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FLIGHTLINE THERMAL ENVIRONMENT TESTING OF F-111
TRANSPARENCIES(U) AIR FORCE WRIGHT AERONAUTICAL LABS
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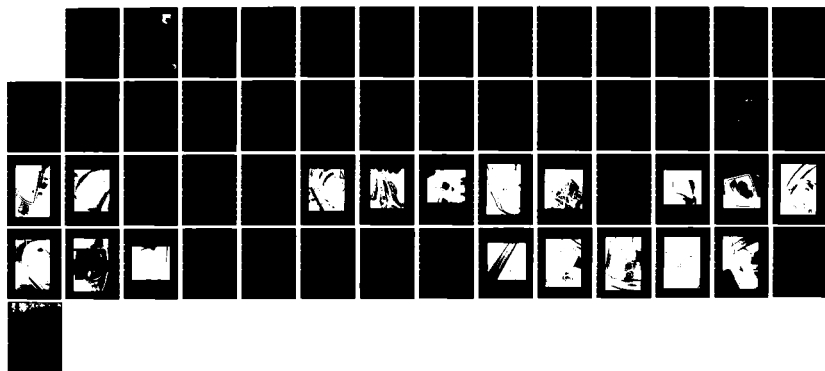
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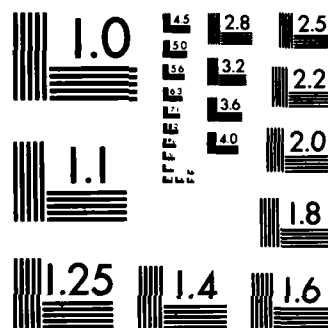
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FLIGHTLINE THERMAL ENVIRONMENT TESTING OF F-111 TRANSPARENCIES

Robert J. Simmons, 1Lt, USAF
Advanced Development Branch
Vehicle Equipment Division

July 1983

Final Technical Report for Period 1 November 1979 - 20 August 1981

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The objective of this effort was to simulate delamination failures occurring on F-111 aircraft located at Cannon AFB, New Mexico. The approach used was to simulate the flightline environment at Cannon AFB using existing laboratory test facilities. Test procedures and results of the tests are discussed. Test results indicated excellent correlation between visible degradation observed in the laboratory specimens and transparencies removed from field service. A design modification to combat the delamination failures was tested and proved to be successful. Results of bird impact testing of the laboratory tested		

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specimens is presented. Results of bird impact testing of units removed from Cannon AFB is contained in the Appendix.

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FOREWORD

The effort documented in this report was accomplished in the Structures Test Facility of the Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, OH 45433. The testing was performed at the request of the Sacramento Air Logistics Center Engineering Group (SM-ALC/-MMSR). The administrative direction and technical support was provided by the Improved Windshield Protection Advanced Development Program Office (AFWAL/-FIEA) of the Flight Dynamics Laboratory under Program Element 64212F project 19269001. Birdstrike testing was performed at the Arnold Engineering Development Center, Arnold Air Force Station, Tennessee.

The work described herein was conducted during the period 1 November 1979 through 20 August 1982. Project supervision and technical assistance was provided by Mr Robert Wittman and Mr Ralph Speelman, successive Program Managers of the ADP. Test direction came from Lt Paul Sandburg of the Structures Test Branch (AFWAL/FIBT). The birdstrike phase of the effort was monitored by Lt Larry Moosman and Lt Robert Simmons (AFWAL/FIEA) with test direction coming from Mr Robert Armstrong and Mr Tony Bisio (VKF/ARO).

The author wishes to acknowledge the contribution of members of the Structures Test Facility and Arnold Engineering Development Center for their cooperation and assistance in successfully completing this effort.

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SECTION I

INTRODUCTION

1. BACKGROUND: The Advanced Design Bird Impact Resistant Transparency (ADBIRT) system developed for the F-111 aircraft has proven itself to be a valuable asset to the Air Force. The transparency system was designed to give increased birdstrike protection in the windshield/canopy area during high speed-low level flight, while maintaining high optical quality and low cost-of-ownership. To date, this system has proven successful during qualification testing and in the operational environment by being able to defeat potentially catastrophic birdstrikes (at least 10 aircraft saves have been reported through 1981). However, as with most new aircraft subsystems, there have been some developmental problems encountered in the field. One such problem was associated with the F-111 aircraft stationed at Cannon AFB, Clovis, New Mexico. The ADBIRT transparencies on these aircraft began to show some visible deterioration after only a short time in service. This deterioration (delamination around the perimeter of the transparency) was determined to be caused by a design deficiency aggravated by the high temperatures encountered on the flightline during the summer months. Aircraft exhibiting this problem were typically parked on the flightline without shielding devices to protect the transparencies from the sun. In the majority of the cases the canopies were closed to prevent rain or dust from entering the cockpit. This configuration, coupled with the high flightline temperatures, caused internal cockpit temperatures to reach approximately 200°F. These elevated temperatures would cause the transparency interlayer to become soft and thermal expansion of the acrylic outer ply would occur. The expansion of the acrylic would be limited by the transparency attachment bolts and, as a result, the interlayer material would be "squeezed out." In the evening, or during flight, the acrylic would contract leaving voids where the interlayer had been lost. The visible result of this was delamination along the perimeter of the transparency.

The Sacramento Air Logistics Center Engineering Group (SM-ALC/MMSR) recognized this as a potential fleetwide problem and requested that the Improved Windshield Protection ADPO assist them in simulating this phenomenon and in determining a suitable engineering design modification to correct the problem.

2. OBJECTIVE: The objective of the test program was three-fold. The first objective was to develop a test procedure which would realistically simulate the flightline thermal environment at Cannon AFB ; verify that the delamination could be reproduced in the laboratory. The second objective was to determine if a proposed design modification could correct the delamination problem; and third, determine if transparent panels had lost any structural integrity as a result of the high temperatures and subsequent delamination.

This report briefly summarizes the development of the F-111 flightline thermal environment test program and gives results of that test program. Subsequent bird impact testing of the transparencies is also discussed.

SECTION II

FLIGHTLINE THERMAL TEST

The objectives of the flightline thermal environment test program were to simulate the flightline temperature encountered during the summer months at Cannon AFB, reproduce the visible structural deterioration of the transparencies and assess the ability of the design modification in correcting the delamination problem. This test series represents the first attempt at devising laboratory test conditions that represent the in-service environment to determine structural/visible degradation. As such, suitable test profiles (temperature/pressure) needed to be generated. In order to save time and expense, an existing facility for pressure and thermal cyclic testing of the F-111 was utilized. This facility is described in detail in Reference 1.

1. TEST SPECIMENS

There were three transparency designs investigated during the course of the testing. All three are Alternate Design Bird Impact Resistant Transparencies (ADBIRT) with two being manufactured by Sierracin/Sylmar and the third by PPG Industries (Table 1).

TABLE 1
FLIGHTLINE THERMAL TEST TRANSPARENCIES

COMPONENT	MANUFACTURER	PART NO.	SERIAL NO.	COMMENTS
Left Hand Canopy	Sierracin	P/N 157400-51	S/N 159	Original Design
Left Hand W/S	Sierracin	P/N 157300-51	S/N 183	Modified Design
Right Hand Canopy	PPG Ind	P/N 1560K0155085DBJ	S/N 905701	Original Design

The left hand canopy was manufactured by Sierracin/Sylmar and represents their standard ADBIRT canopy cross-section (Figure 1). The right hand canopy was manufactured by PPG Industries and represents their standard ADBIRT canopy cross-section (Figure 2). The left hand windshield was manufactured by Sierracin and incorporated the design modification which was proposed by the Sacramento Air Logistics Center Engineering Group in conjunction with the Improved Windshield Protection ADPO and Sierracin/Sylmar. The modification (Figure 1) consisted of providing a longer attachment bolt bushing (.005 inch increase) and lowering the attachment bolt torques (Figure 3) to reduce interlayer squeeze out forces. The extended bushings provided a metal-to-metal contact with the attachment bolts and windshield frame, thus reducing the direct pressure on the plastic transparency. The unmodified Sierracin part was used to help validate the flightline thermal test results and to assure that the modification was successful in defeating the delamination problem. The addition of the PPG part gave an indication of the variances from one manufacturer to the other. The right hand windshield was a glass transparency which was used to provide adequate thermal control and to complete the aircraft ship set and allow the crew module to be pressurized. No effort was made to evaluate the temperature effects on the glass transparency.

2. TEST SETUP

The test fixture consisted of an F-111A crew module (Figure 4) and a shroud (Figure 5) which contained quartz infra-red heating lamps to control the exterior temperature of the transparencies. An interior cabin heater and blower were added to the module to produce the desired interior cabin temperatures. The heater consisted of twenty, 150 Watt calrod heaters and the blower had a 150 cubic foot per minute capacity at full power. Control of the heater and blower held the interior cabin temperature to within $\pm 10^{\circ}\text{F}$ of the transparencies outer surface temperature (a condition not seen on the Cannon AFB units).

3. TEST INSTRUMENTATION

Instrumentation of the transparency specimens and crew module were identical to that described in Reference 1. The installation of all instrumentation was accomplished by Structures Test Branch (AFWAL/FIBT) personnel. Thermocouples were installed on the transparency surface by bonding them with RTV-108 silicone adhesive. There were thirty control points on the three test articles which were continually monitored by recorder-controllers. Each of these control thermocouples has a backup thermocouple mounted adjacent to it which could be monitored if the primary thermocouple malfunctioned. Seventy six data thermocouples were installed on the inner and outer transparency surfaces to obtain a time-temperature distribution.

The data output was acquired and processed by the Flight Dynamics Laboratory Structures Test Facility Data Acquisition and Processing System (DAPS). The data system is shown in the block diagram of Figure 6. A detailed description of the data system recording and monitoring instruments, methods of installation, electrical wiring diagrams and control locations are kept on file at the Structures Test Facility.

4. TEST CONDITIONS AND PROCEDURES

The flightline environmental test series consisted of subjecting the transparencies to 360 thermal cycles, with each cycle consisting of heating the exterior surface of the transparencies from ambient temperature through 160, 180, and 200°F plateaus over an eight-hour period (Figure 7). The transparency interior temperature was held to within +10°F of the exterior temperature by using the cabin blower. The thermal profile used was based upon cockpit temperatures measured on Cannon AFB flightline. Following each thermal cycle the transparencies were cooled in ambient air to 150°F and thoroughly inspected for any visible structural damage or delamination. All visible damage was recorded and the procedure was repeated for the remainder of the cycles.

The flightline thermal cycles had been performed at atmospheric pressure; therefore, a proof load pressure test was added at the

conclusion of the 360 thermal cycles. Twenty zero to +11.2 PSI pressure cycles followed by twenty zero to -5.8 PSI pressure cycles were planned, with all tests being at ambient temperature conditions. All were performed except six zero to -.58 PSI pressure cycles. Figure 8 shows the pressure profile employed.

5. TEST RESULTS

a. Physical Description - Due to the high temperatures used in the flightline thermal profiles, the test specimens began showing signs of thermally induced aberrations soon after the testing began. Each defect was carefully recorded upon initial discovery and was closely monitored for the remainder of the testing. A chronological listing of the defects encountered may be seen below:

CHRONOLOGICAL LISTING OF DEFECTS

DATE	THERMAL CYCLE NUMBER	DESCRIPTION/COMMENTS
9 Nov 79	0	Test began
14 Nov 79	3	Delamination started along the right side of the left canopy (Figures 9 & 10).
23 Nov 79	6	15 to 20 small bubbles formed in the central area of the right canopy (Figure 11).
29 Nov 79	15	Delamination started along the left side of the right canopy.
7 Dec 79	35	Surface crazing appeared on right canopy.
10 Jan 80	77	A series of minute opaque spots, forming streaks across the left windshield was observed (Figure 12).
8 Feb 80	139	A severe optical distortion of approximately 20 square inches, located midway across the left canopy and 3/4 of the way back was discovered (Figure 13).

Each of the defects (with the exception of the opaque streaks and the severe optical distortion) were similar to the defects encountered at Cannon AFB. As the number of thermal cycles progressed, the defects became progressively larger or more extensive. The delamination of the right canopy eventually extended around the entire canopy perimeter. The delamination of the left canopy eventually extended from the aft arch support to the rear module bulkhead. The crazing of the right canopy and the opaque streaking of the left windshield became progressively worse throughout the thermal cycling. There were no new defects observed after thermal cycle number 139.

The ambient temperature pressure cycles were initiated upon completion of all thermal cycles. All pressure cycles were performed routinely until the fourteenth zero to -5.8 PSI cycle. It was during this cycle that the optically distorted area discovered on the left canopy "oil-canned" and returned to its original position upon pressure release. The six remaining vacuum cycles were eliminated after this incident.

b. Discussion of Results - The physical aberrations and visible structural degradation were evaluated for potential cause. Probable explanations follow:

(1) The opaque spots (bubbles) observed on the left windshield were arranged in such a manner as to appear to be parallel streaks across the windshield. By using an optical micrometer, it was determined that the bubbles were located at the bonding surface between the exterior acrylic face ply and the interlayer material. The manufacturer stated that inadequate cleaning of the acrylic's inner surface prior to bonding with the interlayer could result in a poor bond. Localized breakdown of the bond could have resulted at the high temperatures of the thermal cycle.

(2) The delamination patterns observed on the left and right canopies were typical examples of the delamination occurring in the operational units at Cannon AFB. Investigation as to the cause of the delamination was beyond the scope of the effort; however, it was felt

that interlayer squeezeout was the most probable cause. The appearance of the delamination so early in the test series was also consistent with the Cannon AFB units delaminating after only a short time in service.

(3) The bubbles which were observed on the right canopy were determined to be in the interlayer and could be the result of poorly processed PPG-112 interlayer material when subjected to high temperatures. Since this was a pre-production part, the defect was considered to be corrected for production units and no further investigation was undertaken.

(4) There was no explanation for the severe optical distortion encountered on the left canopy. Upon initial discovery of the distortion, the canopy was instrumented to allow close monitoring of surface temperatures in that area. The data proved that no points of extreme temperature were present on the exterior surface. The cause of the distortion was not determined and the scope and intent of this test program did not allow for any investigations as to the cause of the warp were not made.

(5) Another probable cause of the abnormalities discovered (other than delamination) could be attributed to the radiant heat technique employed. In radiant heating each laminate of the transparency has a different relative absorption characteristic versus the wave length of the light radiating it, this could have resulted in the interlayers achieving relatively higher temperatures than would be encountered in exposure to natural sunlight. This drawback to the radiant heat technique is discussed in Reference 1. No further investigations into this problem were made during this test program.

(6) The lefthand windshield which incorporated the modified bushing design did not exhibit any of the visible structural degradation that was observed on the operational units at Cannon AFB. The modification was judged to be successful and appropriate for all F-111 Bird Impact Resistant Transparencies. This design modification has been

incorporated into all F-111 ADBIRT transparencies, and has proven to be a significant improvement in service as the premature delamination problem has been eliminated.

SECTION III

BIRD IMPACT TESTS

The purpose of the bird impact testing was to provide a verification of the structural integrity of the flightline thermal specimens following the flightline thermal environment tests. The limited number of panels available for bird testing did not allow the degradation to be fully quantified; however, they did point out some possible design deficiencies in the ADBIRT system.

The velocity and location of each bird impact were chosen to represent three of the original qualification tests. In this way, correlation could be made with previous data. The following paragraphs give details of the birdstrike testing on the flightline thermal environment test specimens. Appendix 1 provides information on birdstrike tests conducted on transparencies removed from Cannon AFB due to delamination failures. All birdstrike testing was performed at the S-3 Range, Arnold Engineering Development Center, Arnold Air Force Station, Tullahoma, Tennessee.

1. TEST SETUP AND INSTRUMENTATION

A detailed description of the test setup and instrumentation used is contained in References 2, 3, 4, and 5.

2. TEST PROCEDURES AND CONDITIONS

The basic procedure in bird impact testing at AEDC consists of launching bird carcasses at specified velocities into pre-determined impact locations on a test article. For the current tests, two impact locations were required as defined in Figure 14. Impact point "A" was located approximately 17 feet from the end of the sabot stripper tube. Table 2 shows a summary of the test conditions.

All tests were conducted with the crew module oriented at 0° pitch 0° yaw relative to the launcher sightline. Following each shot, the test area and test articles were thoroughly cleaned and disinfected. The test transparency and fuselage structural members were examined in place and details of the damage were recorded. After any necessary repairs were completed, the module was realigned for the next shot. Motion picture and still color photographic documentation of the test fixture was obtained for both pre- and post-fire test conditions. The photographs were used to record any damage to the transparency, frame or aircraft support structure.

3. TEST RESULTS

Table 2 shows velocities and bird weights. Brief discussions of each bird test follows:

(1) Shot 696: Sierracin Left-Hand Canopy S/N 159. Massive failure of the canopy occurred with large amounts of bird debris penetrating into the crew module. Failure initially began in the forward right-hand corner, traveling along the center beam, across the top of the canopy, and then forward to the windshield aft arch. Review of the high-speed movie film showed extensive deflection of the canopy prior to initiation of the failure. Figures 15 and 16 show the damage to the canopy.

(2) Shot 697: Sierracin Left-hand Windshield S/N 125. This panel had seen seven months of in-service exposure and was removed due to scratches on the interior surface resulting from faulty maintenance actions. It was felt that this shot would provide limited correlation data between the flightline environment panels and actual in-service exposure. This panel also had massive failure allowing a large amount of bird debris to enter the crew module (Figure 17). Failure was initiated along the windshield center beam and continued along the aft arch. Bird debris entered the crew module through the pilot's position which could have had disastrous effects if this were an operational birdstrike.

(3) Shot 699: Sierracin Left-Hand Windshield S/N 183: This panel also exhibited a massive failure allowing penetration of bird debris into the crew module. Penetration was the result of a shear failure of the full laminate at the crew module windshield arch support edge (Figures 18 and 19).

(4) Shot 700: PPG Right-hand Canopy S/N 905701. No penetration. Breakage of the polycarbonate structural ply occurred near the center of the canopy. The canopy performed as expected (Figure 20).

4. DISCUSSION OF RESULTS

The results of the birdstrike tests were surprising in that two of the three panels that underwent the flightline thermal environment testing failed to defeat the impact of a 4 lb. bird at the qualification velocity of 500 knots. Possible explanations for the unexpected test results were identified as: (a) structural degradation due to delamination and/or environmental exposure, (b) a transparency design deficiency or (c) an overly vigorous flightline thermal environment test. A reduction in impact velocity to allow for a 10% reduction in strike resistance (due to the environmental exposure) was not used as it was initially felt that the delamination was not structurally degrading. To provide insight into probable answers to the degradation in birdstrike resistance, SM-ALC provided transparencies which had delaminated beyond allowable optical limits during exposure to the flightline environment at Cannon AFB. The results of those bird impact tests are contained in the Appendix.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

The flightline thermal test, as conducted, did appear to produce the same failure mechanism as the flightline environment which exists at Cannon AFB, using higher exterior temperatures then encountered on the flightline at Cannon AFB. Similarities between the laboratory test units and those units removed from service at Cannon AFB indicate that laboratory durability testing is a viable method for simulating the in-service environment. The Sierracin panel which incorporated the modified attachment bushings and reduced installation torques did not have any observable delamination. It was concluded that this modification was appropriate and should be included on all future F-111 laminated transparency procurements.

The flightline environment testing should be run either concurrently with or integrated into the F-111 transparency qualification testing (Reference 1). Improvements to the flightline environment testing would require an in-depth study to define: the temperatures attained at the interlayers due to the radiant heat technique; the corresponding temperatures attainable from solar heating; the appropriate outer surface temperatures that should be used in the future; and the number of thermal cycles required to accurately represent the operational environment.

Based upon the unexpected results of the bird impact test series (runway thermal and Cannon AFB units), a recommendation was made for further evaluation into the effects of aging on F-111 laminated transparency bird impact resistance. A response on this recommendation received from SM-ALC indicated an interest in the problem. Future work in this area is planned.

TABLE 2
BIRD IMPACT TEST SUMMARY: FLIGHTLINE THERMAL PANELS

Shot No.	Date	Bird Temp, °F	Test Area Temp, °F	Bird Wt., lb	Velocity, Knots Requested	Impact Location	Test3 Article	Transparency Identification	Posttest Condition
696	9/11/80	67	89	3.99	490	481	Sierracin L/H Can	P/N 157400-51 S/N 159	Penetration
697	9/12/80	67	88	4.00	490	490	Sierracin L/H WS	P/N 157300-51 S/N 125	Penetration
699	9/18/80	65	80	3.99	490	493	Sierracin L/H WS	P/N 157300-51 S/N 183	Penetration
700	9/19/80	65	78	4.00	490	486	PPG Ind R/H Can	P/N 1560K0155085 DBJ S/N 905701	Structural Ply Cracked

NOTES: 1. Requested bird weight; 4.0 ± 0.10 lbs, all shots

2. See Figure 14

3. L/H - Left hand, R/H - Right Hand, WS - windshield, Can - Canopy

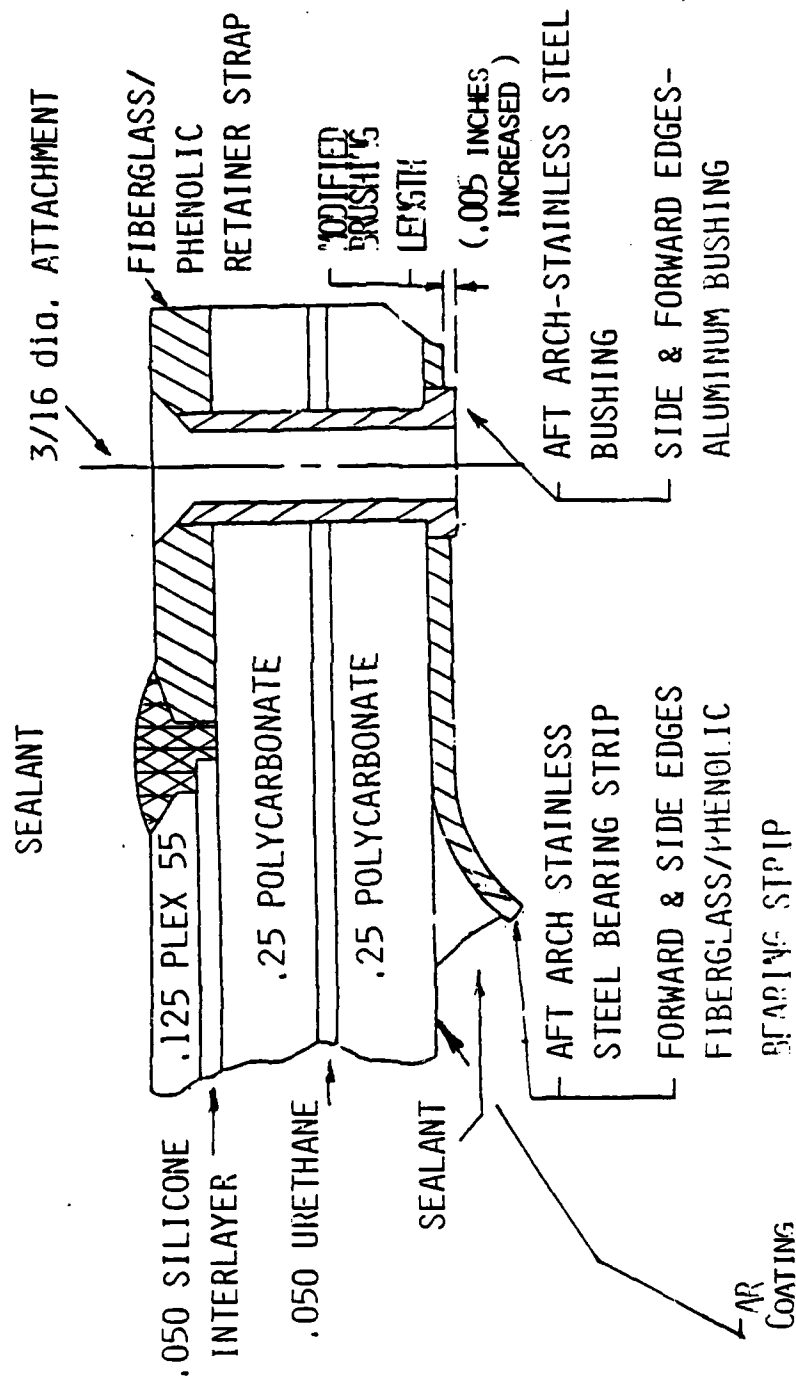
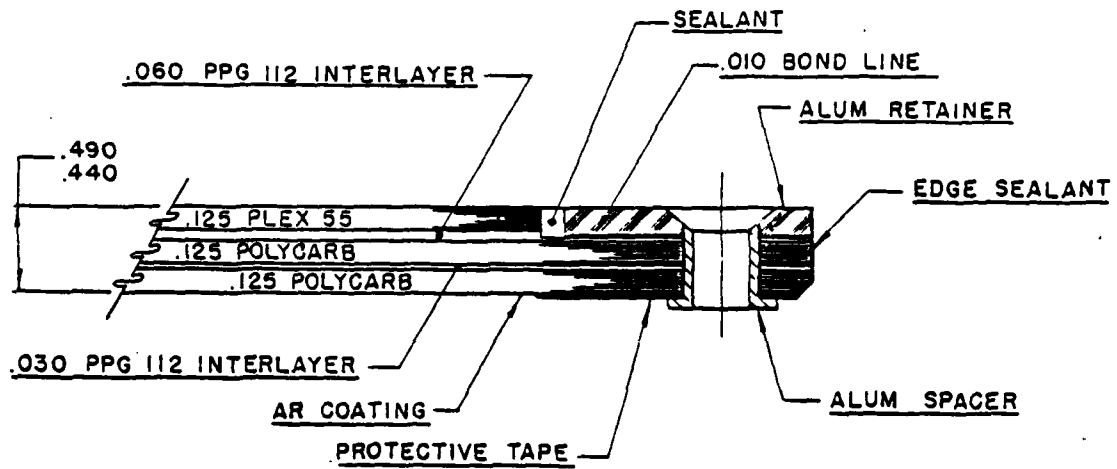
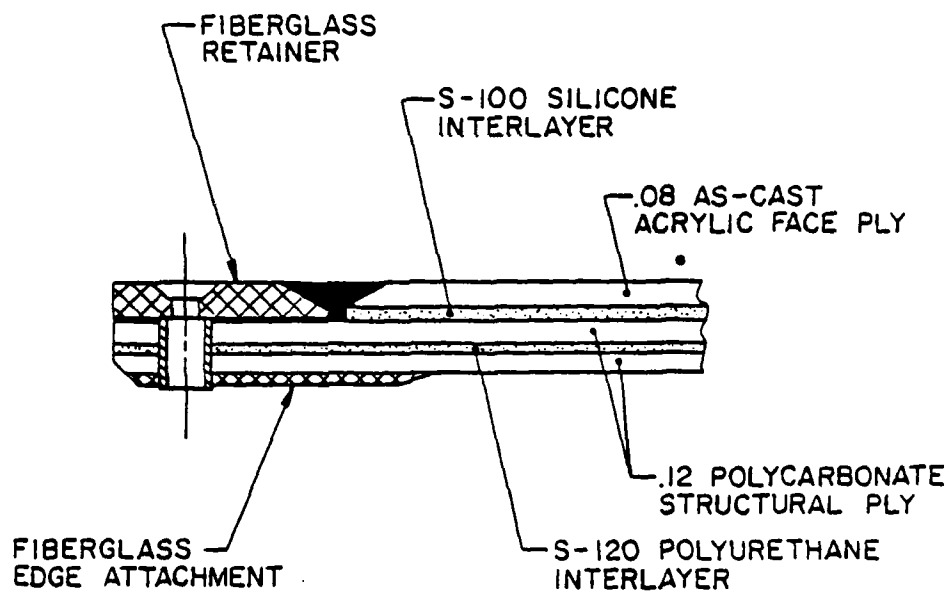


Figure 1. Sierracin F-111 ADBRT Windshield Cross Section;
Unmodified/Modified



(a) PPG



(b) Sierracin

Figure 2. F-111 Canopy Cross Sections: (a) PPG; (b) Sierracin

NOTE: All Torques in Foot-Pounds

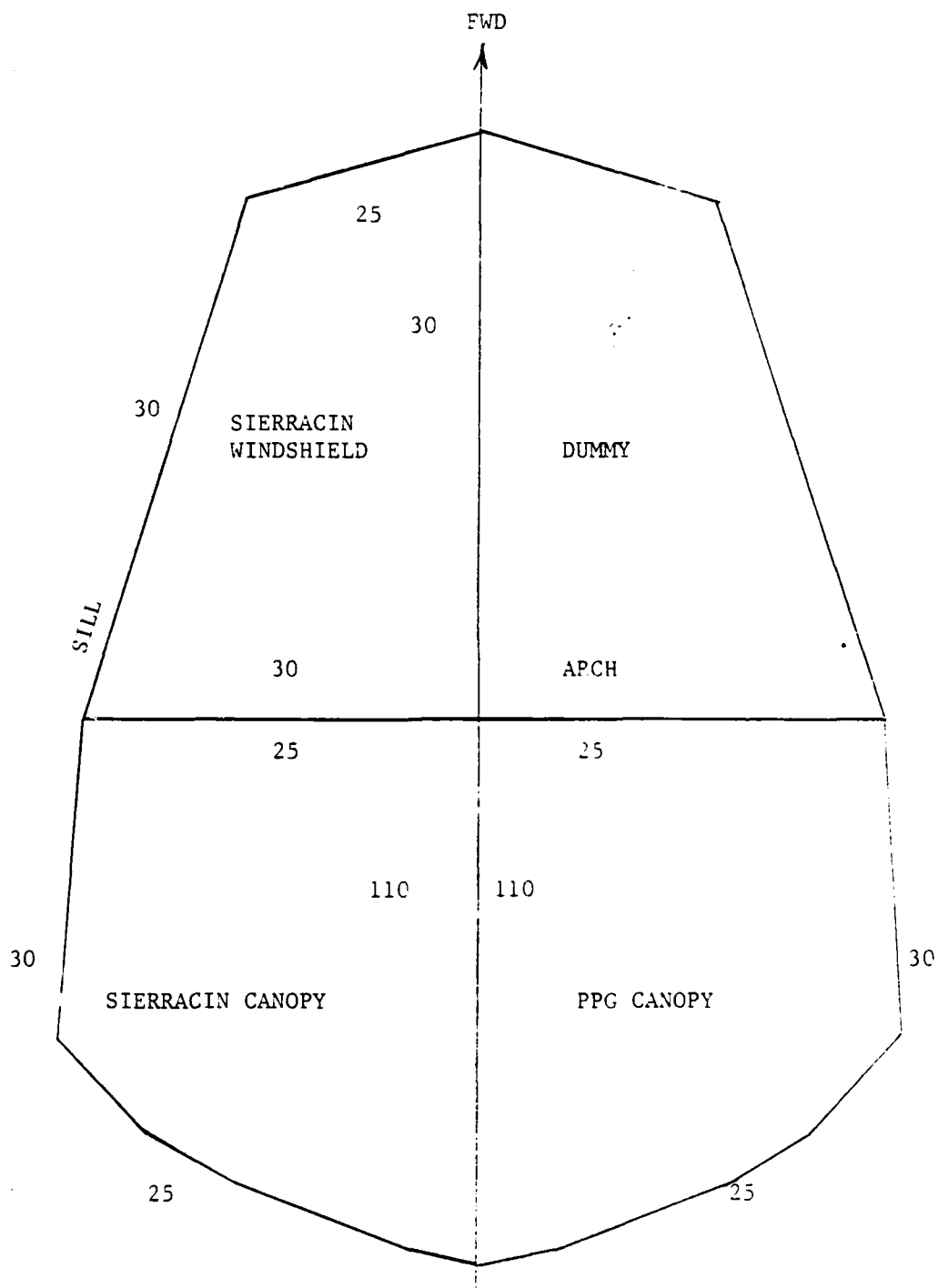


Figure 3. Installation Torque Values used in Flightline Thermal Environment Test

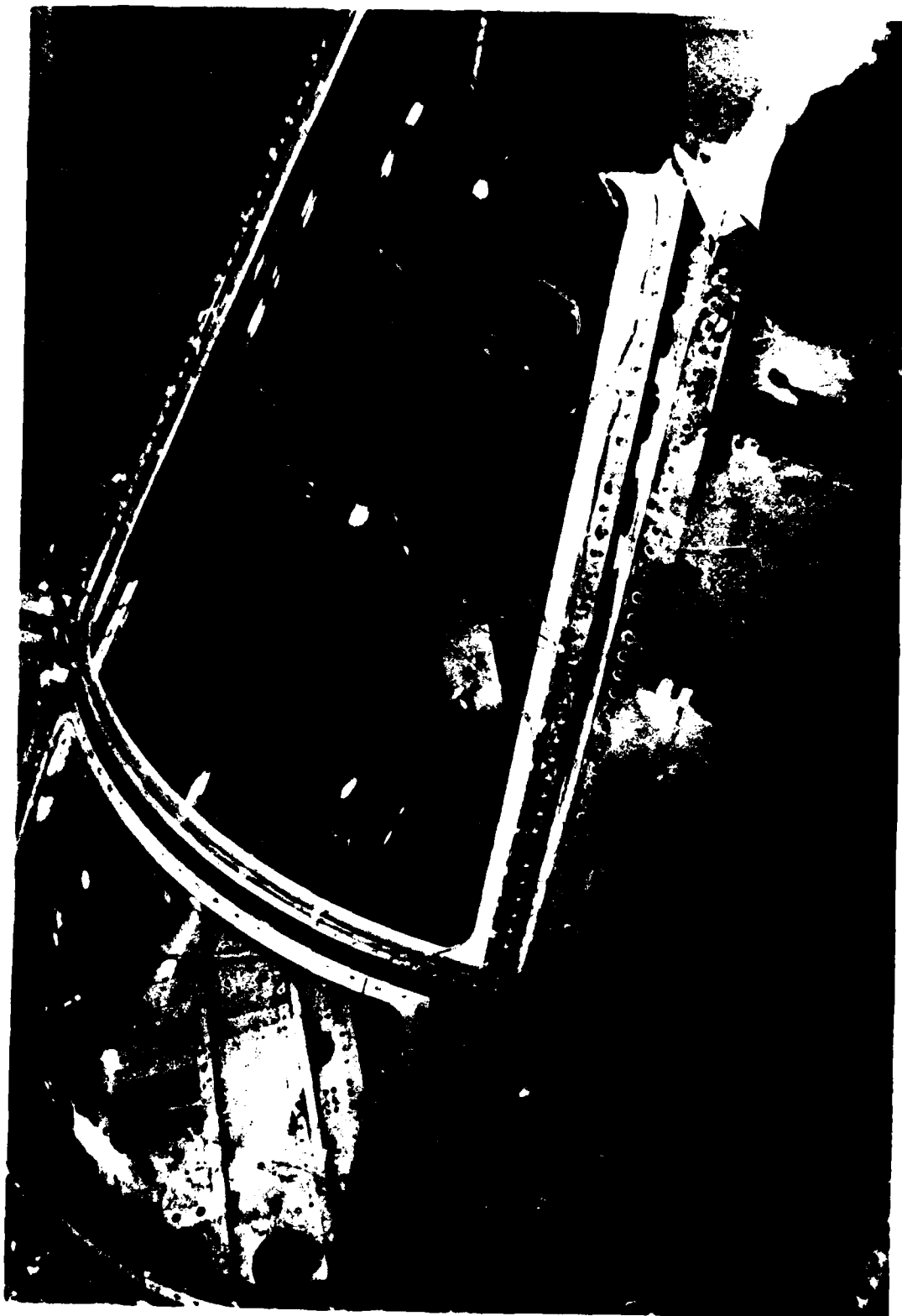


Figure 4. Typical Installation of Transparencies in F-111 Crew Module, Right Hand Side



Figure 5. Reflector Shroud Showing Quartz Lamps

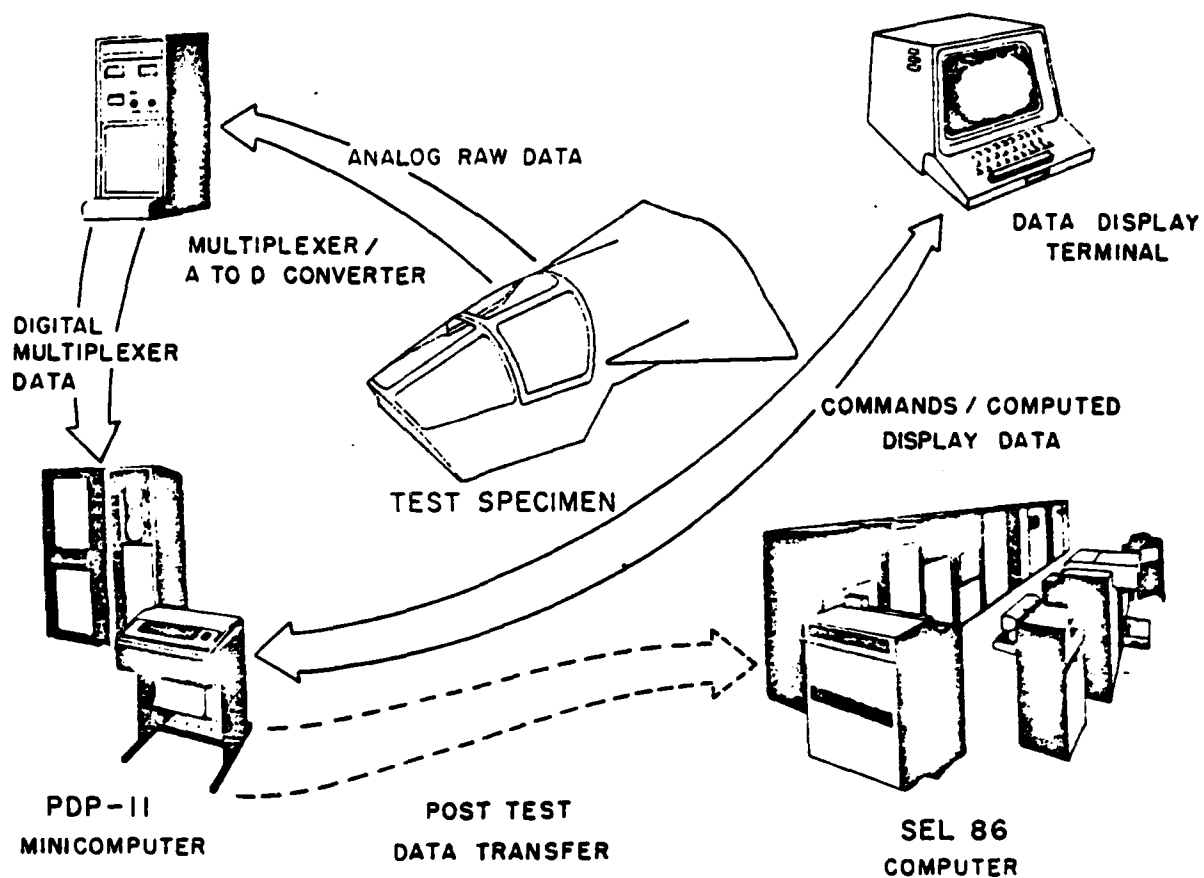


Figure 6. F-111 Transparency Test Data System

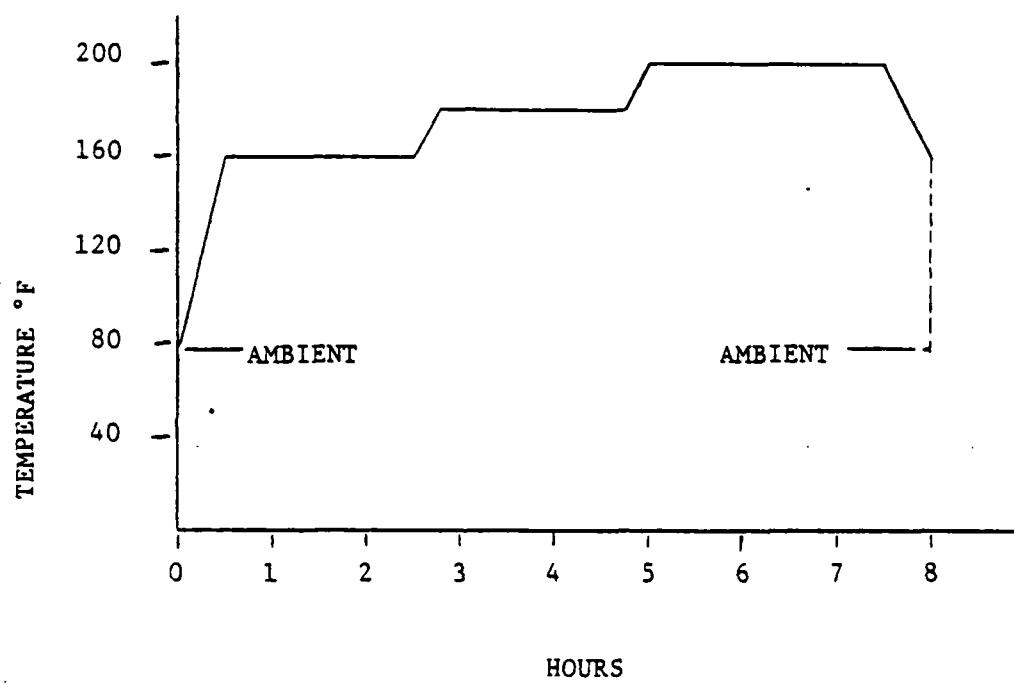


Figure 7. Flightline Thermal Environment Temperature Profile

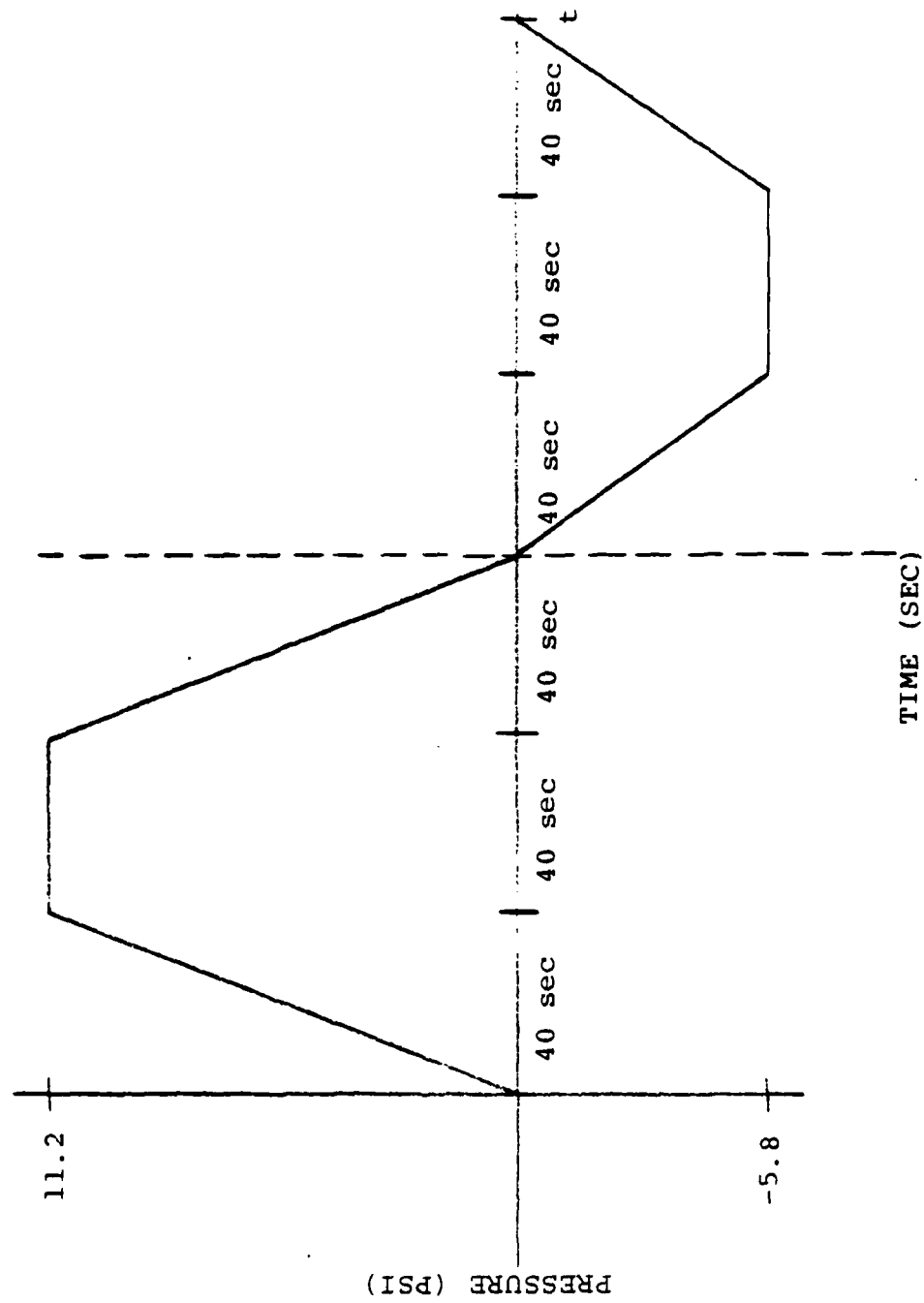


Figure 8. Pressure Profile



Figure 9. Left Canopy Delamination After Thermal
Cycle Number 3



Figure 10. Left Canopy Delamination After Thermal
Cycle Number 3

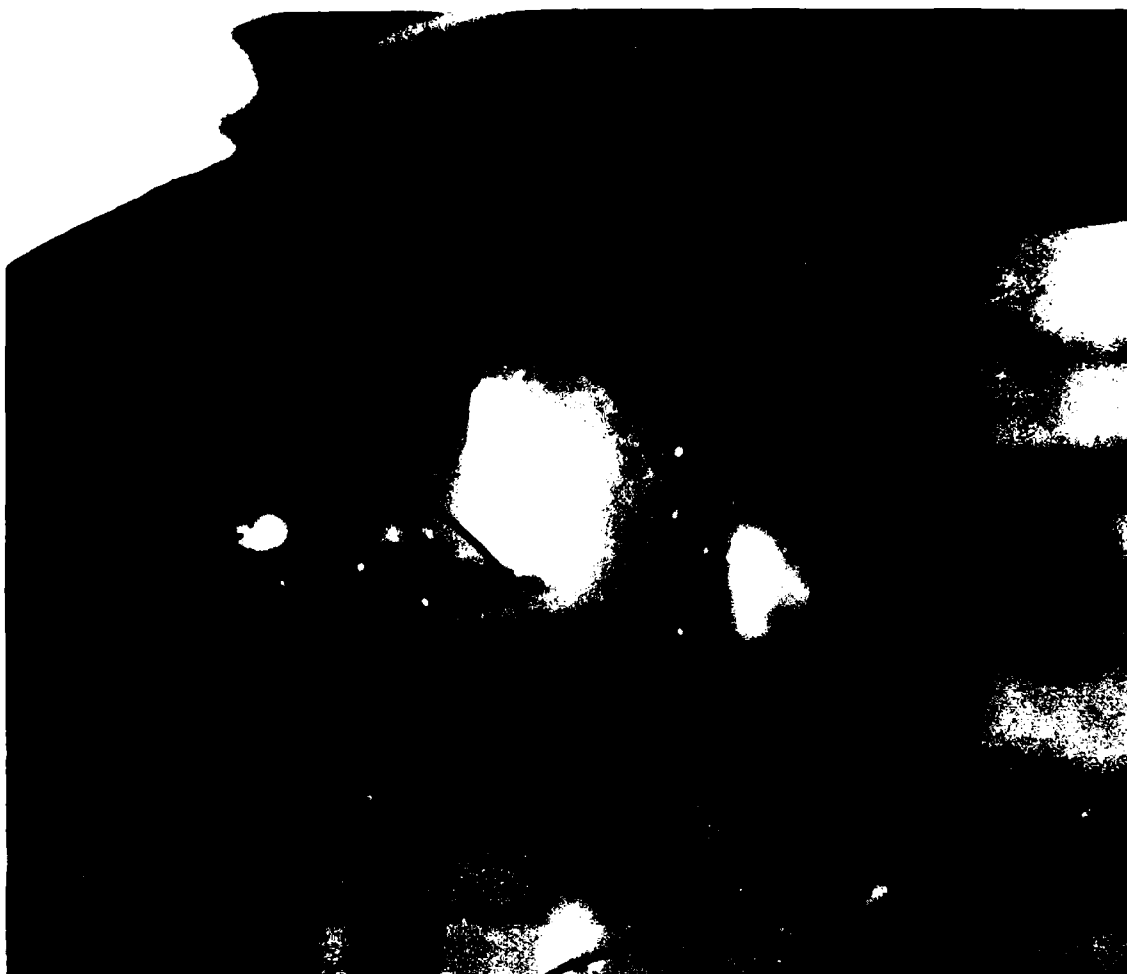


Figure 11. Bubbles on Right Canopy After Thermal
Cycle Number 6



Figure 12. Opaque Streaking on Left Windshield After
Thermal Cycle Number 77



Figure 13. Optical Distortion on Left Canopy After Thermal Cycle Number 139

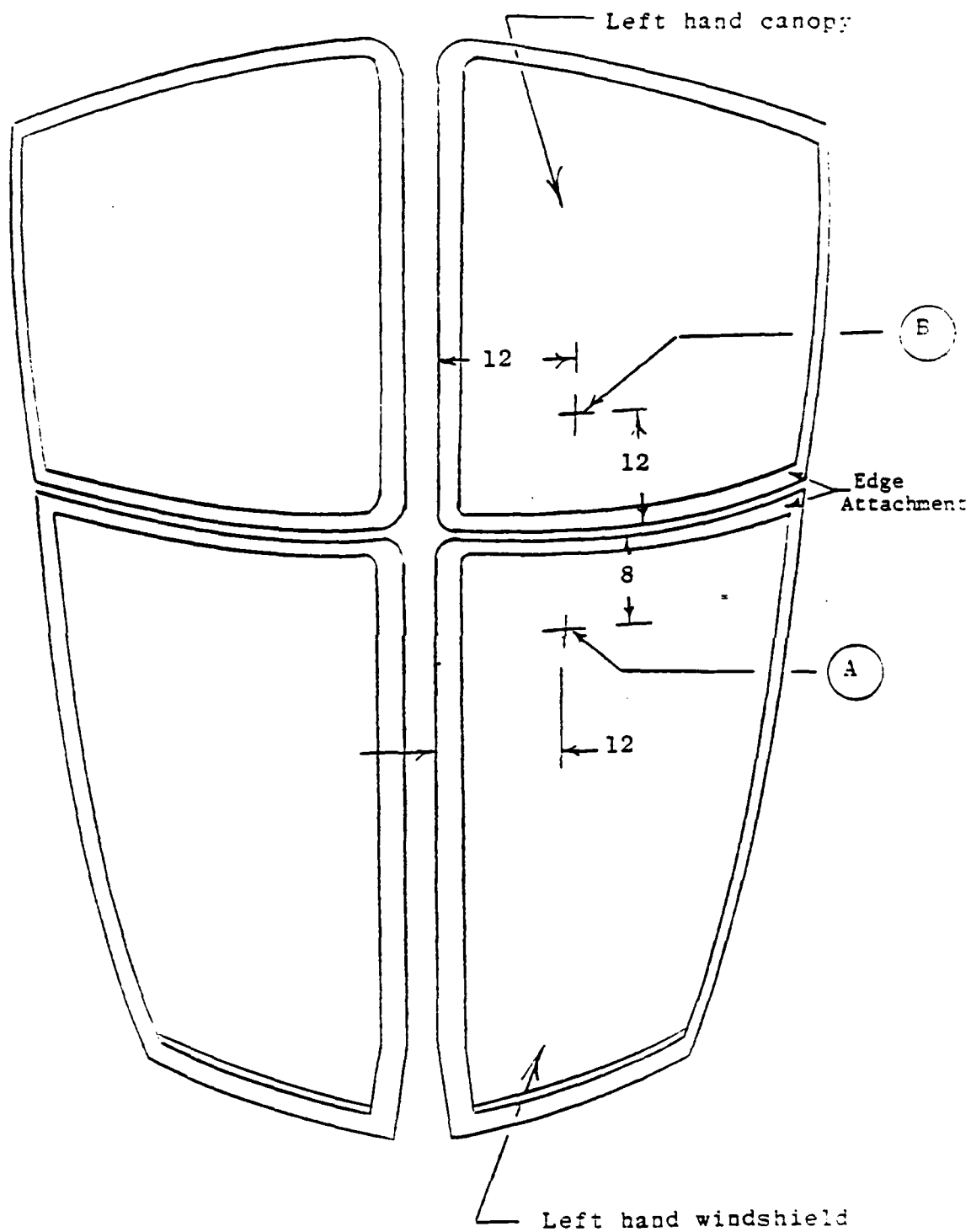


Figure 14. Bird Impact Target Points



Figure 15. Shot 696, Failure of Left Canopy

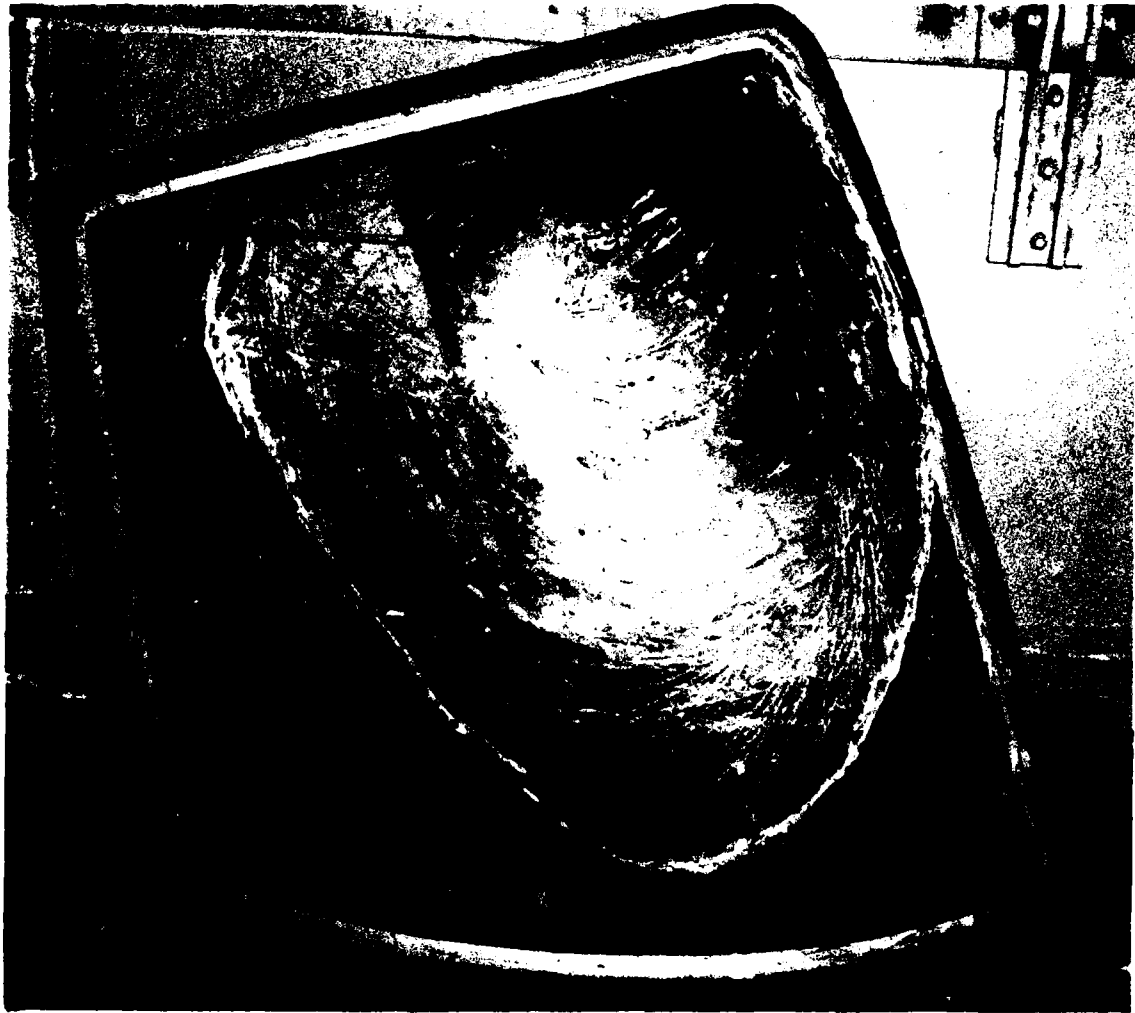


Figure 16. Shot 696, Post Test Condition of Left Hand Canopy



Figure 17. Shot 697, Post Test Condition of Right Hand Windshield
with Seven Months Service



Figure 18. Shot 699, Post Test Condition of Left Hand Windshield
from Flightline Thermal Environment Testing



Figure 19. Shot 699, Post Test Condition of Left Hand Windshield

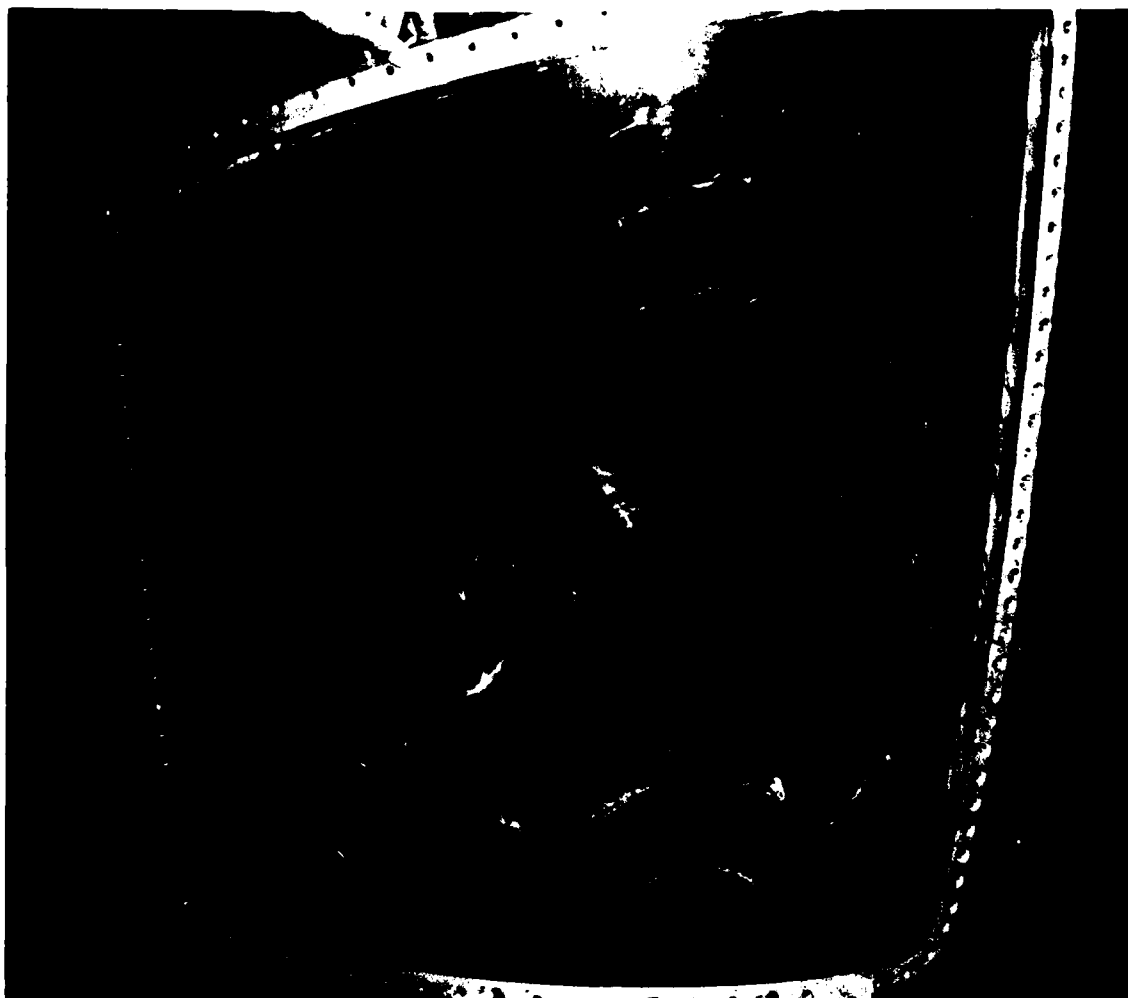


Figure 20. Shot 700, Post Test Condition of Right Hand Canopy from Flightline Thermal Environment Testing

APPENDIX

BIRD IMPACT TESTING OF TRANSPARENCIES
REMOVED FROM CANNON AFB, NEW MEXICO

INTRODUCTION

The purpose of the second bird impact test series was twofold: first, to assess the structural integrity of transparencies that experienced delamination in the field, and second, to assess the general adequacy of the experimental procedure used in the flightline thermal tests.

a. Results - The second bird impact test series was accomplished during the period 3 August 1981 through 20 August 1981 with the results being similar to the first test series. Details of this test series are contained in References 6 and 7.

A summary of the tests are contained in Table A-1. A brief description of the results is provided below. It should be noted from Table A-1 that the tests were performed at a 10% (or greater) reduction in impact velocity to allow for a measure of in-service aging effects. Even at this reduced velocity level, damage to the panels was significant. Figure A-1 shows typical pre-test delamination.

Shot 743: Sierracin Right-Hand Canopy S/N 022. No penetration. The inner structural ply spalled inward and the exterior structural ply, interlayer and acrylic ply spalled outward leaving only the interlayer material intact. A review of the film showed that this panel had extremely large deflections and that impact with the crew members helmet would have resulted. Figure A-2 shows the post-test condition.

Shot 744: Sierracin Right-Hand Windshield S/N 056. This shot resulted in a massive penetration of both bird debris and transparency material. A hole of approximately 250 in² was the result of the impact. The transparency material entered the crew module in one piece with severe crew injury being the probable outcome. Figure A-3 is the post-test photograph showing the area of the hole.

Shot 745: Sierracin Left-Hand Canopy S/N 019. There was no penetration on this shot, however (as with shot 743), there was extensive deflection of the canopy which could have impacted the crew members helmet.

Damage was limited to extensive cracking and spall of the outer acrylic and structural plies (Figure A-4).

Shot 746: Sierracin Left-hand Windshield S/N 121. A small portion of the bird volume penetrated into the crew module at the aft arch location. The inner and outer structural plies were cracked but the windshield remained intact (Figure A-5).

b. Conclusions/Recommendations

(1) Conclusions - Due to the correlation/similarity of the two bird impact test programs described above, the following conclusions are made:

(a) The structural integrity of in-service aged transparencies which have experienced delamination is significantly reduced. Results of the bird impact tests indicate that degradation in impact velocity exceeding 10% may be expected. These tests did not permit distinguishing between the effects of aging and the effects of delamination.

(b) Full-scale laboratory environmental testing is a viable technique in assessing the durability characteristics of F-111 Bird Impact Resistant Transparencies.

(2) Recommendations - In light of the results of the two bird impact test series, the following two-part recommendation is made:

(a) Conduct a controlled evaluation of structural degradation due to laboratory environmental exposure. This would require two shipsets of new ADBIRT transparencies from each of the two ADBIRT vendors (PPG and Sierracin). As a baseline, one windshield and canopy from each vendor would be birdstrike tested in the new condition. One windshield and canopy from each vendor would be subjected to an environmental exposure program. Birdstrike testing would then be conducted to explore the magnitude of structural degradation. The other windshields and canopies from each vendor would be cut into coupons, some of which would be exposed to the same accelerated environment as the full scale parts. The

unexposed and exposed coupons would be used to develop a screening test which could be used to predict degradation in birdstrike resistance, thus reducing future necessity to test full-scale items.

(b) Assess structural degradation resulting from actual in-service aging. This would require two shipsets of each vendor's transparencies removed from field service after roughly two years of service in each of the major theaters of F-111 operation. These transparencies should have the outward appearance of being structurally sound (minimal delamination), but they could be ones removed for optical quality degradation. They should not be parts which have been in storage for any extended period of time following removal from service. One windshield and one canopy from each location would be cut into coupons for comparison with those coupons exposed in Item (a) above. The remaining transparencies would undergo bird impact testing.

(3) The program described in Section (2) above would provide an opportunity to evaluate (in a limited manner) the effects of service life on F-111 bird resistant transparencies. The potential payoffs from a program of this nature would be numerous and include: (1) Definition of degradation of bird impact capabilities due to in-service aging, (2) improvement of laboratory environmental exposure test techniques so that possible design deficiencies may be uncovered early in the development phase, (3) develop a laboratory test method for evaluating the bird impact resistance of F-111 transparencies using coupon specimens (this would reduce the number of full-scale tests when test hardware and test articles are in short supply), and (4) identify possible design deficiencies in the current ADBIRT in order to determine potential modifications which could increase the service life and reduce the cost of ownership of the F-111 transparencies.

TABLE A-1
BIRD IMPACT TEST SUMMARY: CANNON AFB PANELS

Shot No.	Date	Bird Temp, °F	Test Area Temp, °F	Bird Wt., lb	Velocity, Knots Requested	Acutical Location	Impact ²	Test ³ Article	Transparency Identification	Posttest Condition
743	8/13/81	65	84	4.00	450	408	B	Sierracin R/H Can	P/N 157400-52 S/N 022	Inner and outer structural ply cracked and spalled (A (inside) $\approx$ 100 in. ² , A (outside) $\approx$ 60 in. ²) Adhesive inner layer intact, no penetration.
744	8/14/81	73	90	4.00	450	451	A	Sierracin R/H WS	P/N 157300-3 S/N 056	Penetration ($\approx$ 30%). Hole punched in windshield (A $\approx$ 250 in. ²)
745	8/17/81	65	82	4.00	450	451	B	Sierracin L/H Can	P/N 157400-51 S/N 019	Outer structural ply cracked and spalled (A $\approx$ 250 in. ²)
746	8/18/81	68	68	4.00	400	393	A	Sierracin L/H WS	P/N 157330-51 S/N 121	Penetration ($\approx$ 3%) at rear arch location. Inner and outer structural ply cracked but windshield remained intact.

NOTES: 1. Requested bird weight 4.0 ± 0.1 lb on all shots.

2. See Figure 14.

3. L/H - left hand, R/H - right hand, W/S - windshield, Can - Canopy.

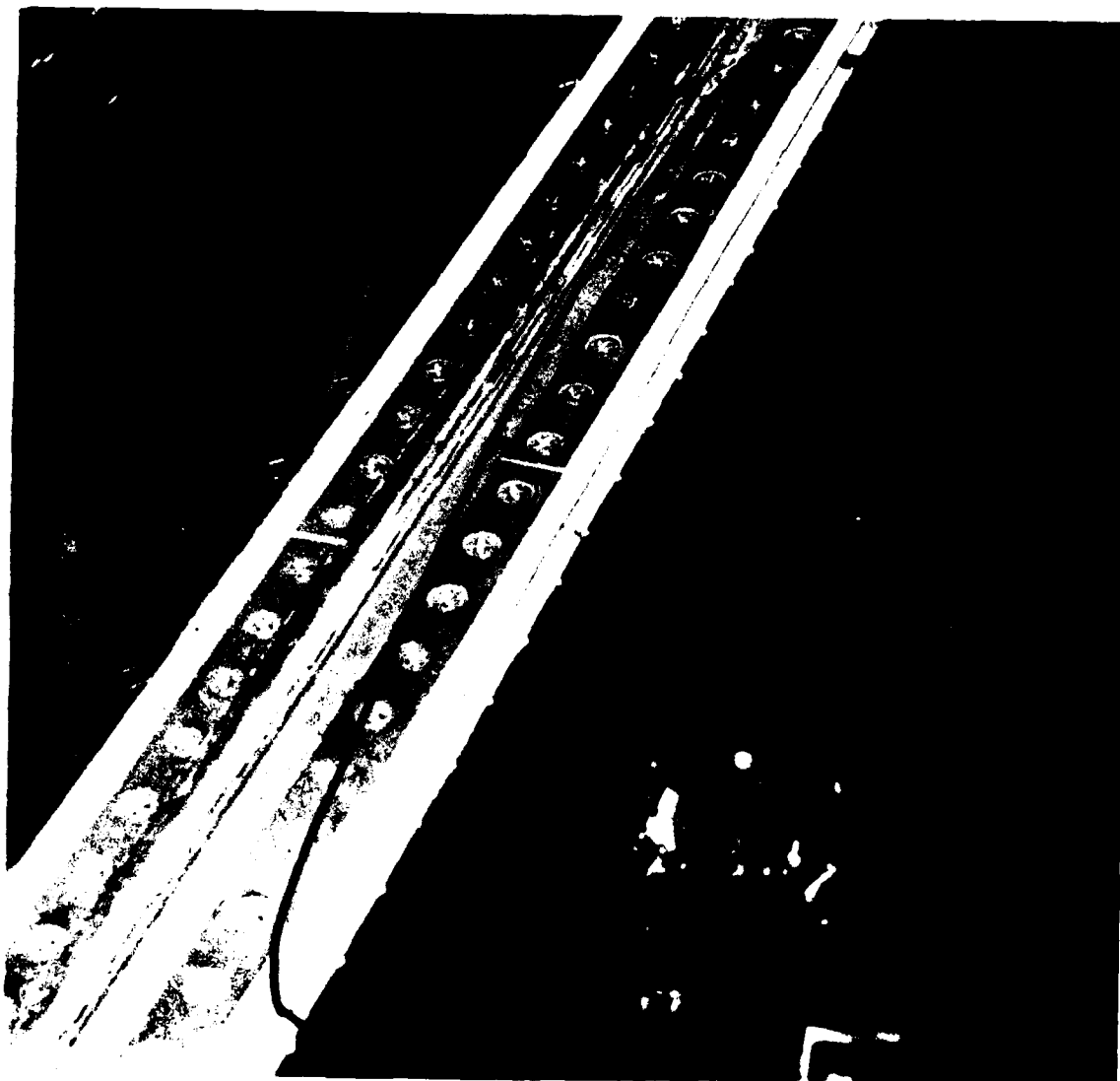


Figure A-1. Typical Delamination Patterns on Units Removed from Cannon AFB



Figure A-2. Shot 743, Post Test Condition of Right Hand Canopy
Removed from Cannon AFB

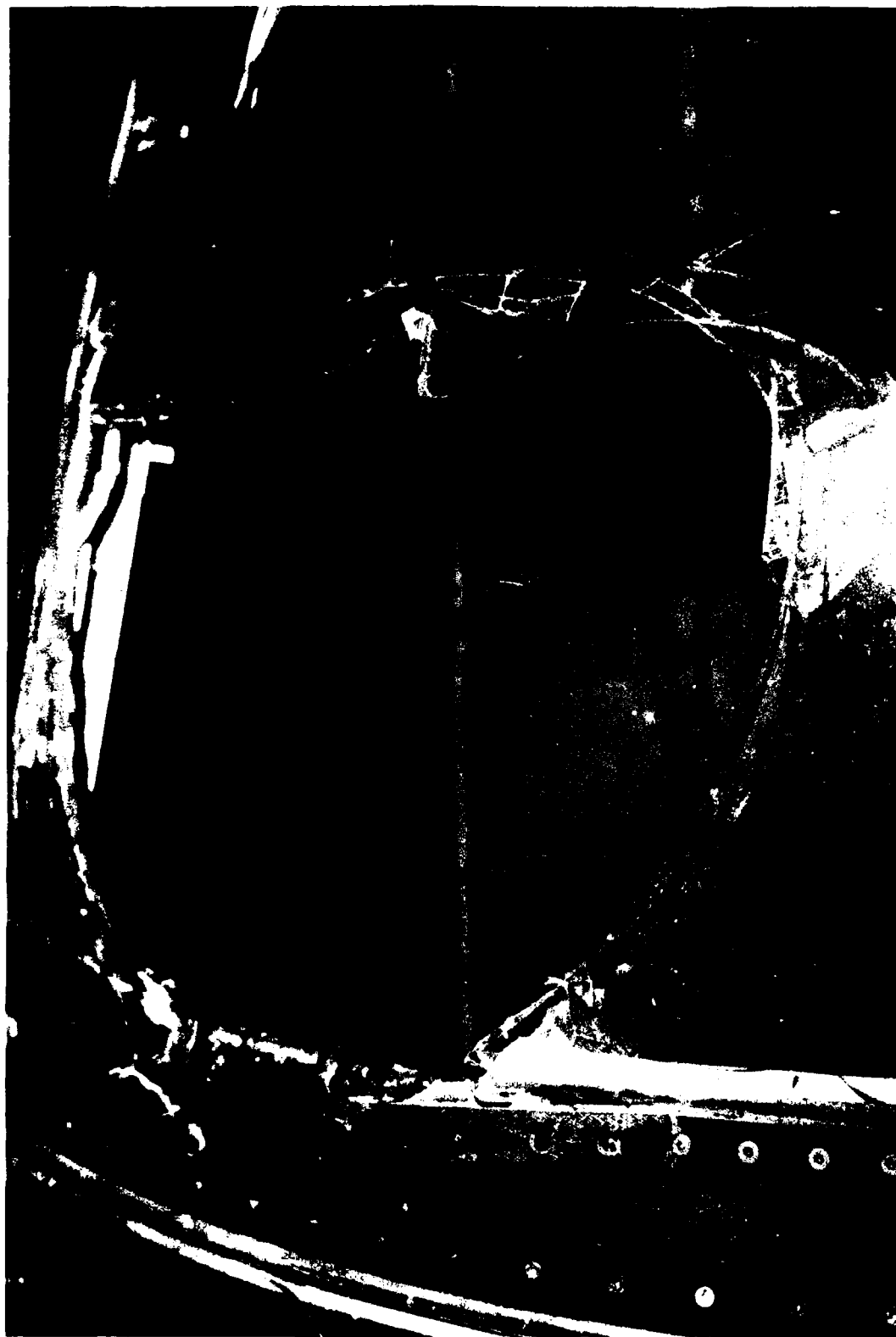


Figure A-3. Shot 744, Post Test Condition of Right Hand Windshield
Removed from Cannon AFB



Figure A-4. Shot 745, Post Test Condition of Left Hand Canopy
Removed from Cannon AFB



Figure A-5. Shot 746, Post Test Condition of Left Hand Windshield
Removed from Cannon AFB

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