord and rubber extrusion, and the acrylics reinstalled, allowing the excess RTV to extrude from the acrylic-to-frame interface. Test 1 was conducted with a 0.200-inch gap around the periphery with an approximately 0.5-inch RTV bead width. Test 2 was conducted with a 0.300-inch gap around the periphery with an approximately 0.75-inch RTV bead width. The RTV was allowed to spread onto the doorframe. Test 3 was conducted with a variable gap around the periphery, as shown in figure 3. This gap better represents the gap conditions found in the aircraft survey. That is, large gaps occurred in the forward/upper and aft/lower corners. The RTV bead width was approximately 1.5 inches with overlap onto the frame around 80 percent of the periphery.

Test 4 was conducted with the variable gaps shown in figure 4. The door was fully assembled to allow installation of the RTV in a simulated field condition. Care was taken to avoid overlap of the RTV onto the frame in areas, such as that shown in figure 5. RTV was installed only in gaps that were greater than 0.100 inch. The RTV was installed using a cartridge, as shown in figure 6. The cartridge tip was preheated to a softened condition and flattened to allow insertion past the bulbous areas to the explosive cord. The RTV was ejected from the cartridge, using a hand-operated gun, which maximized the control of the flow to coordinate with tip movement. The RTV bead was carefully controlled to a maximum width of 0.25 inch and was prevented from contact with the frame, as shown in figure 7. In all RTV installations, the RTV was cured 16 hours or more.

After the test-firings, the acrylics were pushed out of the frames to determine the relative effectiveness of the severance and the difficulty crew members would experience during egress. A piezoelectric load cell was used to determine the maximum forces required. All force applications were perpendicular to the acrylic at the point of contact.

RESULTS

Functional tests were conducted to determine the allowable air gaps between the explosive cord and the acrylic and to demonstrate the RTV repair of large explosive cord-to-acrylic gaps.

Allowable Air Gap Tests

Three tests were conducted, one each at peripheral gaps of 0.100, 0.150, and 0.200 inch. Complete severance and breakout occurred in the 0.100-inch peripheral gap test. Less than 5 percent of the acrylic remained in the 0.150-inch peripheral gap test. However, no breakout or fracturing occurred in the 0.200-inch peripheral gap test.

RTV Repair Tests

Four tests were conducted with RTV installed in gaps larger than the allowable 0.100-inch air gap. Also evaluated were the effects of RTV bead widths and allowing the RTV to overlap onto the window frames.

The results of test 1, which employed a constant peripheral gap of 0.200 inch with a 0.5-inch RTV bead width, are shown in figure 8. Approximately 80 percent of the area was jettisoned. The acrylic was sheared at the acrylic-to-frame interface, that is, the point at which a fiberglass frame was bonded to the acrylic.

The results of test 2, which employed a constant 0.300-inch peripheral gap with a 0.75-inch RTV bead width, are shown in figure 9. The acrylic was not jettisoned except for a small portion at the top. In fact, this piece was hanging by a less than 1-inch long RTV bond of the acrylic to the rubber extrusion. Central cracks indicated that the acrylic had been considerably flexed. Appreciable cracking was evident at the interface between the fiberglass frame and the acrylic.

The results of test 3, which employed a variable gap (large gaps at the corners) and a 1.5-inch RTV bead width, are shown in figure 10. The acrylic was not jettisoned, nor did much cracking occur through the control area. The acrylic-to-frame interface around most of the periphery was not obviously cracked.

The results of test 4, which employed a variable gap to represent a typical aircraft condition, including lengths in which no RTV was installed, and a carefully controlled 0.25-inch or less bead width, are shown in figure 11. The entire periphery was either severed, as expected in the gaps that were 0.100 inch, or fractured at the interface between acrylic and the fiberglass frame. Figures 12 and 13 show more detail on this severance: the acrylic sheared at the frame in the lengths in which the RTV was applied, and the acrylic was fractured on the centerline of the explosive cord, where no RTV was applied.

The pushout testing revealed the actual effectivity of the explosive severance and fracture induced in tests 2, 3, and 4. For test 2, a 12-pound thrust on the center of the acrylic ejected the major portions (center and upper right and upper left areas, shown in fig. 14). The two remaining areas required approximately 100 pounds to push out. The entire periphery was severed at the acrylic-to-frame interface. The areas hinged on the RTV bond line, and in most cases the window cutting assembly frame was broken to clear the area. The pushed-out area for test 3 is shown in figure 15. A 125-pound thrust released the major area. The periphery was 98 percent severed at the acrylic-to-frame interface; an 8-inch length in the lower, center area was not severed. The remaining areas required thrusts of 90, 30, and 85 pounds to clear more than 95 percent of the area. For test 4 with the closely controlled RTV installation, no more than 4 pounds was necessary to push out any portion of the acrylic. The acrylic was severed around the entire periphery. The RTV bonds were all that retained the acrylic in position. Figure 16 shows the pushed-out acrylic.

CONCLUSIONS

The United States Army AH-1G (Cobra) helicopter gunship utilizes explosive cords (window cutting assemblies), mounted against the four stretched acrylic side windows, to create openings for emergency crew ground-egress. Field inspections revealed that large gaps have occurred between the explosive cord and acrylic on 17 percent of a 60-unit sample of window cutting assemblies (a discrepancy occurred on each of the 15 aircraft). The reliability of severance under the conditions of large gaps became a concern affecting the operational status of a fleet of several hundred aircraft. Needed were determinations of the amount of gap between the explosive cord and the acrylic that could be allowed without repair, and a simple, permanent, field method to repair large gaps.

The repair approach selected was to install room temperature vulcanizing silicone compound (RTV) between the explosive cord and the acrylic without disassembly of aircraft components. The tip of an RTV cartridge was flattened to allow insertion in the gaps, and hand-operated guns were used to control the flow of RTV with tip motion. The RTV bonds the explosive cord assembly to the acrylic to prevent further gapping problems. On functioning, the RTV couples the explosive pressure wave into the window, rather than allowing rapid attenuation in air gaps. If a window needed replacement, the RTV would be cut from the acrylic, and following installation of a new acrylic, the RTV rebonded.

Functional tests revealed the relative influence of the explosive cord-to-acrylic gap dimensions and the amount of installed RTV on severability. No RTV was necessary in gaps as large as 0.100 inch at which a 0.050-inch severance margin (total gap of 0.150 inch) was demonstrated. Filling gaps as large as 0.300 inch with RTV proved to be very effective, provided the RTV beads were no greater than 0.25 inch and did not overlap onto the frame of the window. The RTV-filled gaps produced a completely different severance mechanism than did air gaps. The air gaps induced fractures in the acrylic on the centerline of the explosive cord; the RTV-filled gaps induced shear fractures on the peripheral acrylic-to-fiberglass frame interface, outboard of the centerline of the explosive cord. The RTV bond between the acrylic and the window cutting assembly was not broken on firing, and the acrylic remained hanging in the aircraft. However, forces of only 4 pounds were necessary to push the acrylic out to allow crew egress.

The installation of room temperature vulcanizing silicone compound (RTV) is an effective, permanent method of achieving full functionality of the AH-1G window cutting assemblies without disassembly of the aircraft. The RTV will prevent jettisoning of the acrylic, as would a properly positioned window cutting assembly that did not use RTV. Very little effort was required to push out the acrylic.

However, careless application of RTV (bead widths wider than 0.25 inch and beads that overlap the window frames) can significantly decrease the severance efficiency and increase the effort to push out the acrylic.

RECOMMENDATIONS

To accomplish the field repair of AH-1G window cutting assemblies, the following is recommended:

1. No RTV is needed in explosive cord-to-acrylic separation gaps to 0.100 inch.

2. RTV should be installed in gaps between 0.100 to 0.250 inch.

3. RTV beads should not exceed 0.25 inch in width and should not overlap onto the window frames.

4. Window cutting assemblies with gaps that exceed 0.250 inch should be replaced.

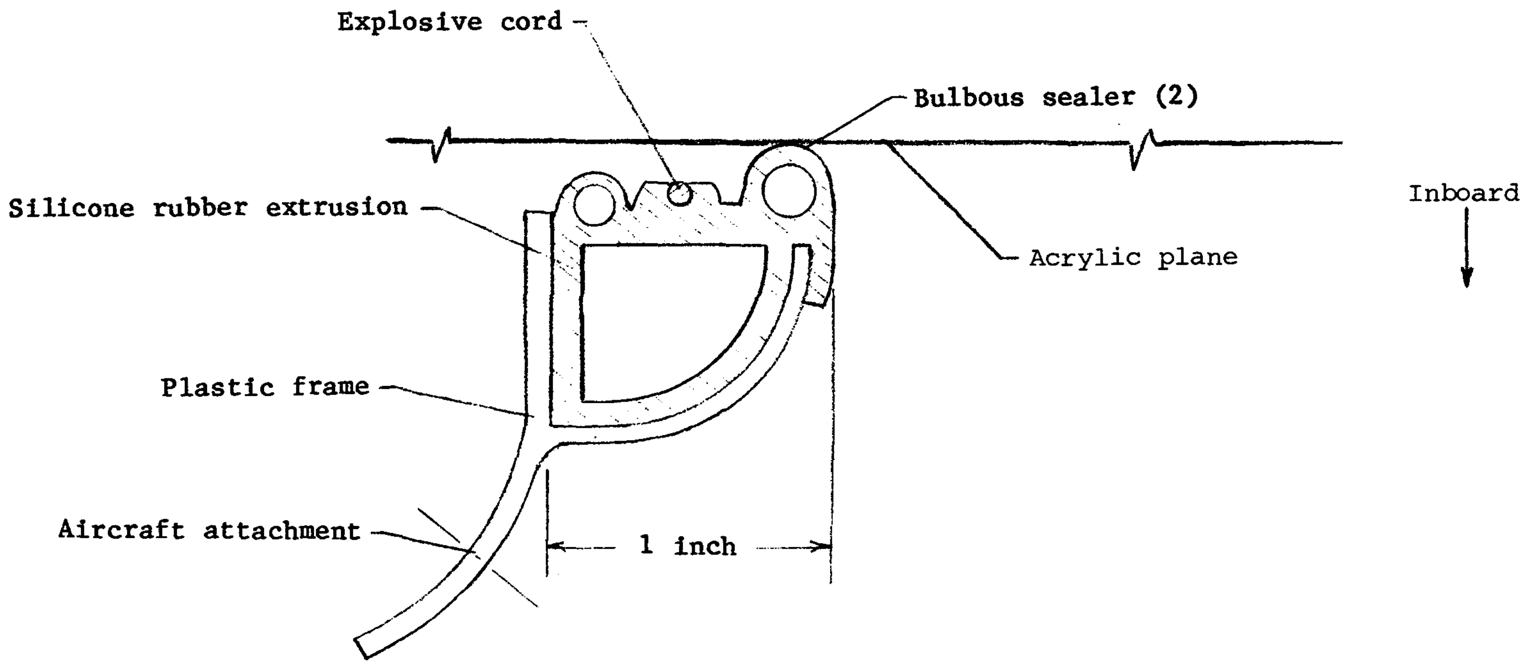

Figure 1.- Cross section of window cutting assembly, showing the explosive cord, silicone extrusion and plastic frame.

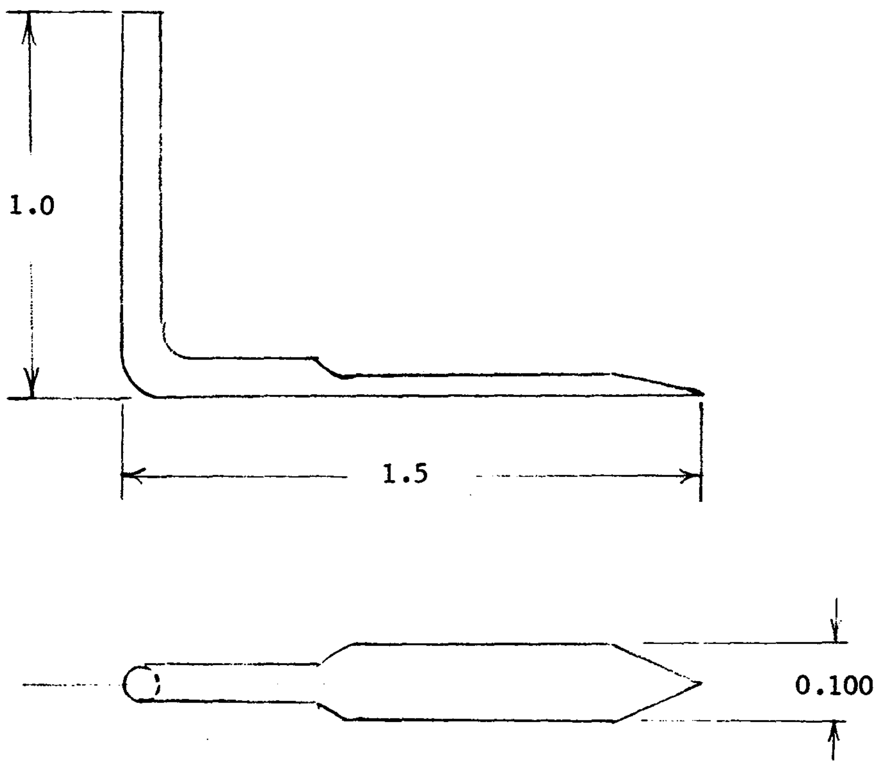

Figure 2.- Inspection tool: insert flattened leg between explosive cord and acrylic and rotate 1-inch leg down to position the 0.100 dimension perpendicular to the acrylic.

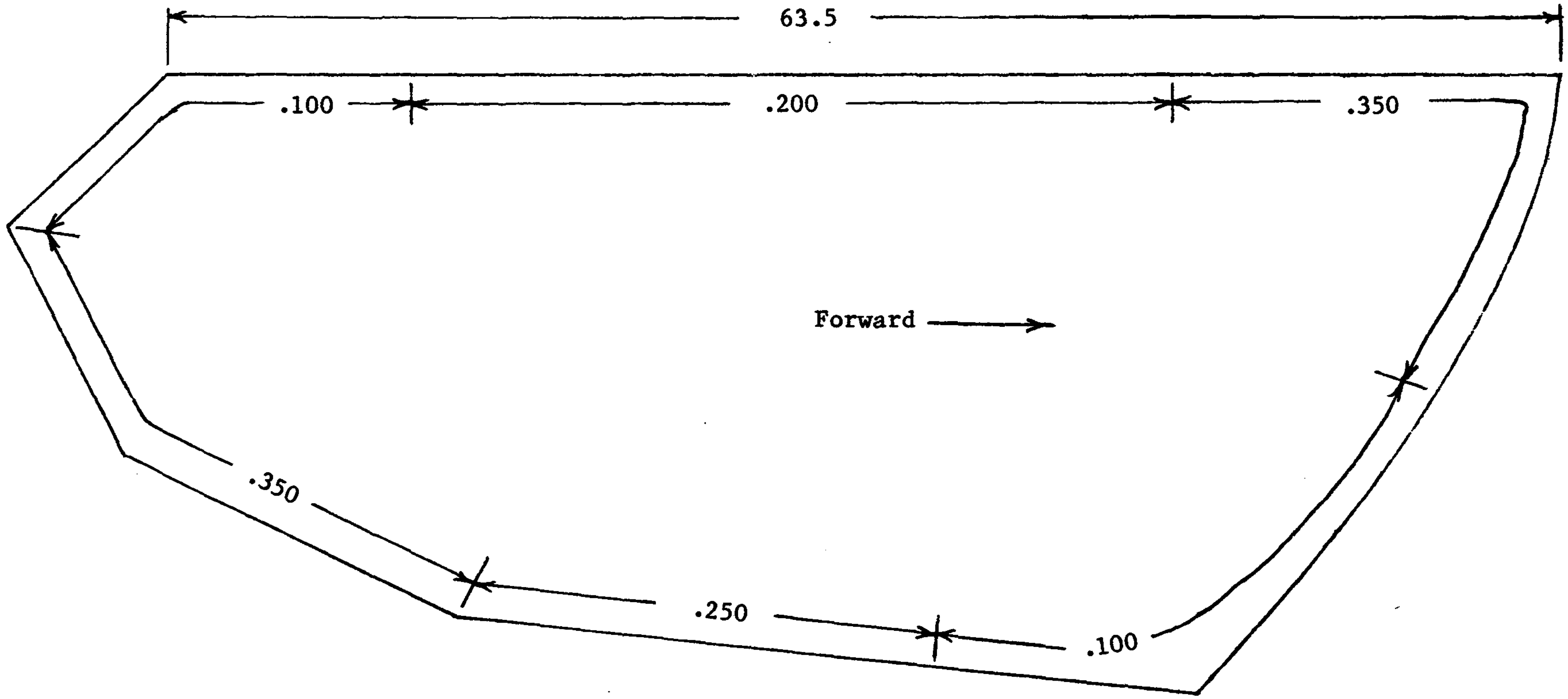

Figure 3.- Explosive cord to acrylic separation distances for Test 3.

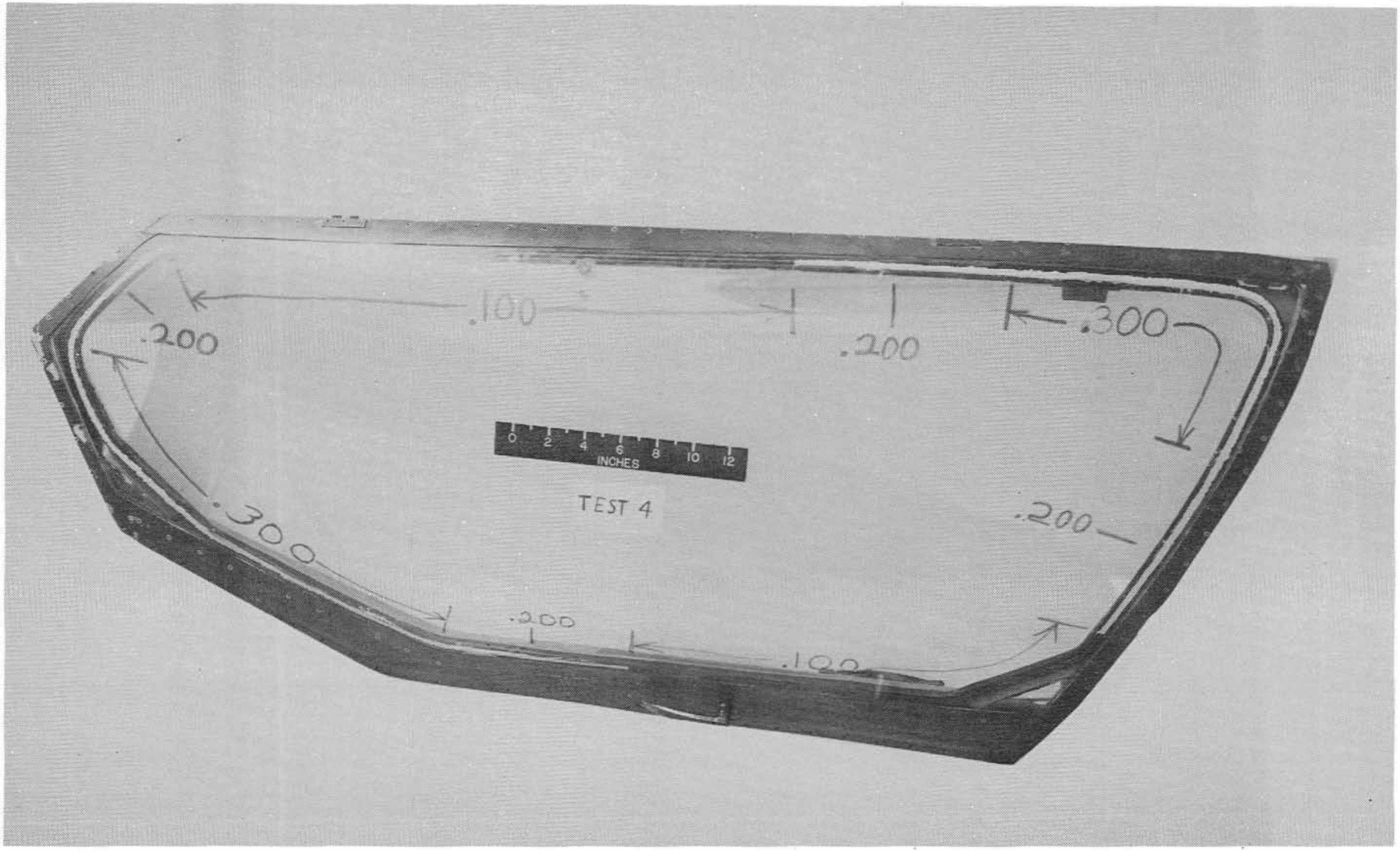

Figure 4.- Explosive cord to acrylic separation distances for Test 4.

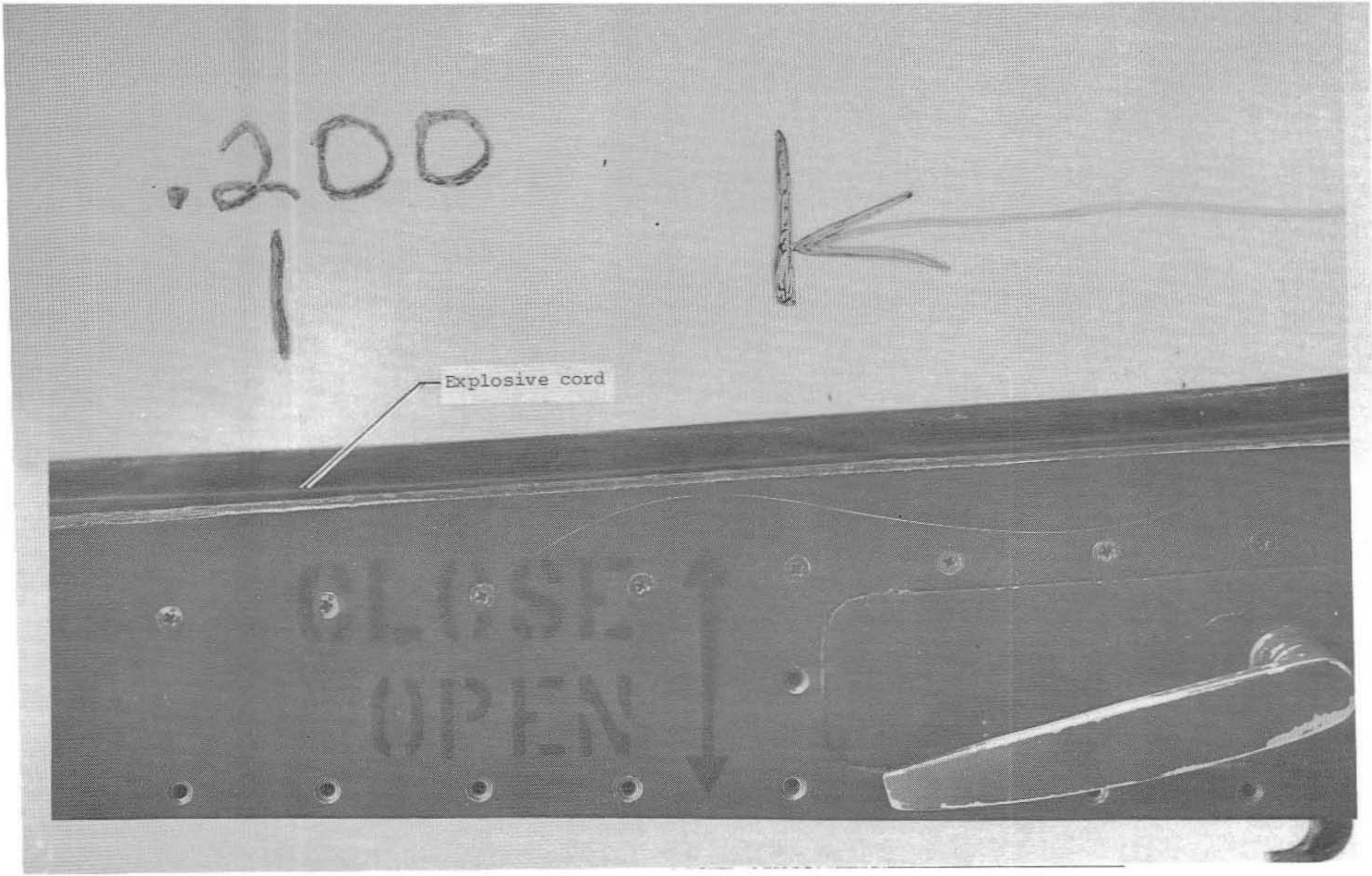

Figure 5.- Illustration of close proximity of explosive cord with acrylic fiberglass frame before installation of RTV.

Figure 6.- Installation of RTV, using field approach of inserting flattened tip over explosive cord. The RTV was injected with a hand-operated gun.

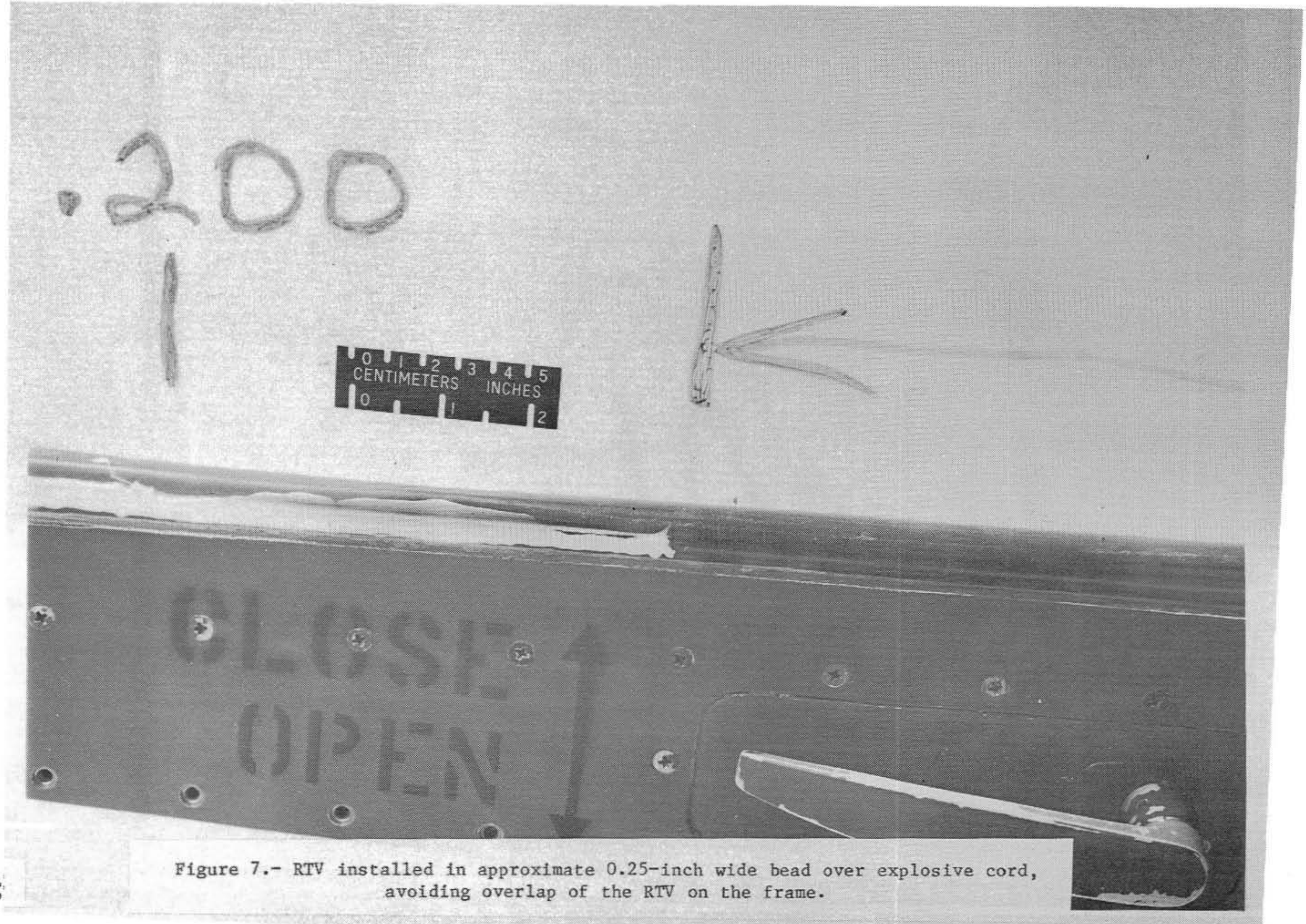

Figure 7.- RTV installed in approximate 0.25-inch wide bead over explosive cord, avoiding overlap of the RTV on the frame.

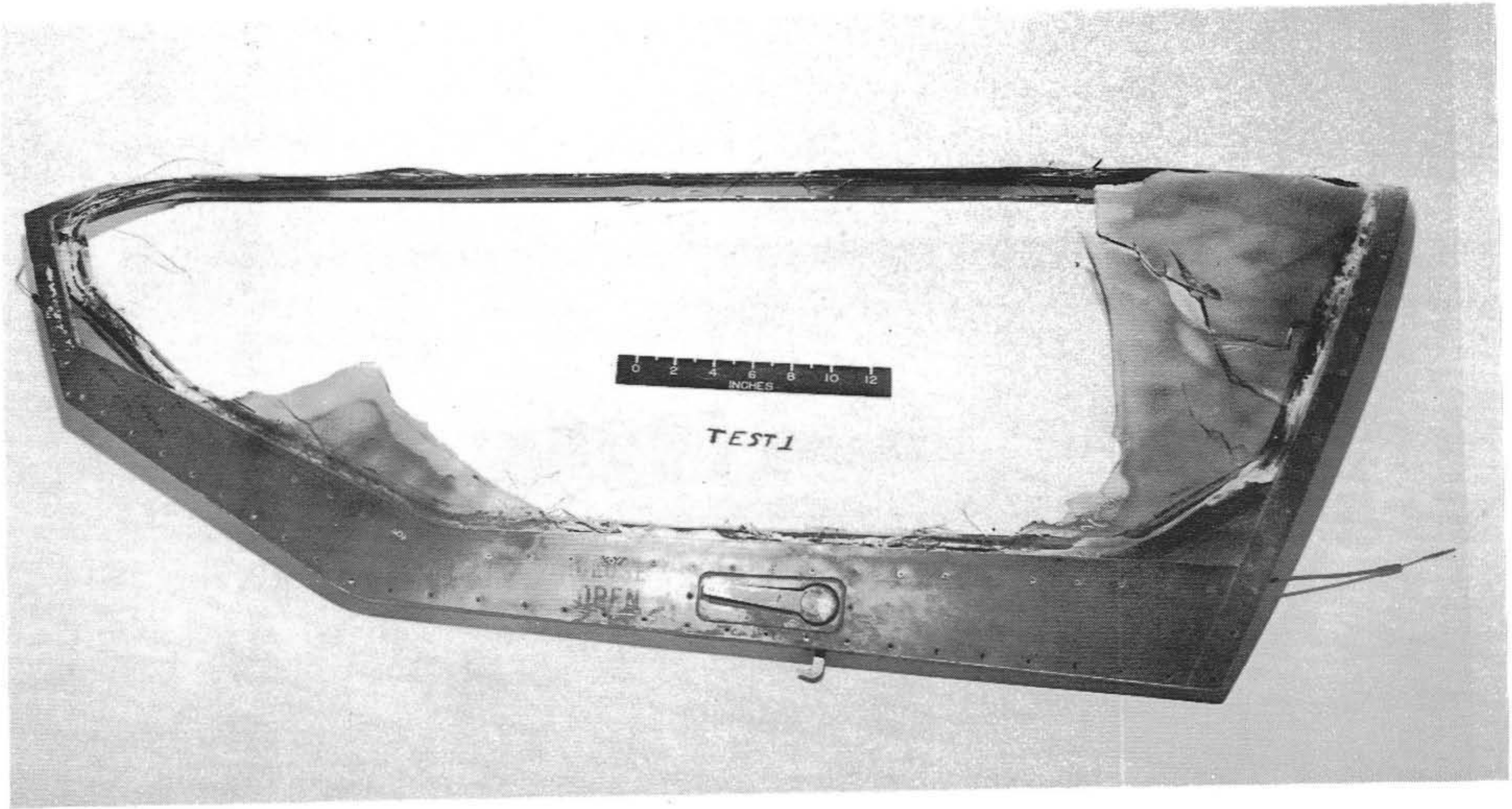

Figure 8.- Functional results of Test 1.

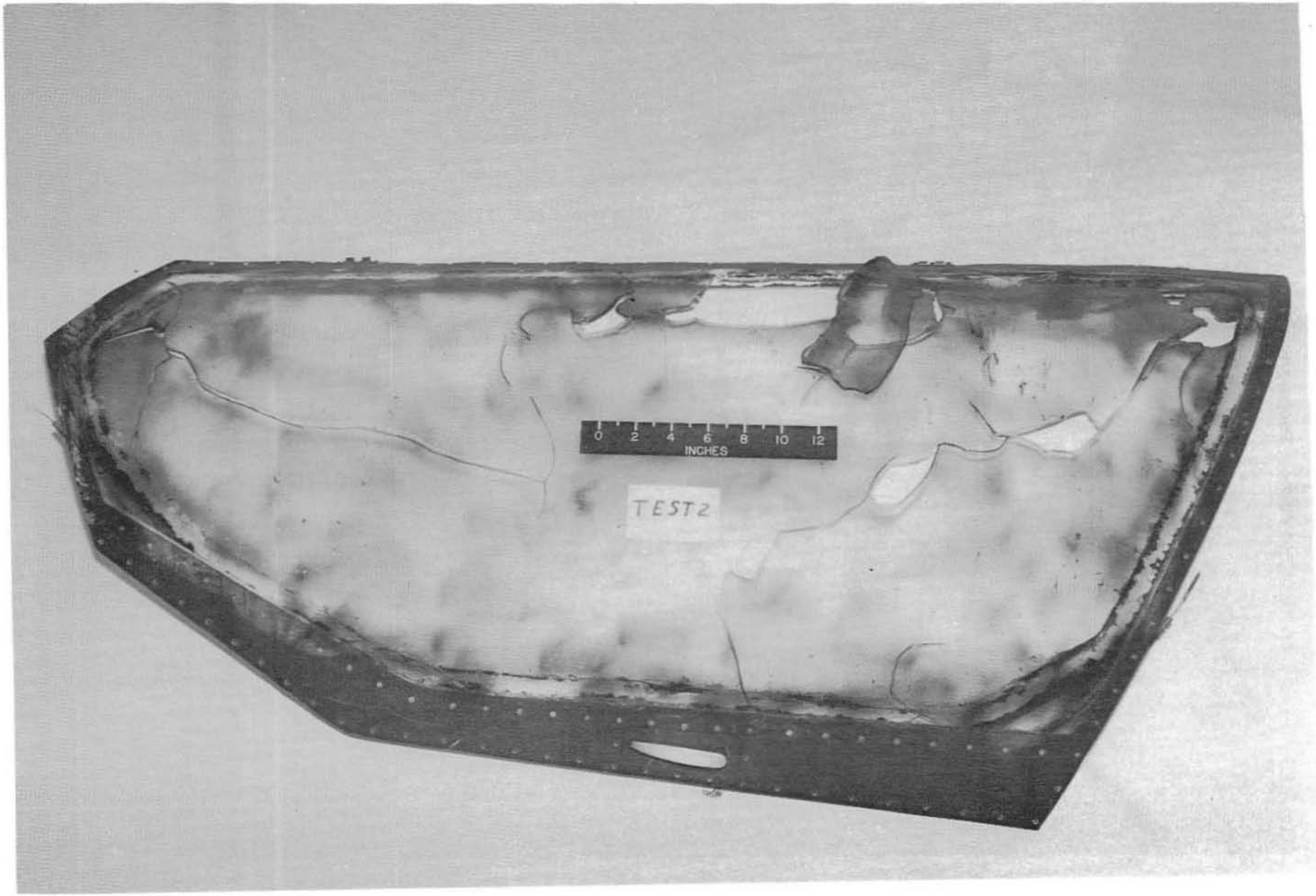

Figure 9.- Functional results of Test 2.

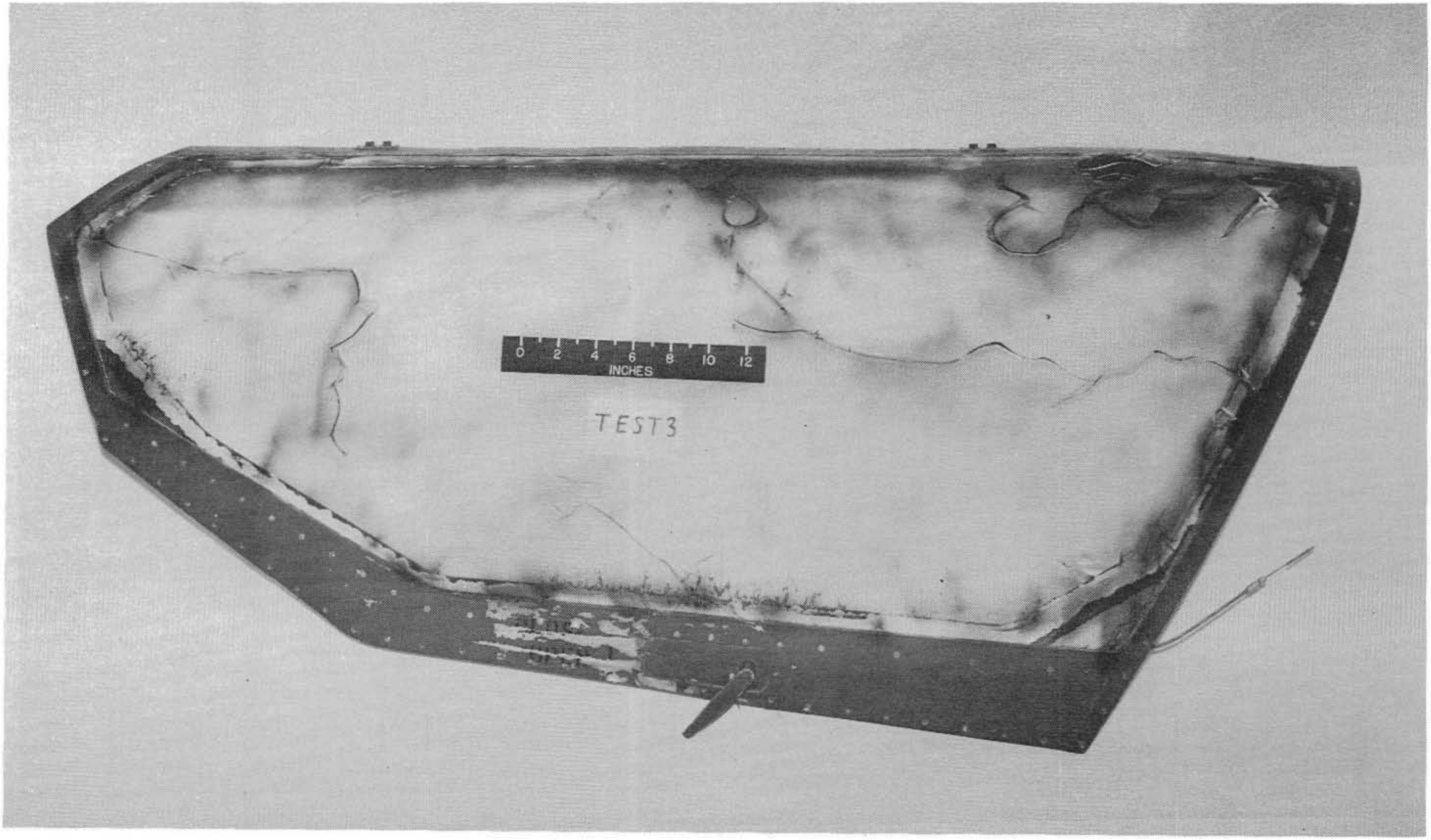

Figure 10.- Functional results of Test 3.

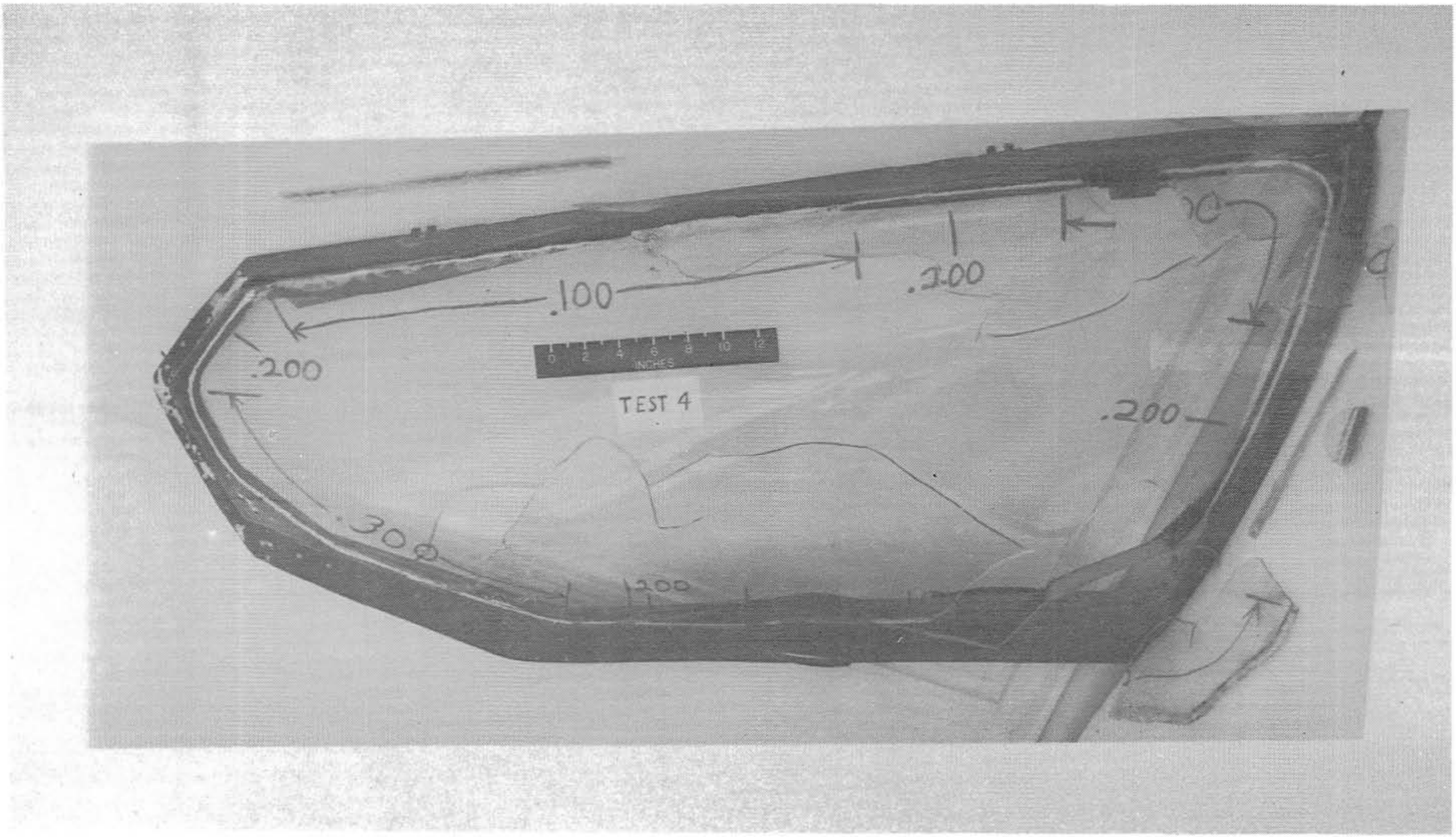

Figure 11.- Functional results of Test 4.

Figure 12.- Closeup of lower, center position explosive severance in Test 4, showing fracture of acrylic at frame on left and on centerline of the explosive on the right (no RTV). See test setup in Figure 7.

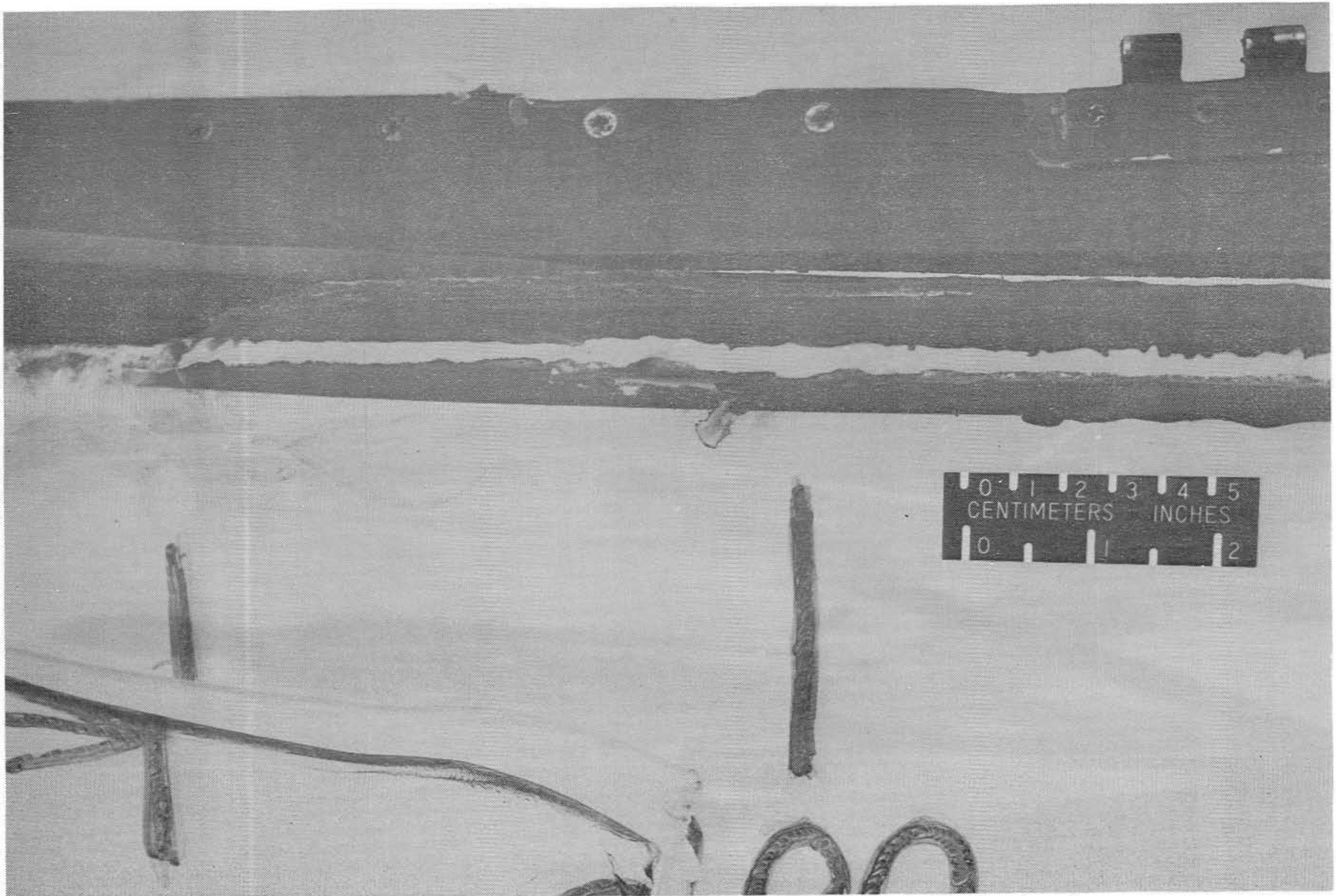

Figure 13.- Closeup of upper, center position explosive severance in Test 4, showing fracture of acrylic on explosive centerline on left (no RTV) and at the frame on the right.

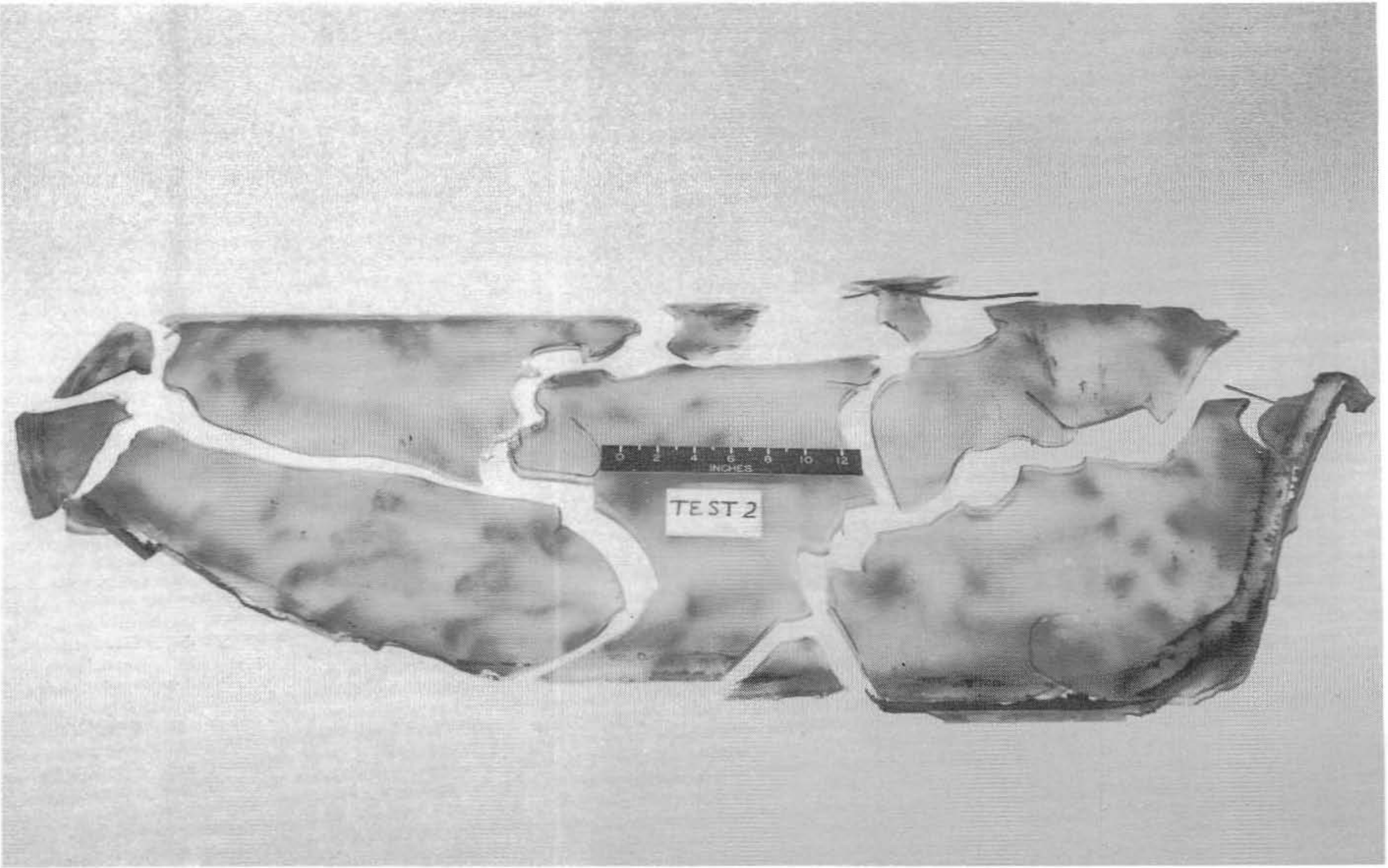

Figure 14.- Acrylic pushed out of the frame in Test 2.

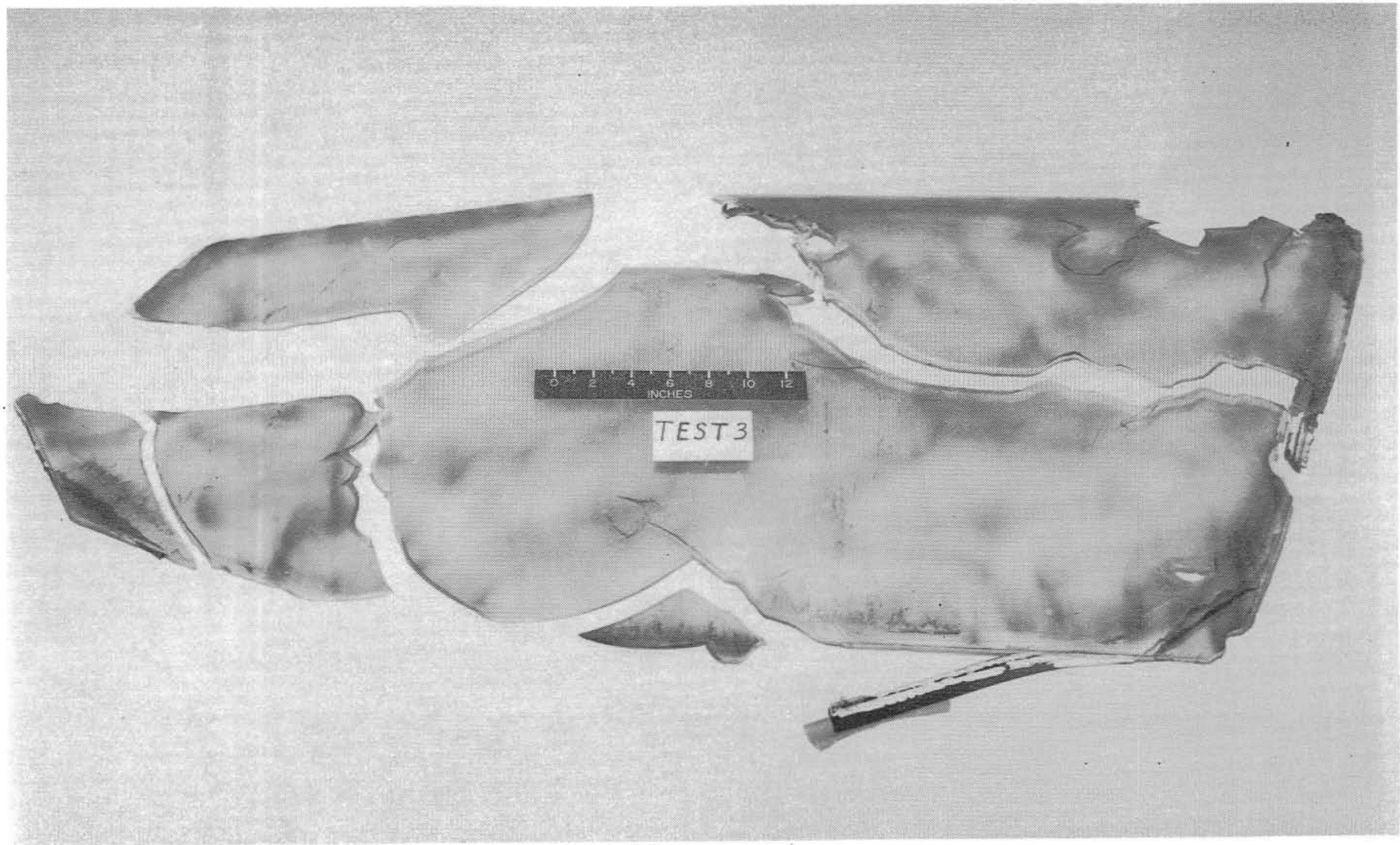

Figure 15.- Acrylic pushed out of the frame in Test 3. The only portion not severed was the small piece, bottom center. Also attached on the bottom is a portion of the window cutting assembly extrusion and frame.

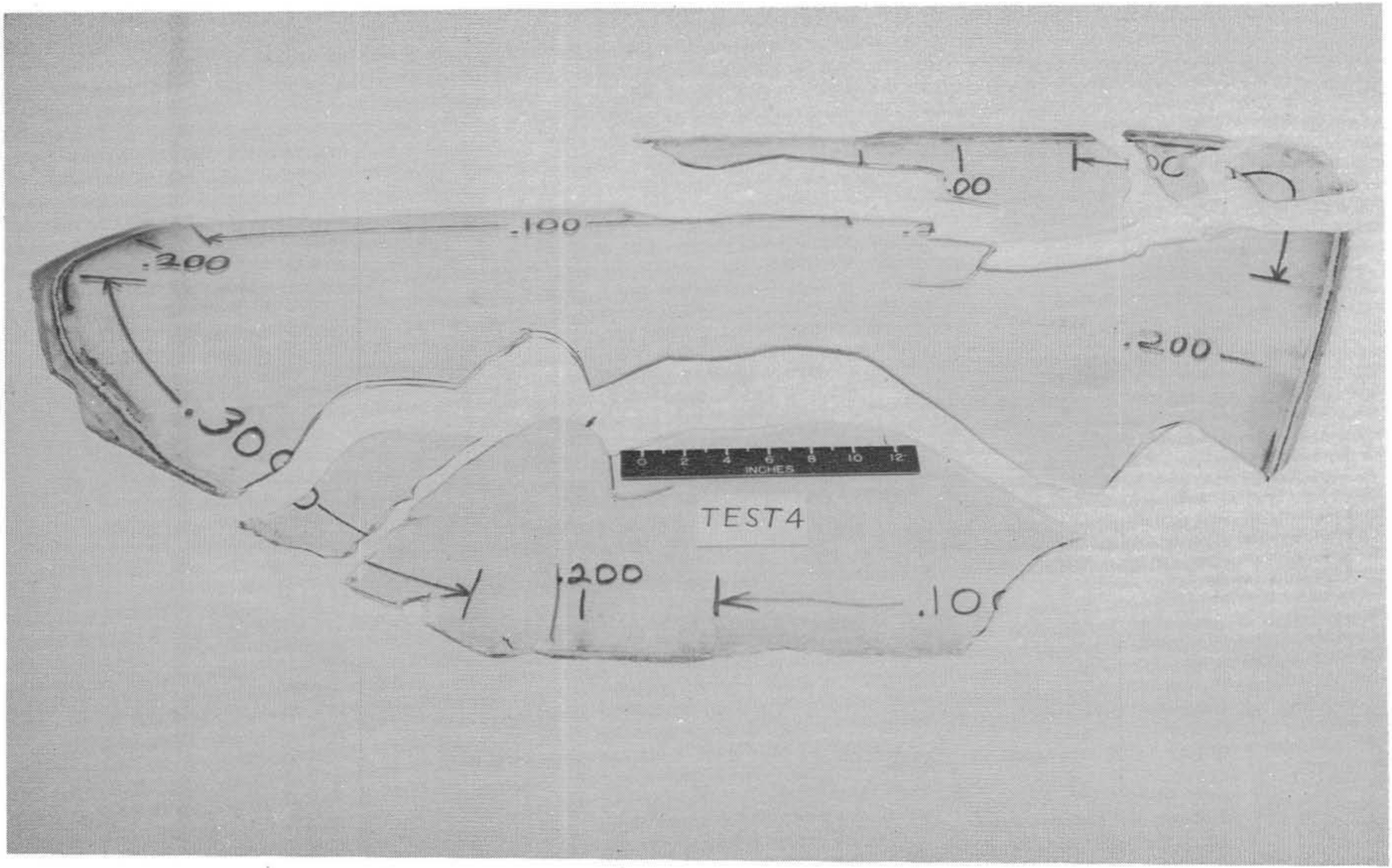

Figure 16.- Acrylic pushed out of the frame in Test 4. The missing section at the lower right had fallen out during the firing. See Figure 11.

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16. Abstract

The U.S. Army uses explosively actuated window cutting assemblies to provide emergency crew ground-egress. Gaps between the system's explosive cords and acrylic windows caused a concern about functional reliability for a fleet of several hundred aircraft. A field repair method, using room temperature vulcanizing silicone compound (RTV), was developed and demonstrated to fill gaps as large as 0.250 inch.

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