ORION

SERVICE DIGEST

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ORION

P-3 WINDSHIELDS

FRONT AND BACK COVERS When the Royal New Zealand Air Force No. 5 Squadron retired its venerable Mark V Sunderlands in 1966 and took delivery of five P-3Bs, it ended twenty-five years of flying boat operations and became the first non-American squadron to be equipped with land-based Lockheed Orion ASW aircraft.

The colorful history of No. 5 Squadron can be traced to the formation of a small aerial reconnaissance unit in 1941. Based in Fiji and equipped with eight de Havilland biplanes, the unit was responsible for surveillance of that sector of the Pacific. In 1942 with the acquisition of PB2B-1 Catalinas the Squadron proper was formed and entered into the ASW business, with Headquarters at RNZAF Base Hobsonville, on Auckland's Waitemata Harbour. No. 5 Squadron patrolled the South Pacific for the remainder of World War II from its home base and from Lauthala Bay, Fiji, where a forward detachment was maintained.

After the War with Catalinas and from 1953 with Sunderlands, No. 5 Squadron operated solely from Fiji and maintained a tight ASW training schedule while performing divers mercy and rescue flights. These latter services not only saved many lives but won enduring goodwill for New Zealand throughout the South Pacific.

Soon after receipt of its P-3Bs, the Squadron took part in SEATO "Operation Seadog" in the South China Sea, and notched the first of many submarine "kills" achieved since then in exercises. The long-range capability of the P-3B is regularly exploited with several non-stop flights of over 5000 miles to the Squadron's credit.

Today No. 5 Squadron, from RNZAF Base Whenuapai, Auckland, ranges the Pacific flying shipping patrols, search and rescue missions, and fishery protection assignments as well as participating in Allied Naval Exercises from bases in Australia, Singapore, the Philippines, and the United States. The intrepid qualities of the Squadron are personified by its crest and motto "Keitou Kalawaca na Wasaliwa" which, when freely translated from Fijian, means "We span the Oceans".

Our cover shows a No. 5 Squadron P-3B on the run-in for an RP attack at the RNZAF Kaipara Training Range.

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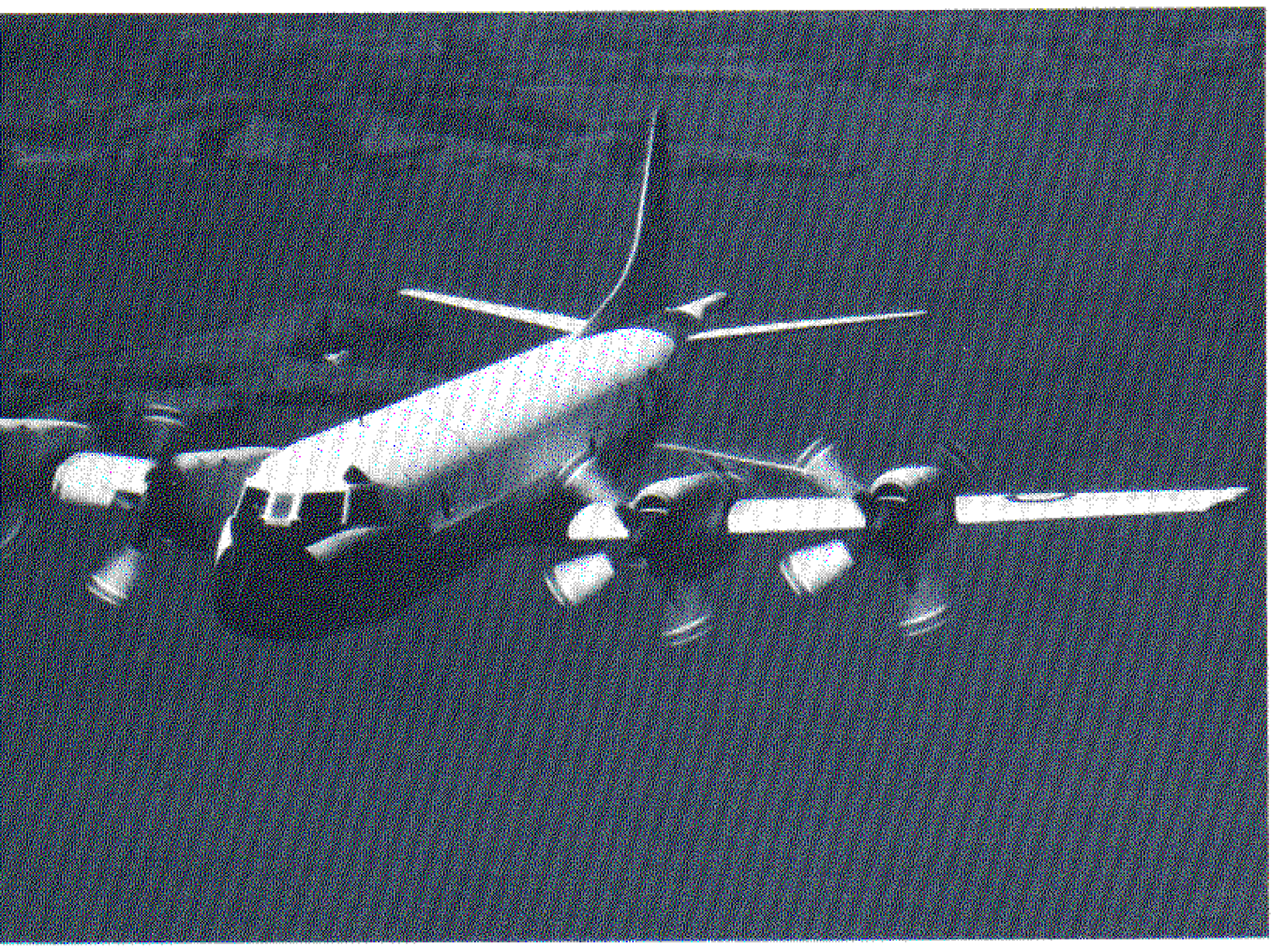
P-3 WINDSHIELDS

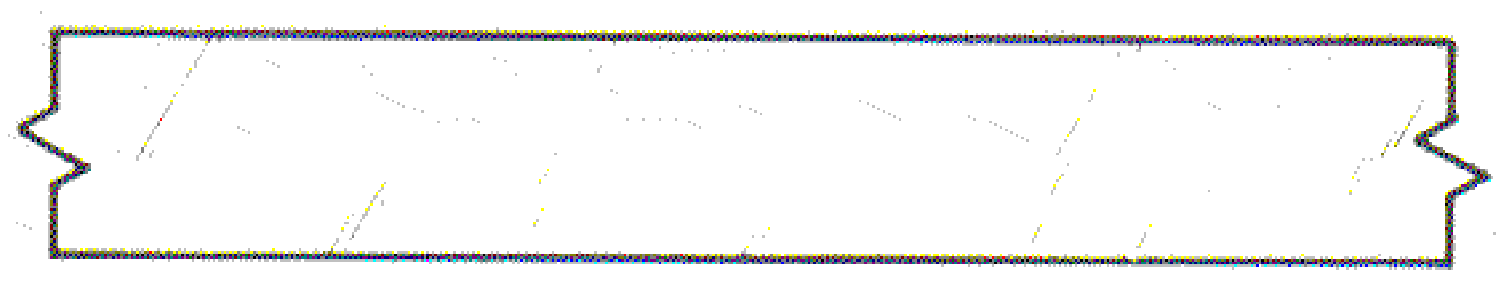
WINDSHIELD DESIGN DEVELOPMENT



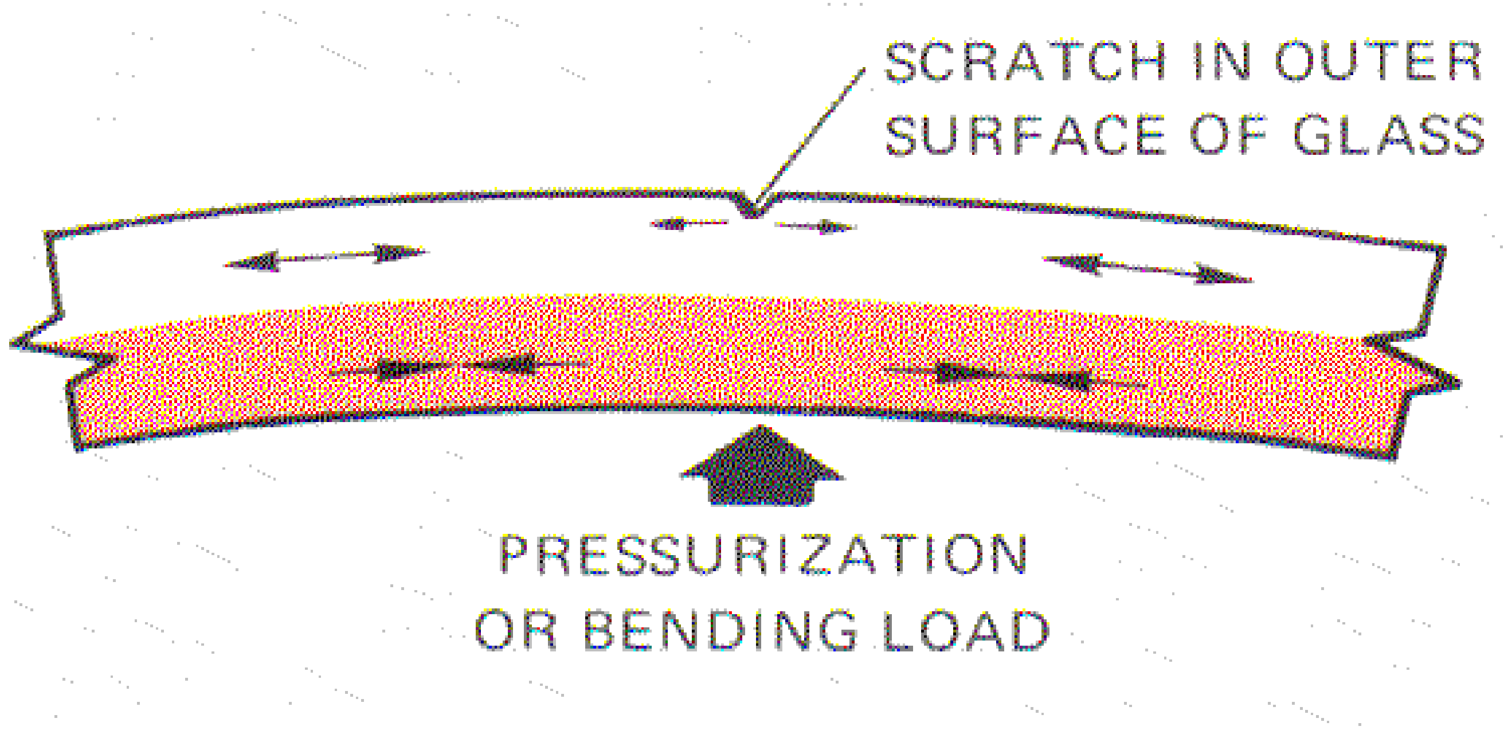
GLASS, BECAUSE OF its many desirable properties, has probably been the material most commonly used in aircraft windshield construction since the advent of cockpit and cabin pressurization. Its optical superiority over the various transparent plastic materials, combined with higher structural strength, greater resistance to weathering and aging, and chemical stability, makes it the logical choice of material for windshields where optimum visibility is required. The almost universal use of windshield wipers on large aircraft makes glass even more desirable as windshield material because its extreme hardness results in resistance to scratches and abrasion.

However, glass is extremely brittle. It has a relatively low strength-to-weight ratio when utilized for purposes such as window panels, and accurately contoured panels are costly and difficult to produce. For some time, glass was available only in the annealed state. In this form, panels of sufficient thickness to withstand the aerodynamic and cabin pressurization loads imposed on aircraft windshields were prohibitively heavy. Because of these and other characteristics, the use of glass on aircraft has generally been limited to only those applications where optical quality is of first importance. The development of tempering processes which permitted substantial reductions in thickness without reductions in strength and weight finally made the use of this material more practicable.

The brittleness of glass makes it extremely sensitive to surface, edge, or corner damage such as scratches or nicks; even microscopic flaws can act as stress risers and reduce the effective strength of an annealed glass pane considerably. (See Figure 1.) This characteristic is a much lesser problem when glass is in the tempered form. In the thermal-tempering process annealed glass is heated to near the "forming" temperature (1000° to 1300°F), then suddenly chilled with a blast of cold air so that the surfaces of the glass are "set" before the inner core cools and hardens. Because of this differential in cooling rates, compression forces are set up in the surfaces while tension forces are set up in the inner core as shown in Figure 2A. Thus, under normal shear or bending loads compression forces in the surface layers of a tempered glass panel must be overcome before the critical tension loads of the inner core are reached (see Figure 2B). In particular, this means that surface scratches or cracks on a sheet of tempered glass do not tend to propagate either inward beyond the surface compression layer or along the surface layer. On

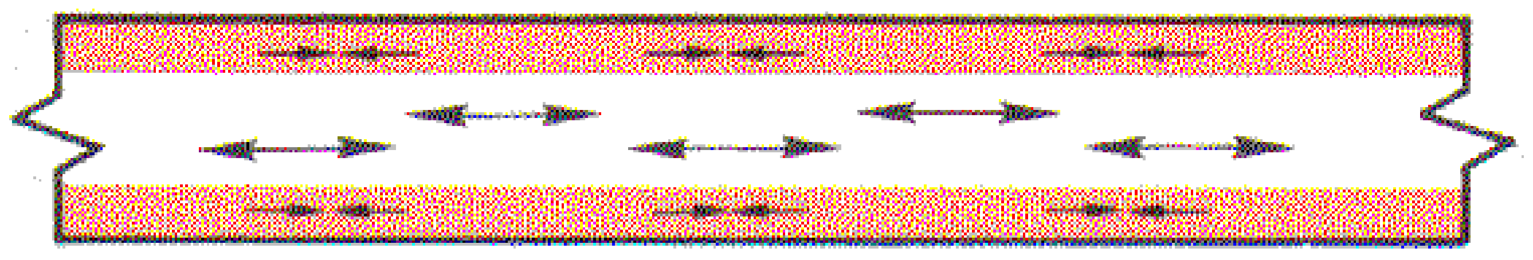


A SECTION OF NORMAL PLATE GLASS UNDER STATIC CONDITIONS. NO LOAD AND NO STRESS.

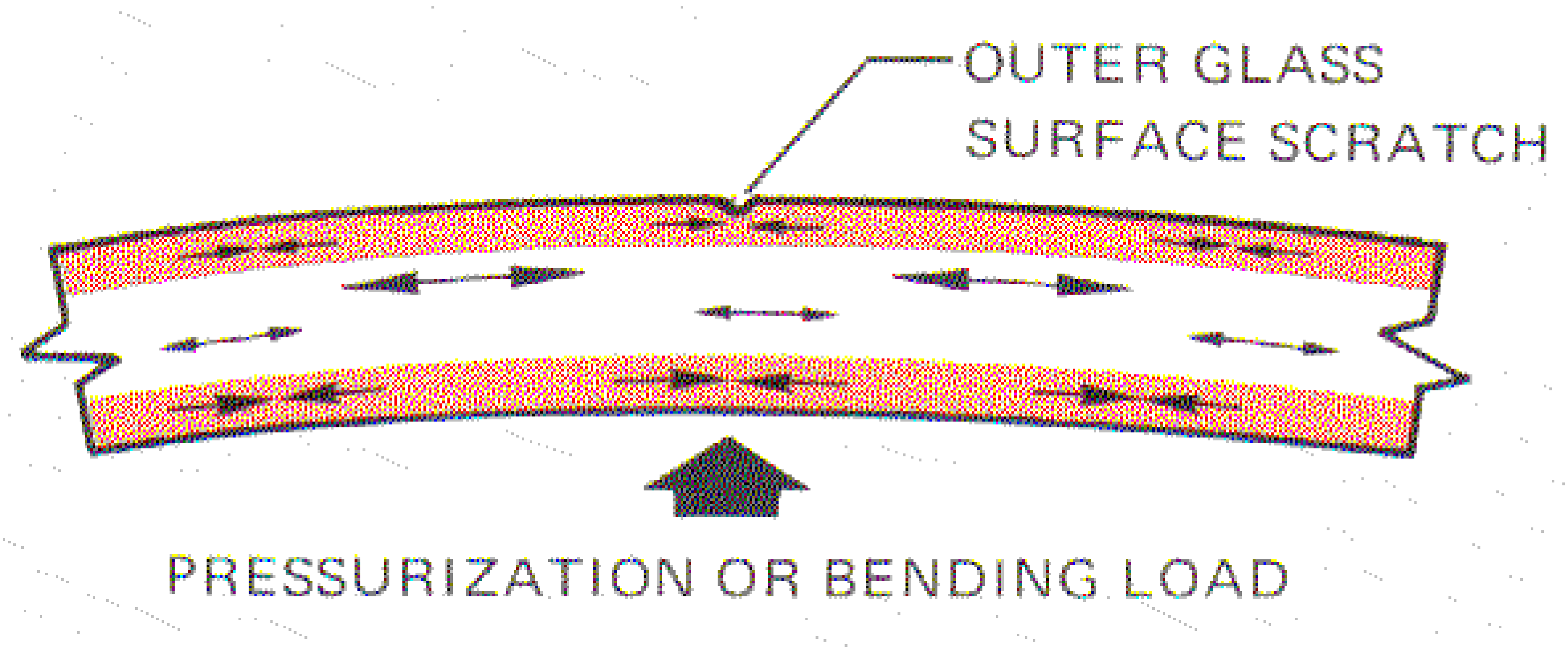


B SECTION OF NORMAL PLATE GLASS SUBJECTED TO STRESSES CAUSED BY PRESSURIZATION OR BENDING LOAD. LOAD PLACES OUTER SIDE OF GLASS IN TENSION AND INNER SIDE OF GLASS IN COMPRESSION. SCRATCH, ACTING AS STRESS RISER IN SURFACE OF GLASS UNDER TENSION, IS LIKELY TO PROPAGATE AND CAUSE FAILURE OF GLASS.

Figure 1. Sections through an Annealed Glass Pane



A SECTION OF TEMPERED GLASS UNDER STATIC CONDITIONS. GLASS SURFACE LAYERS ARE IN COMPRESSION BALANCED BY TENSION STRESSES IN THE CORE.



B SECTION OF TEMPERED GLASS SUBJECTED TO STRESSES CAUSED BY PRESSURIZATION OR BENDING LOAD. APPLICATION OF LOAD VARIES THE INHERENT STRESSES OF THE TEMPERED GLASS (INDICATED BY THE SIZE OF THE ARROWS). A SCRATCH WHICH HAS NOT PENETRATED THE SURFACE COMPRESSION LAYER IS NOT LIKELY TO PROPAGATE, AS LONG AS THE BENDING LOAD TENSION STRESSES AT THE OUTER SURFACE OF THE GLASS DO NOT OVERCOME THE INHERENT COMPRESSION STRESSES.

Figure 2. Sections through a Tempered Glass Pane

the other hand, deep scratches or other damage that extend through the surface compression layer can cause immediate failure of the tempered glass sheet.

The degree to which a glass pane can be thermally tempered depends upon its thickness. Glass 1/4-inch or more thick can be fully tempered to a flexure strength (modulus of rupture) in the range from 25,000 to 30,000 psi. Glass less than 1/4-inch thick can not be tempered to such a degree, therefore 3/16-inch glass is normally semitempered to a flexure strength of 18,000 to 21,000 psi, and 1/8-inch glass can only be slightly tempered to 12,000 to 14,000 psi. The flexure strength of an annealed glass pane ranges from 4,000 to 8,000 psi.

A chemical process can also be used to temper certain types of glass. During this process the glass pane is immersed in a molten salt bath which causes a chemical change in its surface composition. The chemical change sets up compression forces in the surface layers of the glass, thereby imparting a certain degree (depending upon the formula of the salt bath) of temper to the pane. Presently, there is only limited use of chemically-tempered glass in the aircraft industry.

Laminated glass panels were developed to impart shatterproof characteristics to the glass. Such panels are produced by laminating a ply consisting of several 0.025-inch thick clear polyvinyl butyral plastic sheets between plies of preformed and pretempered glass as shown in Figure 3. The vinyl and glass plies are then bonded by application of pressure and heat; the temperature, below the bubbling temperature of the vinyl, is considerably less than that required for tempering the glass. Because vinyl has a natural affinity for glass, the bond is effected without the use of cement.

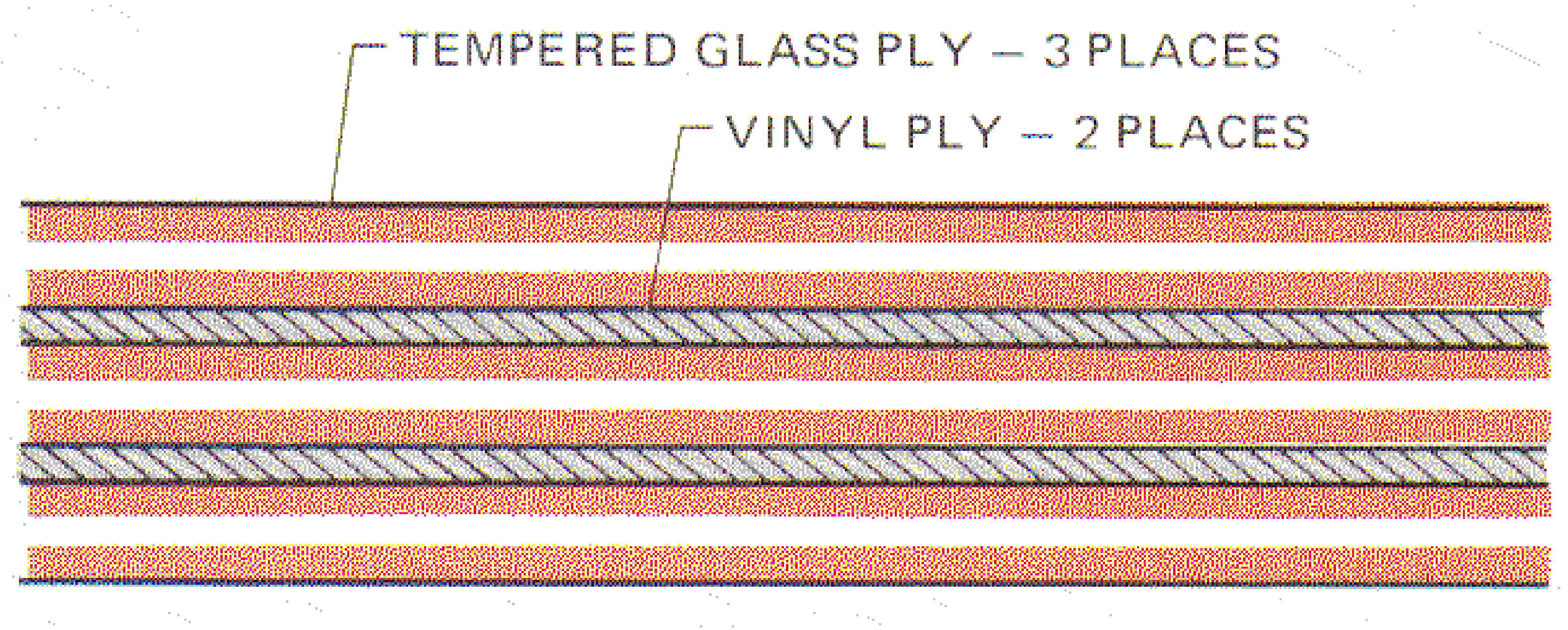


Figure 3. Section through a Laminated Glass Panel

WINDSHIELD EVOLUTION The development of laminated panels of tempered glass and a vinyl plastic material was the starting point in the evolution of the present day electrically-heated, impact-resistant windshield. The windshield shown in Figure 4A was representative of designs that immediately followed World War II. With the exception of sliding "clear vision" windows, these panels were made up of three plies of 1/8-inch tempered and polished plate glass, laminated with two thin plies of vinyl (polyvinyl butyral). The sliding panels consisted of two plies of 3/16-inch tempered glass separated by a single thin ply of vinyl (see Figure 4B). All the windshield panels were clamped to the windshield frame from the inside with retaining strips. From the maintenance viewpoint, this method provided a comparatively trouble-free installation with adequate reserves in structural strength. Nevertheless, it offered little protection against midair collisions with birds. To put it into technical jargon, this windshield installation was not designed to be "birdproof."

Early birdproof windshield panels were similar to the example shown in Figure 4C. They were much thicker overall than previous designs due primarily to a 3/8-inch thick center ply of vinyl sandwiched between 3/16-inch thick outer and 1/4-inch thick inner tempered glass plies. The resistance of the panel to bird strike impacts great enough to shatter both glass plies (see Figure 5) was derived from the ability of the vinyl ply to absorb the shock load by stretching and deforming. To ensure this resistance, it was essential that the vinyl be held around the

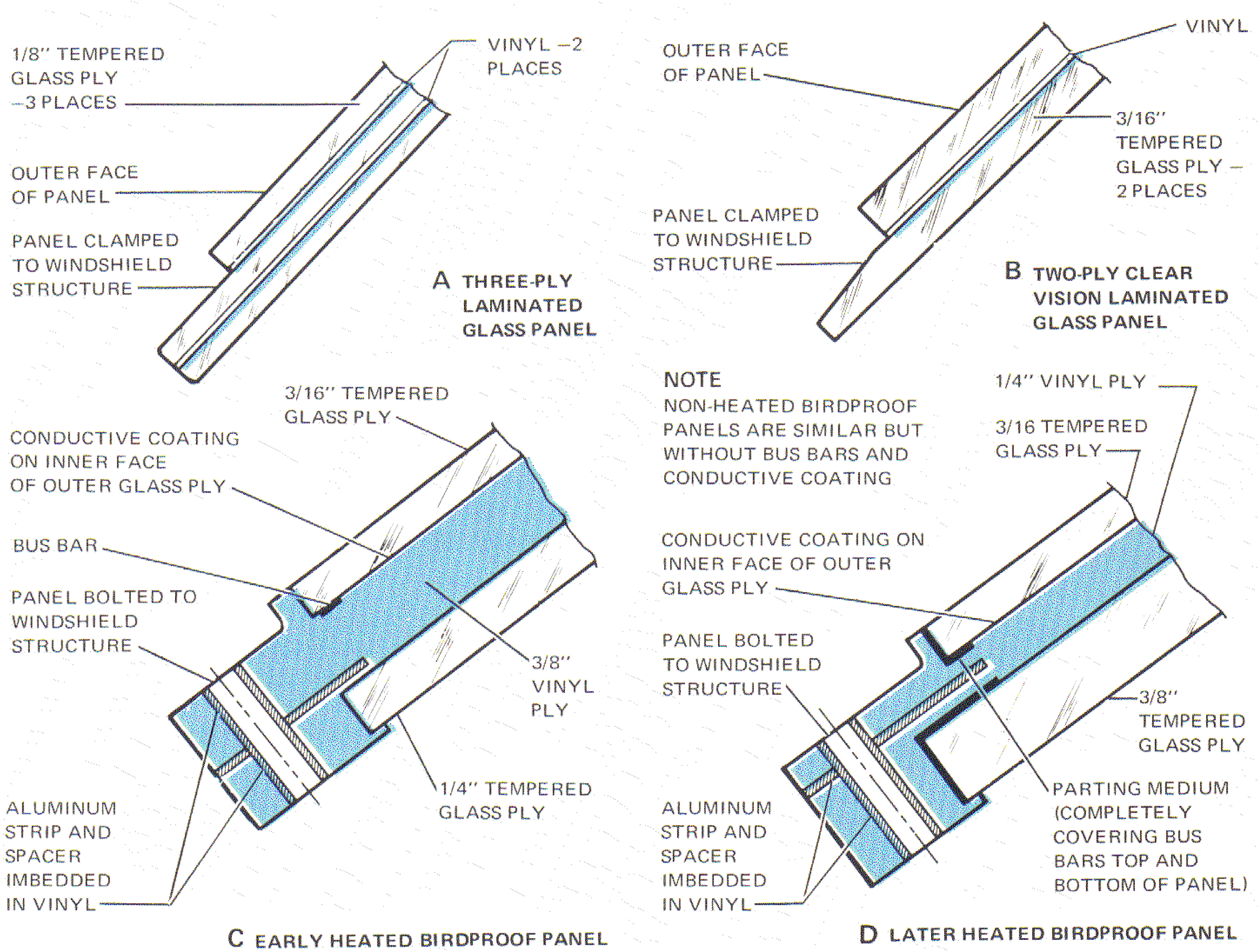


Figure 4. Sections through Windshield Panels of Earlier Design

edges with more security than the clamping action of previous designs provided. Therefore, the vinyl ply was bolted directly to the aircraft structure. To further refine the design and provide even more installation security, an aluminum insert was imbedded in the vinyl around the periphery of the panel and an aluminum spacer was installed in each bolt hole (see Figure 4C). This construction prevented deformation of the vinyl ply at the panel edges during installation and under pressurization loads.

Development of the early birdproof panels was followed by development of a panel which could be electrically heated by means of resistance wires about 0.001-inch in diameter imbedded between the outer glass ply and the vinyl center ply. These wires were connected to bus bars of very thin silver frit imbedded between the plies near the top and bottom edges of the panel. These heated panels were not used operationally on Lockheed aircraft to any great extent, but were the forerunners of electrically-heated panels which Lockheed adopted later for commercial transports and patrol aircraft.

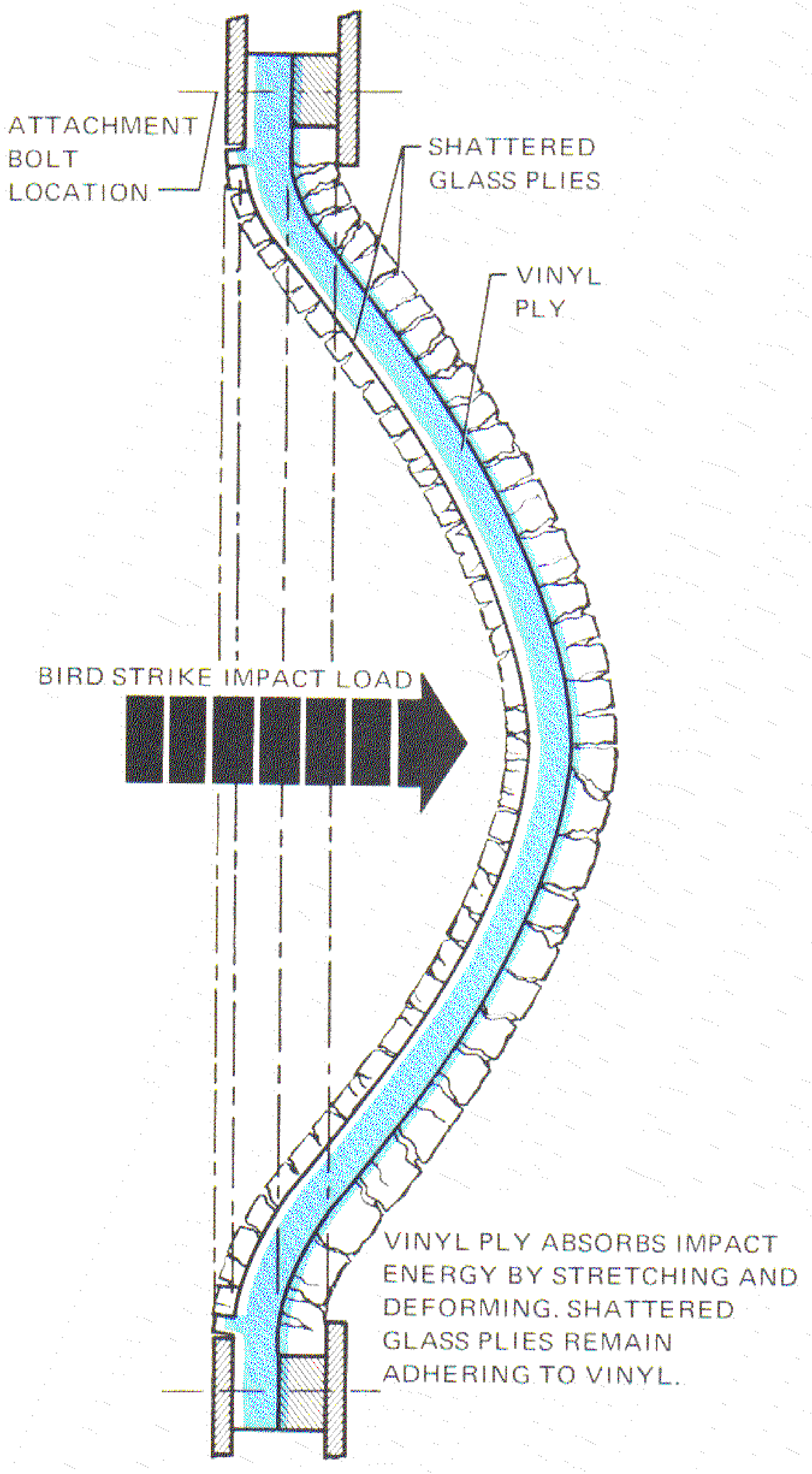


Figure 5. Manner in which a Birdproof Windshield Panel Resists a Bird Strike

NESA and Electrapane Panels Heated panels of improved design feature, as a heating element, a transparent conductive coating of stannic oxide on the inside surface of the outer glass ply instead of resistance wires. This conductive coating, about 20 millionths of an inch thick, is called by the Pittsburgh Plate Glass Company trade name of "NESA," while similar panels manufactured later by the Libbey-Owens-Ford Glass Company use the trade name "Electrapane." This approach to anti-icing has proved to be more successful than the wire-heating method.

There is an interesting sidelight to the development of the original panel with a conductive coating. The trade name NESA is actually an acronym for "Non Electro-Static formulation A." This term may seem even more obscure than the trade name until we delve a little further into history. Prior to World War II, aircraft speeds and operating altitudes had increased to the point where the buildup of static electricity in the windshield panels was becoming a problem. The original NESA panel with a conductive coating and a connection to ground was designed to meet this contingency. Some commercial airplanes used this device at that time, and later it was fitted to several wartime military aircraft. Use of the same transparent coating as a heating element was a subsequent development and nowdays all electrically-heated panels still provide this means for windshield static discharge.

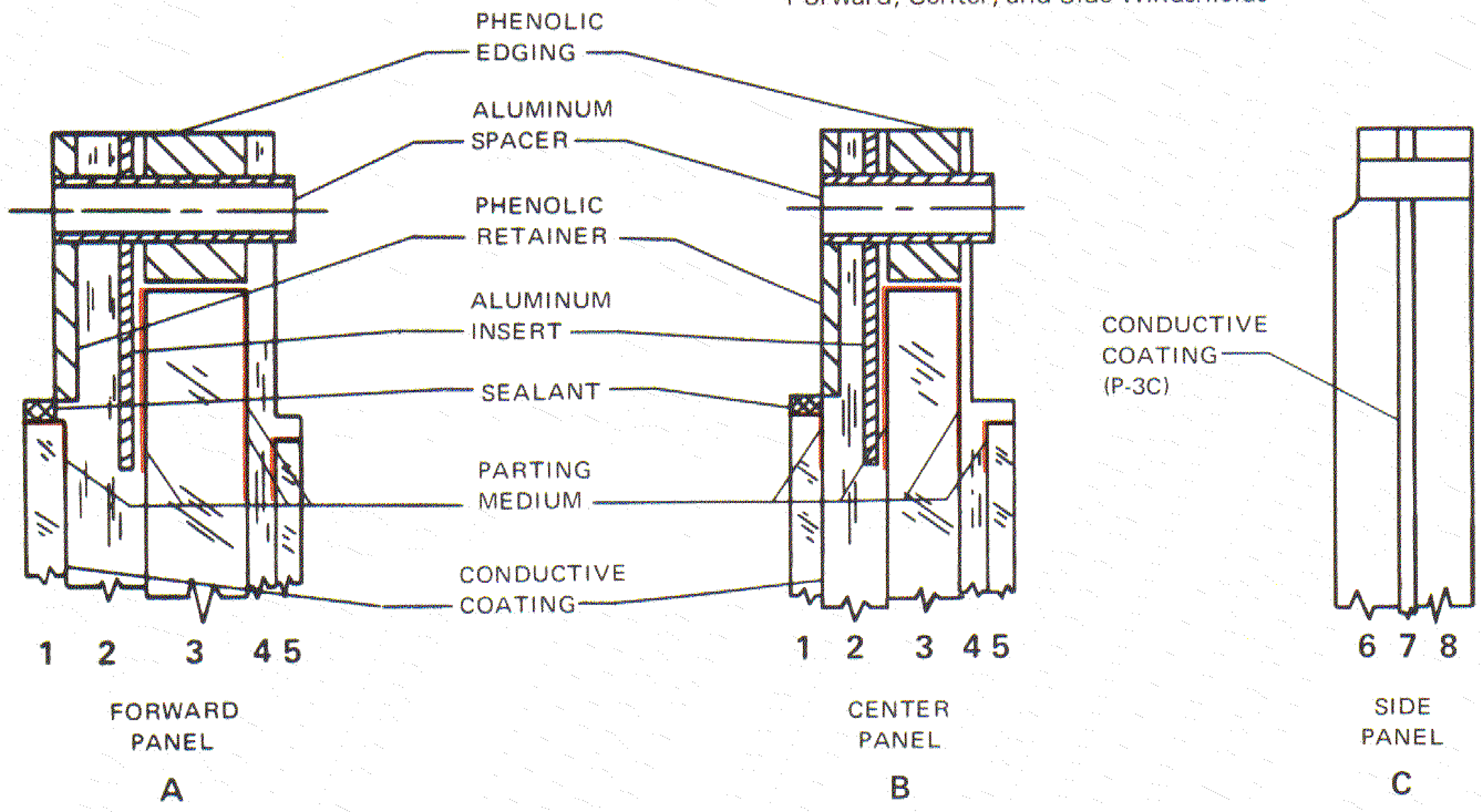
Later Developments Improved aircraft performance, in terms of higher speed and altitude, required parallel improvements in windshield design. The greater pressure differentials encountered at higher altitudes, and the need for panels of greater area, dictated the need for increased structural strength. Figure 4D shows that in the next evolutionary step, the thickness of the inner glass ply (the principal load-carrying member) was *increased* while thickness of the vinyl ply was *reduced* correspondingly so that the overall thickness of birdproof windshield panels remained the *same*.

Laminated glass panels were further strengthened by reinforcing the edges with cotton-phenolic retainers and edging as shown in Figure 6. Primarily, these reinforcements improve transfer of pressurization and bird-impact loads from the panel to the aircraft structure. In addition, they act as a "plug" around the panel edge, helping to prevent extrusion of polyvinyl butyral birdproof ply material during panel installation and to prevent flow of this material from the edge of the panel assembly during its service life. The insulating qualities of these cotton-phenolic reinforcements also tend to minimize heat transfer between the panel and the aircraft structure.

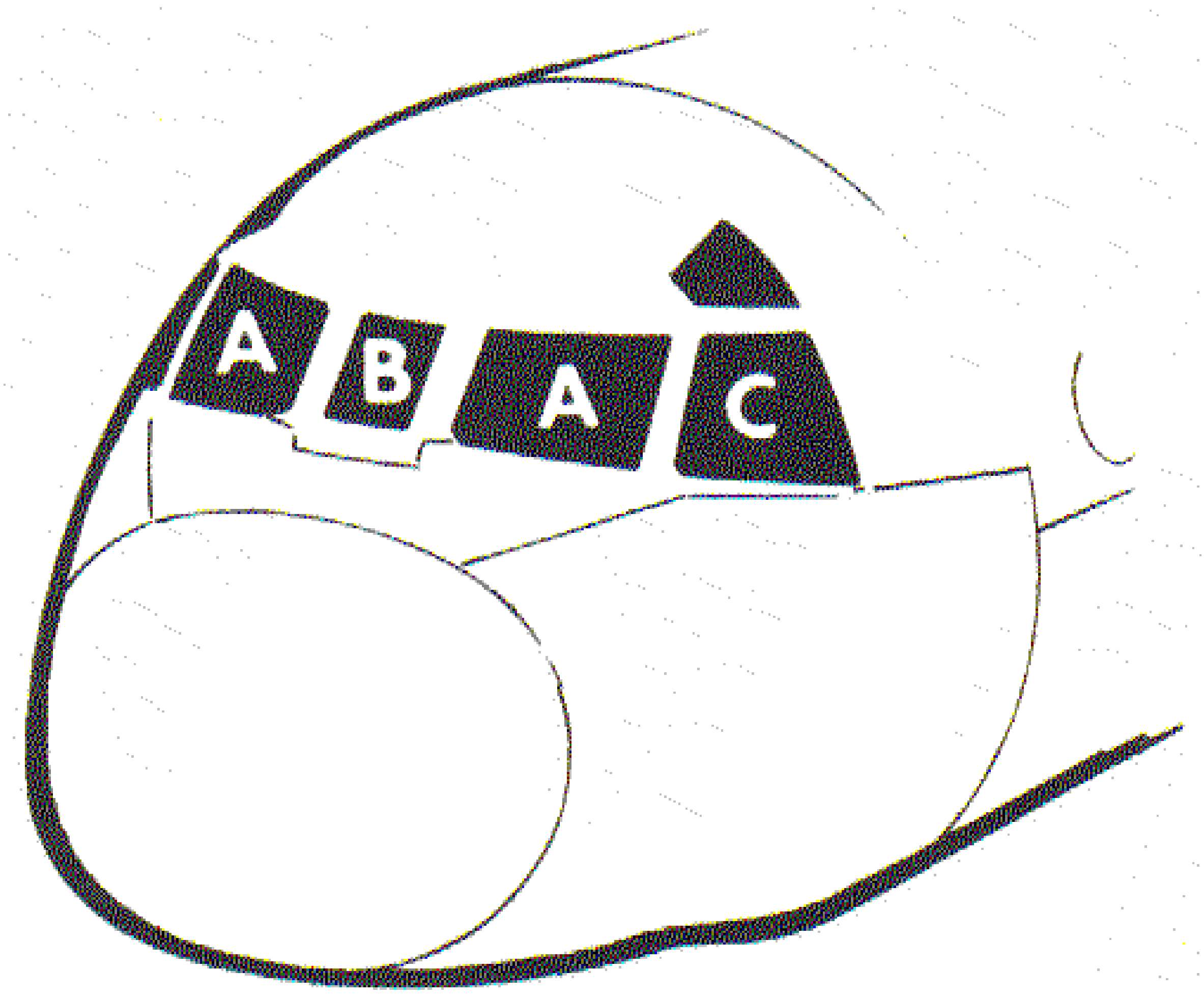
Another design refinement on electrically-heated panels incorporated a parting medium around the panel edges between the glass and vinyl plies. The parting medium allows a slight amount of movement between the glass and vinyl plies at a point where the panel is subjected to flexing under pressurization loads. It also relieves high shear stresses which can occur at the edges of the panel at very low temperatures. Use of the parting medium to allow these movements to take place without restraint has been found to be less injurious to the panel than extending the bond to the very edge of the glass plies. The parting medium also completely covers, and therefore protects, the bus bars located at the top and bottom edges of the panel.

P-3 Windshield Panels The windshield cross sections of the P-3 Orion and its antecedent, the

Figure 6. P-3 Windshield Configuration. Sections through Forward, Center, and Side Windshields



1 OUTER GLASS PLY - (3/16 INCH)
2 OUTER VINYL PLY (APPROX 0.290 INCH ON FORWARD PANEL; APPROX 0.265 INCH ON CENTER PANEL)
3 MAIN GLASS PLY (1/2 INCH ON FORWARD PANEL; 3/8 INCH ON CENTER PANEL)
4 INNER VINYL PLY (APPROX. 0.120 INCH)
5 INNER GLASS PLY (1/8 INCH)
6 OUTER ACRYLIC PANE (0.660 INCH)
7 INTERLAYER (APPROX. 0.163 INCH VINYL OR CAST-IN PLACE RESIN)
8 INNER ACRYLIC PANE (0.660 INCH)



Lockheed L-188 Electra commercial transport, follow the basic pattern described above except that each panel has two additional plies, one each of vinyl and glass, on the inner face making a total of five plies. This design change was adopted for the Electra after birdproofing tests on the windshield installation showed its necessity. Production installation of 5-ply panels on Orion aircraft began with P-3 BUNO 152164; P-3 BUNO 152163 and earlier were retrofitted with 5-ply panels through incorporation of P-3 Airframe Change No. 58.

Why Electric Anti-Icing? In the preceding chronological discussion on the development of electrically heated windshields this rather obvious question has been purposely avoided. One might well question the advisability of developing a somewhat complicated method of electrical ice prevention for the windshield, when other well-tried methods such as the use of alcohol spray or hot air might accomplish this with less trouble.

Electrical heating of laminated glass windshields provides more than just a desirable anti-icing feature, it also maintains plasticity of the vinyl plies of the panel. The physical properties of the vinyl plies vary considerably with changes in temperature. Considering the range of ambient temperatures that could normally be encountered during a typical patrol mission, the vinyl would be brittle in the lower part of the temperature range and quite plastic in the upper part. Panel temperature is not so critical on most piston-engined aircraft, but it is more or less essential to heat the panels on the faster and larger turbine-powered aircraft to meet birdproofing requirements without restricting aircraft performance.

Since the desired birdproof characteristics (energy-absorbing ability) of a windshield depend to a large degree upon the plasticity of the vinyl, panel temperature is an important factor. The optimum temperature range for maximum energy absorption by the vinyl is between 80°F and 120°F. At lower temperatures birdproof characteristics of the panel decline rapidly and, depending upon the actual configuration, impact resistance can be reduced by 30 percent to 50 percent when panel temperature is still a quite moderate 60°F. Electrical heating has proven to be an effective means of maintaining the temperature of the energy-absorbing vinyl ply within the optimum range.

Paradoxically, the resistance of a vinyl and glass laminated windshield panel to pressurization loads can be several times greater at lower temperatures than when it is heated to its normal operating temperature range. When cold and hard, vinyl has about the same strength as glass, and under these conditions the strength of a laminated panel is proportional to its total thickness. This fact is merely of academic interest since any given electrically-heated panel is designed with more than adequate safety factors at normal operating temperatures as standard practice and the strength of each glass and vinyl ply is considered separately for stress purposes.

WINDSHIELD SIDE PANELS Windshield side panels presented a different set of design problems, but the design objective of providing the largest possible field of view for the flight crew remained the same. Among the factors considered were the structural and economic merits of laminated plastic panels versus laminated glass panels, optical requirements, weight, and so forth. Studies also indicated that the threat of damage to side panels from bird strikes is considerably less, consequently the elaborate birdproofing measures used on the forward windshield panels were unwarranted for the side panels.

It is known that the structural characteristics of acrylic plastic can be improved by stretching the as-cast material. This stretching process consists of heating the plastic to near its forming temperature, stretching it biaxially as much as 100 percent, then cooling it in the stretched condition. Compared to as-cast acrylic stock, stretched acrylic has improved ductility, reduced notch sensitivity, and improved resistance to crazing, shattering, and weather exposure.

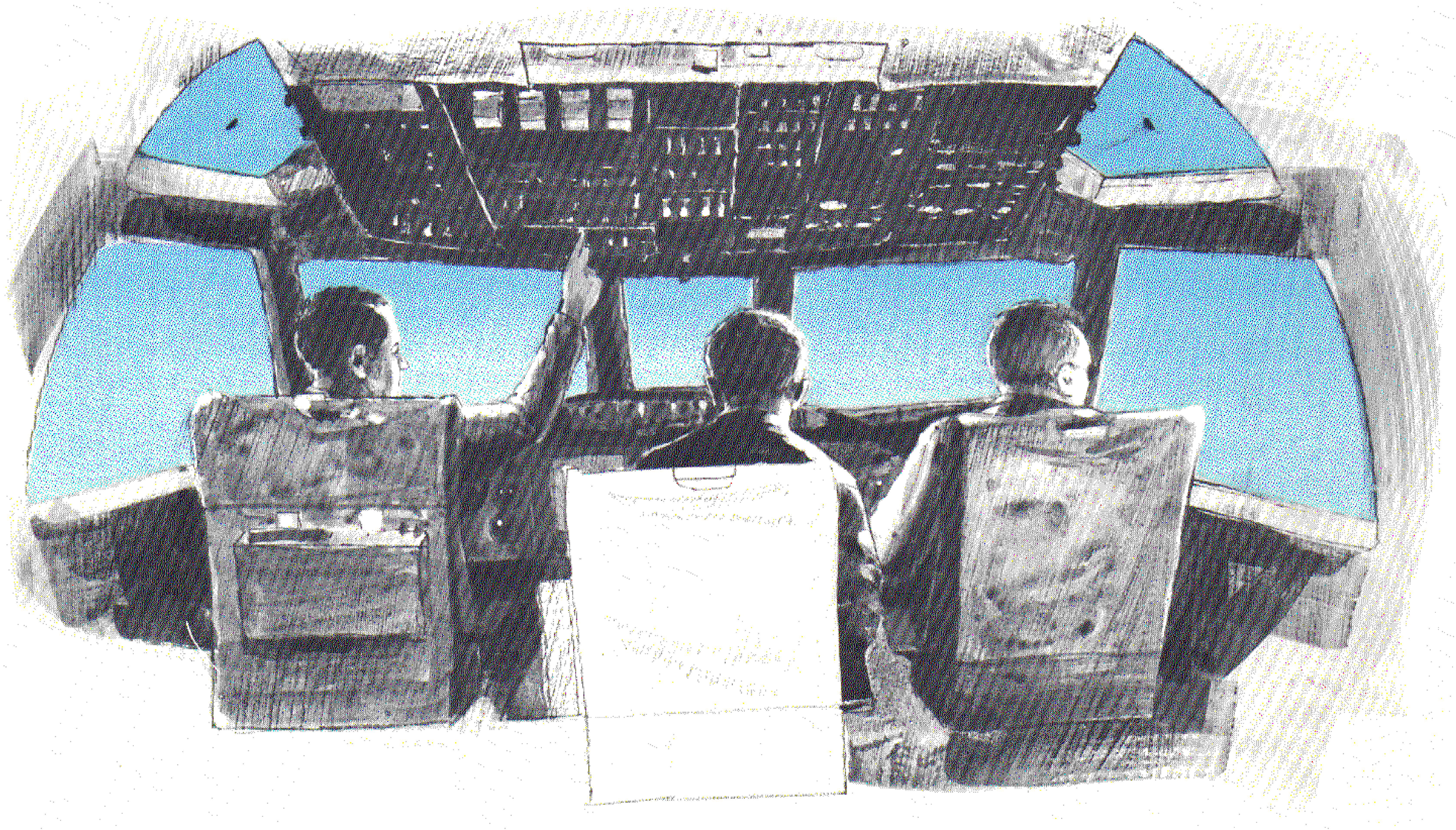
After careful consideration of all pertinent factors, windshield side panels curved to fair into the normal contour of the fuselage were designed. The curved side panels on P-3A and P-3B aircraft are made of two plies of formed, biaxially-stretched acrylic plastic separated by an interlayer comprised of polyvinyl butyral sheets each 0.025-inch thick, or of cast-in-place clear plastic resin. Nominal thickness of each acrylic plastic pane is 0.660 inch and the interlayer thickness varies from 0.075 to 0.200 inch as required for an overall panel thickness of 1.388 to 1.507 inches.

P-3C aircraft are equipped with electrically-heated side panels, the basic construction of which is similar to P-3A and P-3B panels. That is, each heated panel is comprised of two plies of stretched acrylic plastic separated by a multisheet polyvinyl butyral or a cast-in-place clear plastic resin interlayer. The overall dimensions including shape and thickness of heated panels are identical with those of unheated panels, and the two panel types are physically interchangeable. However, the interlayer thickness of heated panels can vary only from 0.125 to 0.200 inch to attain the same overall panel thickness.

The significant differences between heated and unheated panels are the provisions for panel heating. The heating element is a vapor-deposited gold conductive film on the inner surface of the outer ply. Bus bars imbedded in the interlayer at the forward and aft edges of the panel connect the heating film to the side panel heat control system. Duplicate temperature sensors and a thermostat are also imbedded in the interlayer near the aft edge of the panel. Although the method of heating is similar to that used on the forward windshield panels, operation of the control system is somewhat different.

The Navy has initiated a windshield side panels modification program (P-3 Airframe Change No. 200) to add panel heating capability to the panels presently installed in P-3A and P-3B aircraft. The Navy will, during PAR, remove the side panels from the aircraft, deliver them to the Sierracin Corporation in Sylmar, California for modification, and install the modified panels in the aircraft. The aircraft electrical systems will also be modified during PAR to accommodate the new side panel configuration and complete the change. After Airframe Change No. 200 is issued, the pertinent Maintenance Instruction Manuals NAVAIR 01-75PAA-2-2.4 and NAVAIR 01-75PAA-2-13.2 will be revised to incorporate side windshield panel heating system descriptions and circuit diagrams for the P-3A and P-3B aircraft.

Unheated side panels will be modified by installing a 0.050-inch thick polyvinyl butyral interlayer and a 0.125-inch thick stretched acrylic ply on the outer surface of the panel. A conductive coating will be applied on the inner surface of the added acrylic ply, and each modified side panel assembly will be equipped with bus bars, thermal sensors, a thermostat, electrical leads, and terminal blocks. Upon completion of assembly, the edges of the added plies will be sealed with an elastomeric coating to provide environmental protection for the heating components. The modified P-3A and P-3B side panels will be physically interchangeable with the heated side panels on P-3C aircraft.



WINDSHIELD TEMPERATURE CONTROLS

The advantages gained by heating a laminated aircraft windshield electrically are:

1. Anti-icing
2. Increased impact resistance.
3. Means for windshield static discharge.
4. Increased service life of the panel under low ambient temperature conditions.

Several pertinent factors were considered in determining the control temperature for P-3 aircraft windshield panels. As explained earlier, physical characteristics of the vinyl plies show considerable variation with respect to temperature. As the temperature increases, the vinyl loses strength due to softening; vinyl hardening at lower temperatures results in loss of its shock-absorbing qualities. The temperature range in which the vinyl plies of laminated panels can absorb maximum impact energy, such as from bird strikes, is from 80°F to 120°F, and this is the principal factor used to establish windshield control temperature.

It is practically impossible to produce a glass pane conductive coating that will achieve absolutely uniform heating effect over the entire coated area. Heating effect is a function of coating resistance which is, in turn, related primarily to coating thickness; secondary resistance factors are bus bar parallelism and perpendicularity to current flow, and panel shape. Because of these variables, tests are made after coating deposition and prior to panel lamination to determine the points of average power dissipation (K_a), or heating effect and the point of maximum heating (K_m). This information is then used to position the thermistor at a K_a location. To ensure overheat protection for the vinyl ply at K_m the upper control temperature limit was established at a value somewhat lower than that which would be optimum from the standpoint of vinyl characteristics alone.

The unavoidable time lag between the actual panel (vinyl ply) temperature, the temperature sensed by the thermistor, and control circuitry response to thermistor signals was considered in establishing the control temperature range. To avoid undue instability (too-frequent on-and-off cycling) in system operation, a control range of 10°F was selected. In consideration of all these factors, then, the control range of 90°F to 100°F was established.

To ensure that forward windshield panel heat is controlled within this temperature range, the overall electrical resistance of the conductive coating is measured by the manufacturer and the panel is graded accordingly as type A, B, or C (see Table 1). The conductive coating resistance of an individual panel is accommodated by connecting one of the panel leads to a corresponding tap on the system power transformer (see Figure 8).

On the other hand, the laminated stretched acrylic windshield side panels are not birdproof, and the primary reasons for heating them are merely to antifog or defog their surfaces. This merely requires that the panel surface temperature be maintained above the dewpoint. Since a side panel heating element consumes only a fraction of the power consumed by a forward windshield panel heating element, elaborate compensation for the heating element resistance of individual side panels is unnecessary, consequently the side panels are not graded according to the resistance of their heating elements.

CIRCUIT DESCRIPTION Presently there are two basic configurations of P-3 windshield heating installations. All P-3 aircraft (P-3A, P-3B, and P-3C) are equipped with electrically-heated forward windshield panels. P-3C aircraft also have

Table 1. Resistance Ratings of Electrically-Heated Windshield Panels

RESISTANCE RATING	PILOT'S AND COPILOT'S PANELS	CENTER PANEL	P-3C SIDE PANELS
RA	80.5 to 89.7 (ohms)	137.7 to 152.3	16.7 to 22.6
RB	72.8 to 82.0	124.5 to 139.2	
RC	65.1 to 74.3	111.4 to 126.0	

electrically-heated side windshield panels. In the future all P-3A and P-3B aircraft will be retrofitted with electrically-heated side windshield panels through incorporation of P-3 Airframe Change No. 200.

Forward Windshields The forward windshield heat system has two individual circuits, one for the pilot's forward panel and another for the copilot's forward panel and the center panel. Each circuit is provided with an individual control unit. Control switches and indicator lights for both systems are located on the left inboard overhead instrument panel (see Figure 7). Circuit breakers, control units, relays, and transformers are located in the forward electrical load center. The following description applies to the pilot's windshield circuit which is shown in Figure 8. Notes on this illustration point out the differences in the copilot's circuit.

Earlier P-3 aircraft were produced with Barber-Colman CYLZ-5837 windshield heat control units. Later aircraft in the P-3A and P-3B production series, and all P-3C aircraft, were equipped with the United Controls 2473-1B control unit. The two control units, shown in block schematic form in Figure 8, are physically interchangeable and are functionally similar except that the Barber-Colman unit requires both 28-volt DC and 115-volt AC power inputs whereas the United Controls unit requires only the DC input. Either unit *may be used* on P-3A and P-3B aircraft. However, the P-3C electrical system does not provide the 115-volt AC power required by the Barber-Colman unit, and the United Controls unit *must be used* on this model.

Also, the two control units differ in the manner in which their outputs are controlled internally. The Barber-Colman unit uses a pilot relay which is controlled by a magnetic amplifier and an associated control circuit; the United Controls unit

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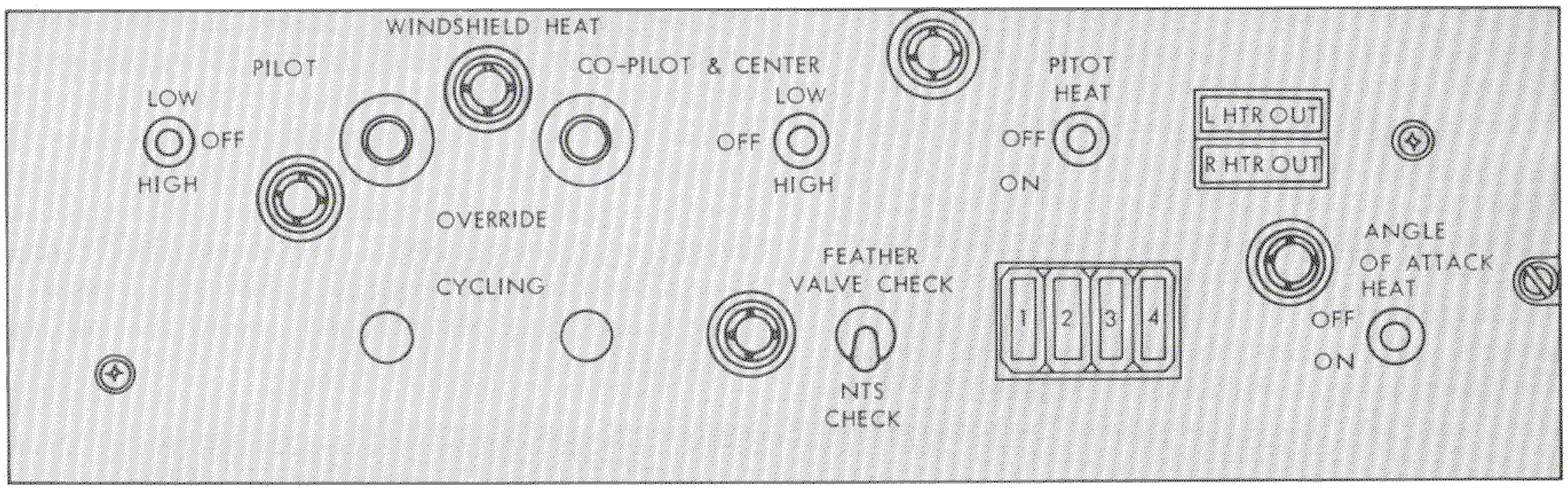

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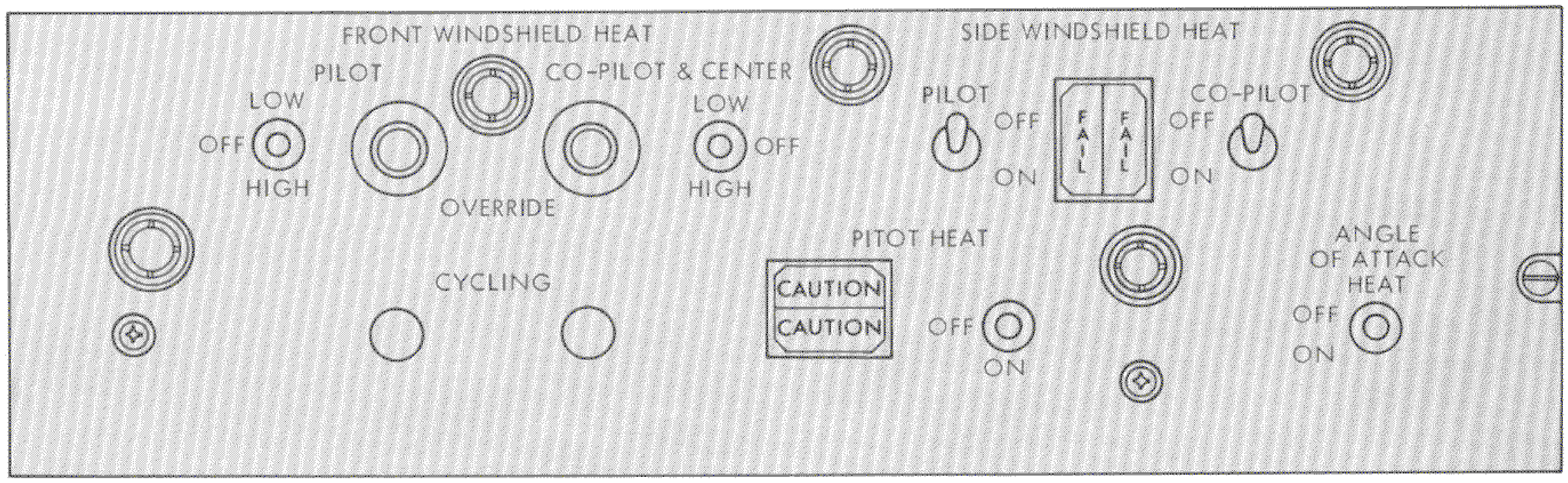
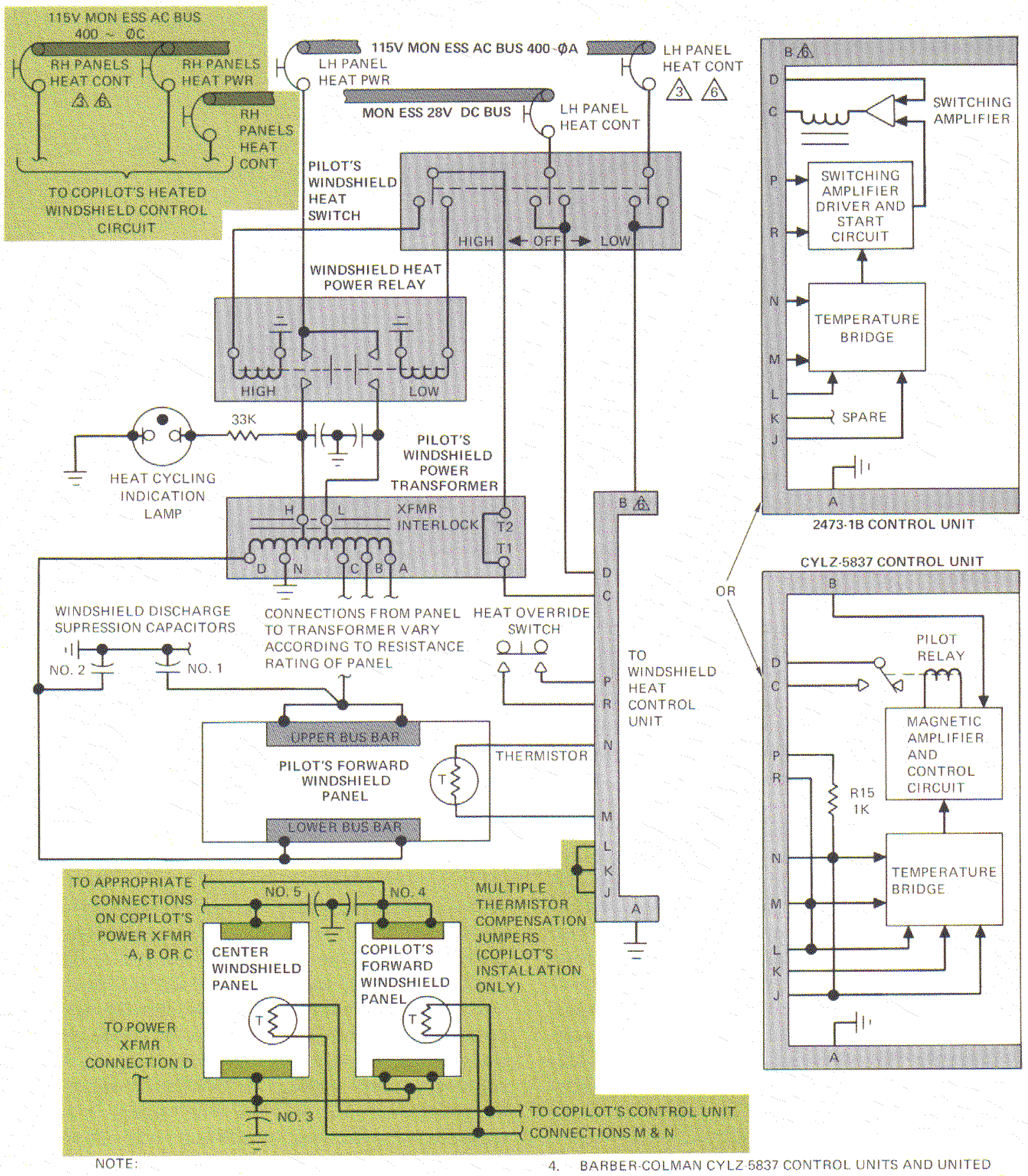


Figure 7. Windshield Temperature Control Panel



NOTE:

1. ALL SWITCHES AND RELAYS ARE SHOWN WITH THE SYSTEM DE-ENERGIZED.

2. PILOT'S WINDSHIELD HEATING CIRCUIT SHOWN; COPILOT'S CIRCUIT SIMILAR EXCEPT AS NOTED ON SCHEMATIC.

△3 P-3A and P-3B AIRCRAFT ONLY.

4. BARBER-COLMAN CYLZ-5837 CONTROL UNITS AND UNITED CONTROLS 2473-1B CONTROL UNITS ARE PHYSICALLY AND FUNCTIONALLY INTERCHANGEABLE ON P-3A AND P-3B AIRCRAFT. P-3C AIRCRAFT USE 2473-1B CONTROL UNITS ONLY.

5. OSBORNE ELECTRONIC 9671 TRANSFORMER USED ON PILOT'S CIRCUIT; 9672 TRANSFORMER USED ON COPILOT'S CIRCUIT.

△6 NOT REQUIRED WITH 2473-1B CONTROL UNIT.

Figure 8. Forward Windshield Heat Control Schematic

uses a switching amplifier controlled by a switching amplifier drive and start circuit. Inside the Barber-Colman unit, the +28-volt DC power is connected to one contact of the pilot relay; the 115-volt AC power is used to energize all control unit operating circuits. Inside the United Controls unit, the +28-volt DC power is divided; one part goes through a regulator circuit and is then routed to internal circuits requiring regulated power for operation. Other circuits operate on the unregulated +28-volt DC power.

The primary control element in either the Barber-Colman CYLZ-5837 or the United Controls 2473-1B control unit is a temperature bridge. Although the bridge elements of the two units differ considerably in circuitry details, their functions and operations are similar. In general, the circuitry functions as a resistance bridge, with the thermistor located in the windshield panel serving as one variable resistance leg of the bridge. Resistance of the thermistor varies inversely with changes in sensed temperature, i.e., the resistance decreases as temperature increases and vice versa. The resistance change is very nearly linear with temperature changes over the range used for P-3 aircraft windshield heat control. The thermistor, then, is the real control component in the windshield heating system. The two thermistors in the copilot's system (one each in the center panel and the copilot's forward windshield panel) are connected in parallel and act as a single component for control of this system.

Automatic operation of the windshield heating systems is initiated manually by actuation of the pilot's and copilot's heat switches to either HIGH or LOW position. Control power at +28-volts DC is routed from the Monitorable Essential DC Bus through the switch to control unit connector pin D. Also, for aircraft equipped with Barber-Colman CYLZ-5837 control units, 115-volt AC power is routed from the Phase A Monitorable Essential AC Bus through the switch to control unit connector pin B.

When the panel temperature as sensed by the thermistor is below 100°F (upper limit of the control temperature range), thermistor resistance is such that the bridge circuitry is in balance. In the Barber-Colman unit, this condition initiates action of the magnetic amplifier to energize the pilot relay, closing contacts to permit passage of control voltage through the relay. A second set of pilot relay contacts (not shown on diagram) complete a magnetic amplifier feedback circuit to provide relay "snap-action" upon de-energization. In the United Controls unit, the switching amplifier drive and start circuit generates a signal that biases the switching amplifier transistor causing output of control voltage to control unit connector pin C.

Control power is routed from control unit connector pin C through a transformer interlock and a second set of windshield heat switch contacts to energize one of two (high or low) power relay coils, depending on heat switch setting (HIGH or LOW). Each coil, when energized, closes a corresponding set of contacts to route 115-volt AC power from Phase A of the Monitorable Essential AC Bus to the appropriate (high or low) power transformer primary winding. Because of added load due to the forward windshield center panel, the transformer in the copilot's system has greater capacity than the pilot's system transformer. The recessed neon CYCLING indicator lamp, connected to the power transformer input leads, illuminates when the power relay is energized to indicate application of heat to the windshield panel. Heater power is routed to the windshield panel bus bars from one of three (A, B, or C) transformer output terminals as determined by the resistance rating of the panel. The power transformer utilizes a center ground to reduce the voltage differential between the bus bar and ground. This reduces the dielectric stress in the panel and high voltage hazard to operating and service personnel. Two power connections are provided for each bus bar on the pilot's and copilot's forward windshield panels because of bus bar length.

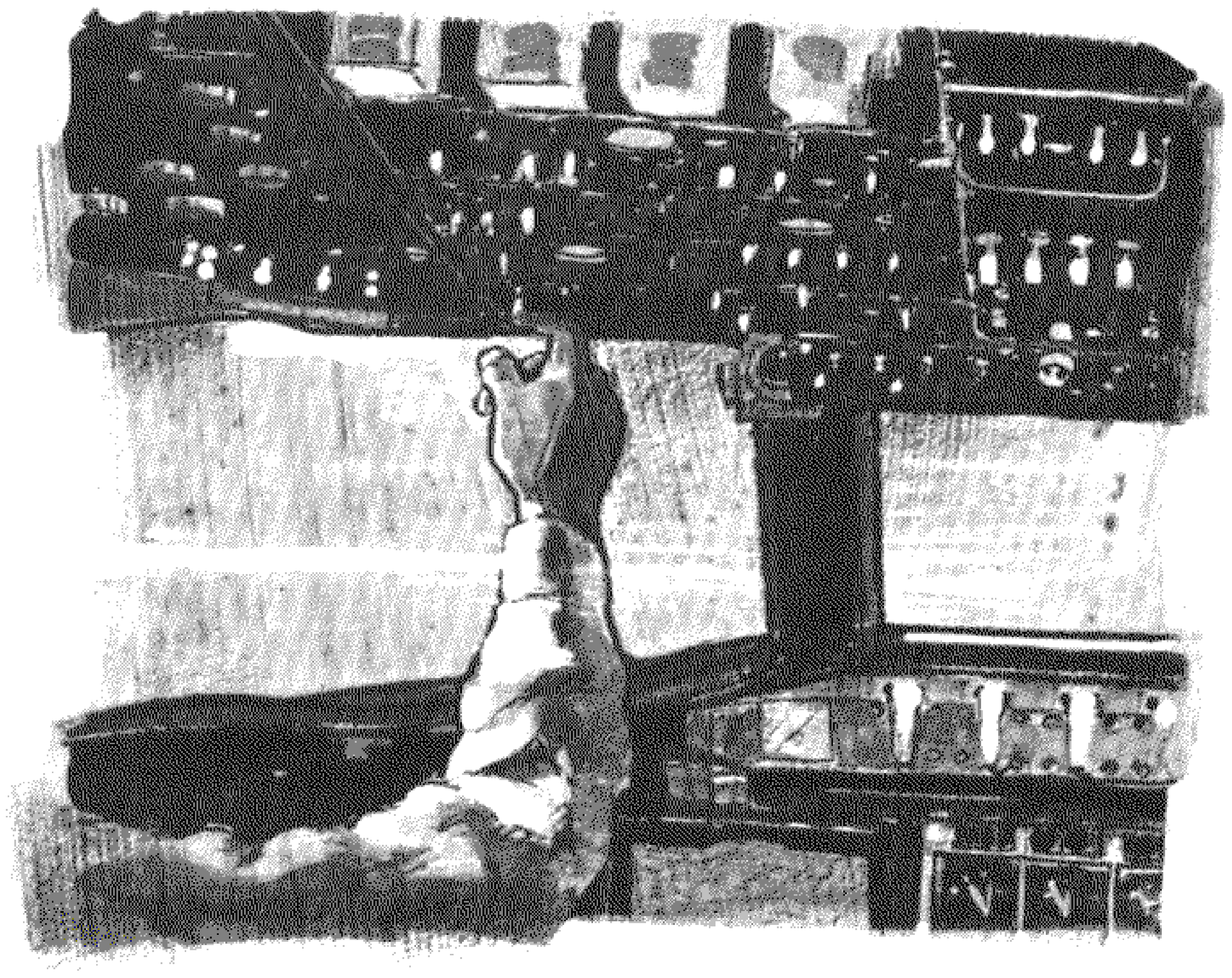
As windshield panel temperature rises from application of heating power, thermistor resistance decreases until, at the upper control temperature limit of 100°F, the bridge circuit becomes unbalanced. In the Barber-Colman control unit, this condition causes the pilot relay to be de-energized through action of the magnetic amplifier, interrupting control voltage to the power relay. In the United Controls unit, the bias signal is removed from the switching amplifier transistor, interrupting control voltage to the power relay. When the power relay is de-energized, contacts open and heater power is removed from the power transformer. The CYCLING indicator lamp is extinguished when the power relay is de-energized.

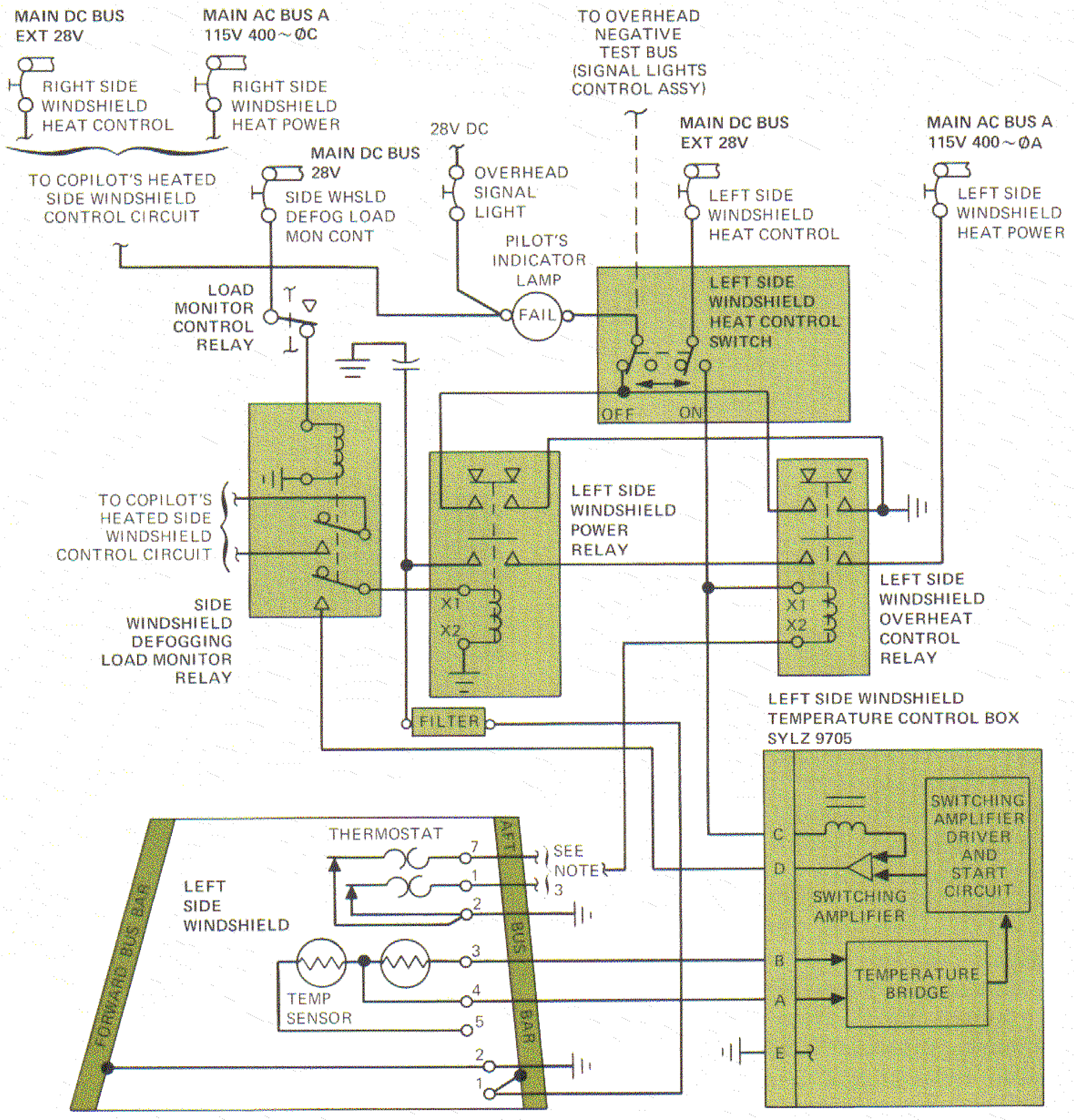
With removal of heater power, the windshield panel cools and thermistor resistance increases until, at the lower control temperature limit of 90°F., the bridge circuit again becomes balanced, activating the control unit circuitry as explained previously to resume windshield heating.

Circuitry in either control unit is so arranged that the heating system will be inoperative when the thermistor is either shorted (zero resistance) or open (infinite resistance). Thermistor characteristics are such that at about -35°F, its resistance approaches infinity and is sufficiently high to inhibit normal control of system operation. To permit system startup when the windshield panel is below this cutoff temperature, a manually-operated OVERRIDE switch is provided. With the Barber-Colman CYLZ-5837 control unit, a resistor R15 is connected in parallel with the thermistor when the switch is actuated. Effective resistance in the temperature (resistance) bridge thermistor leg is thus lowered sufficiently to initiate system operation. As the panel temperature rises, thermistor resistance decreases accordingly to a value where normal automatic control of system operation is enabled and the OVERRIDE switch can then be released. If the switch is held or sticks closed, combined resistance of the thermistor and resistor R15 will cause the control unit to shut off heater power at slightly lower than the normal cutoff temperature (100°F), thus protecting the windshield panel from overheating damage. Similar low-temperature starting capability is provided with the United Controls 2473-1B unit although the method is different. Actuation of the OVERRIDE switch completes a loop through the switch amplifier driver and start circuit whereby switching amplifier operation is initiated.

Side Windshields P-3C aircraft are equipped with heated pilot's and copilot's side windshield panels, each of which has an independent control circuit. As stated previously, P-3A and P-3B aircraft will be retrofitted with heated side windshield panels during a modification program. The two (pilot's and copilot's) control circuits share, and are controlled by, a common side windshield defogging load monitor relay. Since the two control circuits are identical, only the pilot's (LH) system is shown in Figure 9. The method of panel heating is generally similar to that used with the forward windshield panels, except that a power transformer is not used and the bus bars are located in the forward and aft edges of the panels rather than at the top and bottom. Controls and indicator lamps for each circuit are located on the left inboard overhead panel adjacent to the controls and indicator lamps for the forward windshield heating system. Individual system control units and relays are located in the RH forward electronics rack C3; system circuit breakers are located in the main and forward electrical load centers. Operational of the side windshield heating system is controlled by a load monitor control relay. The relay, operating in series with a LOAD MONITOR CONTROL SIDE WHSHLD DEFOG circuit breaker located in the main electrical load center, routes 28-volt DC power from the Main DC Bus to energize the side windshield defogging load monitor relay and enable system operation.

Operation of each side windshield heating system is controlled by a transistorized Barber-Colman SYLZ-9705 control unit which operates on +28-volt DC power supplied from the Extension Main DC Bus through a SIDE WHSHLD HT CONT circuit breaker located in the forward electrical load center and a SIDE WINDSHIELD HEAT switch. The control unit is similar in design and function to the United Controls 2473-1B unit used for the forward windshield panels. Inside the control unit, the +28-volt DC power is divided; one part goes through a regulator circuit and is then routed to internal circuits requiring regulated power for operation. Other circuits operate on the unregulated +28-volt DC power. The primary control element in the control unit is a temperature (resistance) bridge circuit. Each side windshield panel contains a wire-grid temperature sensor which functions as one variable resistance leg of the temperature bridge as the basic control component for the system. Unlike the forward windshield thermistors, resistance of the wire-grid sensors vary directly with changes in sensed temperature, i.e., an increase in panel temperature results in a corresponding increase in sensor resistance.





NOTE:

1. ALL SWITCHES AND RELAYS ARE SHOWN WITH THE SYSTEM DEENERGIZED.

2. PILOT'S SIDE WINDSHIELD DEFOGGING CIRCUIT SHOWN; COPILOT'S SIDE WINDSHIELD DEFOGGING CIRCUIT SIMILAR.

3. NORMAL WIRE CONNECTION IS TO TERMINAL NO. 1. IF TERMINAL NO. 1 IS SEALED SHUT, CONNECT WIRE TO TERMINAL NO. 7.

4. CIRCUITRY SHOWN ON THIS DIAGRAM IS FOR P-3C AIRCRAFT ONLY. P-3A & B AIRCRAFT WILL BE RETROFITTED WITH HEATED SIDE PANELS THROUGH INCORPORATION OF P-3 AIRFRAME CHANGE NO. 200. REFER TO THIS AIRFRAME CHANGE AND THE APPROPRIATE MAINTENANCE INSTRUCTION MANUAL FOR SIDE WINDSHIELD HEAT CIRCUITRY OF P-3A & B AIRCRAFT.

Figure 9. P-3C Side Windshield Defogging Circuit Schematic

Automatic operation of either side windshield heating system is initiated manually by actuation of the respective (PILOT or COPILOT) SIDE WINDSHIELD HEAT switch to the ON position. Control power at +28 volts DC is routed from the Extension Main DC Bus through a SIDE WHSHLD HT CONT circuit breaker located in the forward electrical load center and the switch to control unit connector pin C and to the coil of the side windshield overheat control relay. The energized overheat control relay, operating in series with the SIDE WHSHLD HT PWR circuit breaker located in the main electrical load center, routes 115-volt AC heater power from the Main AC Bus (Phase A for pilot's system and Phase C for copilot's system) to one contact of the side windshield power relay. When the side windshield panel temperature, as sensed by the wire-grid sensor, is below 122°F (upper limit of the control temperature range), sensor resistance is such that the bridge circuit is in balance, and this condition causes the switching amplifier to complete the control voltage circuit through the amplifier to control unit connector pin D. Circuits external to the control unit route control voltage from pin D to one contact of the side windshield load monitor relay.

The side windshield defogging load monitor relay which controls operation of the side windshield power relay is energized from the Main DC Bus through the SIDE WHSHLD DEFOG circuit breaker and the load monitor control relay both located in the main electrical load center. During side windshield heat system operation, the load monitor relay is de-energized; closed load monitor relay contacts complete the control voltage circuit to energize the side windshield defogging load monitor relay which, in turn, energizes both (left and right) side windshield power relays, each of which controls electrical heating of its respective side windshield panel. When energized, the power relay routes 115-volt AC heater power from the side windshield overheat control relay to the aft bus bar in the side windshield panel and panel heating is thereby initiated.

As side windshield panel temperature rises from application of heater power, the wire-grid sensor resistance also increases until, at the upper control temperature limit of approximately 122°F, the bridge circuit becomes unbalanced and signals the switching amplifier driver and start circuit to deactivate the switching amplifier and interrupt the control voltage thus de-energizing the side windshield power relay and shutting off the 115-volt AC heater power to the side windshield panel.

Upon removal of heater power, the side windshield panel cools and resistance of the wire-grid sensor decreases accordingly until, at the lower control temperature limit of approximately 116°F, the bridge circuit again becomes balanced, activating the control unit circuitry as explained previously to resume windshield heating.

Each side windshield panel contains a thermal switch which opens when panel temperature goes to 150°F (±8°F) to prevent the panel from overheating in the event of control system malfunction. When the thermal switch opens, the overheat control relay is de-energized, shutting off the 115-volt AC heater power through the side windshield power relay to the side windshield panel bus bar.

If either propellor deicing or empennage deicing (or both) are selected while only one aircraft generator is operating, the load monitor control relay is automatically energized, de-energizing the side windshield defogging load monitor relay. This, in turn, de-energizes both (left and right) side windshield power relays and thus removes power from the side windshield heating elements. The load monitor control relay remains energized until an additional generator comes "on line" or until the deicing loads are removed.

If the APU is the only operating generator, operation of the load monitor control relay is the same as during other one-generator operations *except* that as the aircraft ascends through 8,000 feet (±500 feet) additional systems, including the propellor and empennage deicing and the side windshield heating systems, are shut down *automatically* by the altitude automatic load monitoring system. Upon descent through 8,000 feet (±500 feet) a holding relay keeps the load monitor control relay energized by means of a latching circuit, consequently the systems that were automatically shut down remain in that state. "Normal" one-generator operation of the load monitoring system below 8,000 feet is resumed when the holding relay is de-energized to interrupt the latching circuit to the load monitor control relay by simultaneously placing both the propellor and empennage deice control switches in the OFF position momentarily.

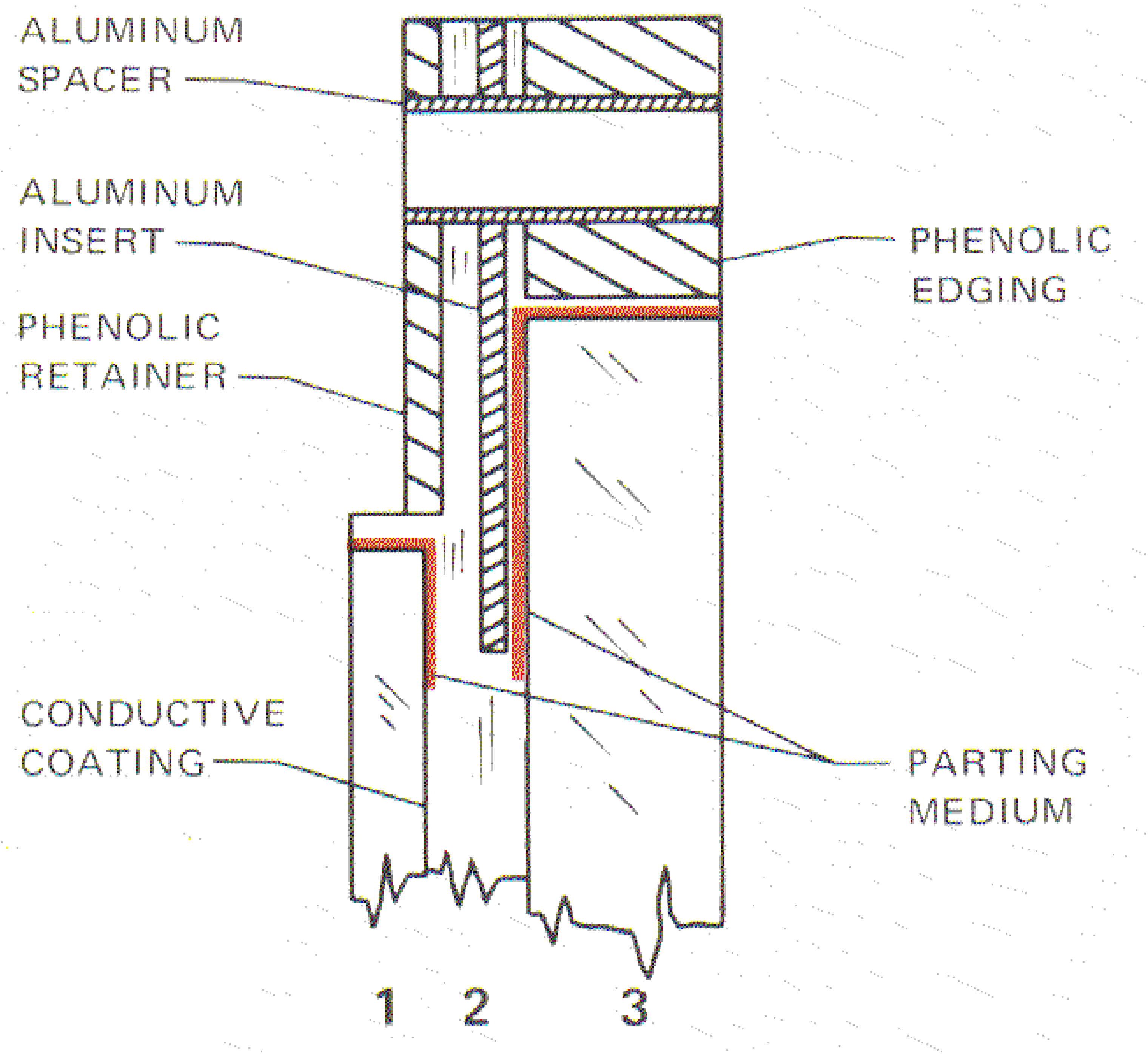
System circuitry for the P-3A and P-3B aircraft retrofitted for side windshield panel heating will be similar to that for the P-3C; however, priorities of the monitored aircraft electrical loads will differ.

WINDSHIELD STRUCTURAL INTEGRITY

Environmental testing of structural components is an essential part of airplane development, and the windshield – a particularly vulnerable item – has always received a great deal of attention in this regard. Generally, windshield testing may be conveniently divided into pressurization tests which are carried out under laboratory conditions, and birdproofing tests during which missiles are fired at windshield panels.

When the P-3 Orion was derived from the Lockheed L-188 Electra commercial airliner, the windshield was redesigned to improve flight station visibility, a characteristic which was already considered excellent when compared with that of other contemporary aircraft. Obviously, the changes in windshield configuration demanded a separate series of pressurization tests on the panels, but after the Navy and Lockheed reviewed the nature of these design changes in light of the basic similarity between the P-3 and L-188 windshield installations, duplication of the already existing L-188 birdproofing test data (corroborated by windshield operational data from commercial airlines) was deemed unwarranted. Thus, birdproofing test data presented in this article, although performed upon L-188 panels, should also be considered representative of P-3 panels.

Figure 10. Section through YP3V-1 Test Panel



1 OUTER GLASS PLY (3/16 INCH)
2 VINYL PLY (APPROX. 1/4 INCH)
3 MAIN GLASS PLY (1/2 INCH)

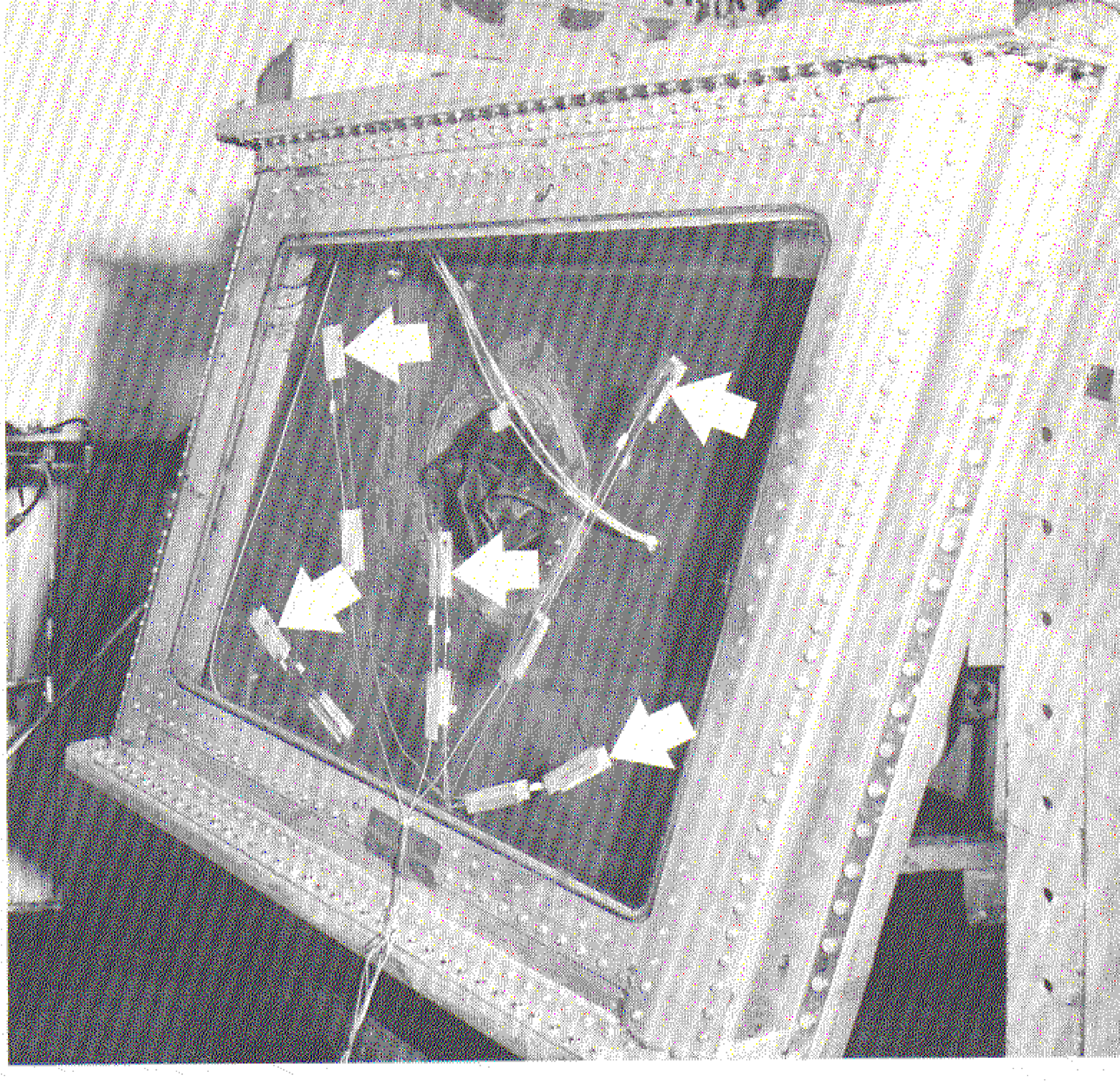


Figure 11. Test Assembly with Windshield Panel Installed. Arrows indicate back-to-back thermocouples on panel surfaces.

PRESSURIZATION TESTS Of the tests conducted on P-3 windshield panels, the series performed on the YP3V-1 pilot's panel may be considered as typical. It should be noted that this particular panel did not have the additional nonstructural glass and vinyl fragmentation shield plies added later through incorporation of P-3 Airframe Change No. 58, but otherwise it was structurally similar to present production units (see Figure 10).

The test panel was mounted in a pressure-tight box, the sides of which provided support on the four edges of the panel to simulate the flight station window frame installation (see Figure 11).

Thermocouples were installed in back-to-back pairs on both panel surfaces as shown in the figure. Temperature and pressure test parameters were based on a maximum flight altitude of 25,000 feet with the cabin pressure equivalent of 8,000 feet and a maximum service pressure differential of 5.46 psi (11.1 inches Hg). Ambient outside air temperature was considered to be -65°F and cabin air +70°F. Pressure differentials employed during the test program were 16.38 psi for pressure proof and creep tests, and from zero to 11.9 psi (slightly more than twice maximum normal operating pressure) for the pressure cycling tests.

First in the pressurization test series were proof pressure tests to demonstrate that the panel installation could withstand operating pressure differentials. Although the maximum anticipated operating pressure differential was 5.46 psi, this series of tests demonstrated that the panel could withstand 16.38 psi (three times maximum normal operating pressure).

The proof tests were conducted at 81°F room temperature with the panel faces heated to 100°F. As the tests progressed, the pressure differential across the panel was stabilized at several levels where deflection readings of the panel outer face were taken. The maximum outward deflection of 0.434 inch was measured at the center of the panel when the pressure differential was increased to 16.38 psi. Upon completion of the proof tests the panel was examined thoroughly and found to be structurally sound.

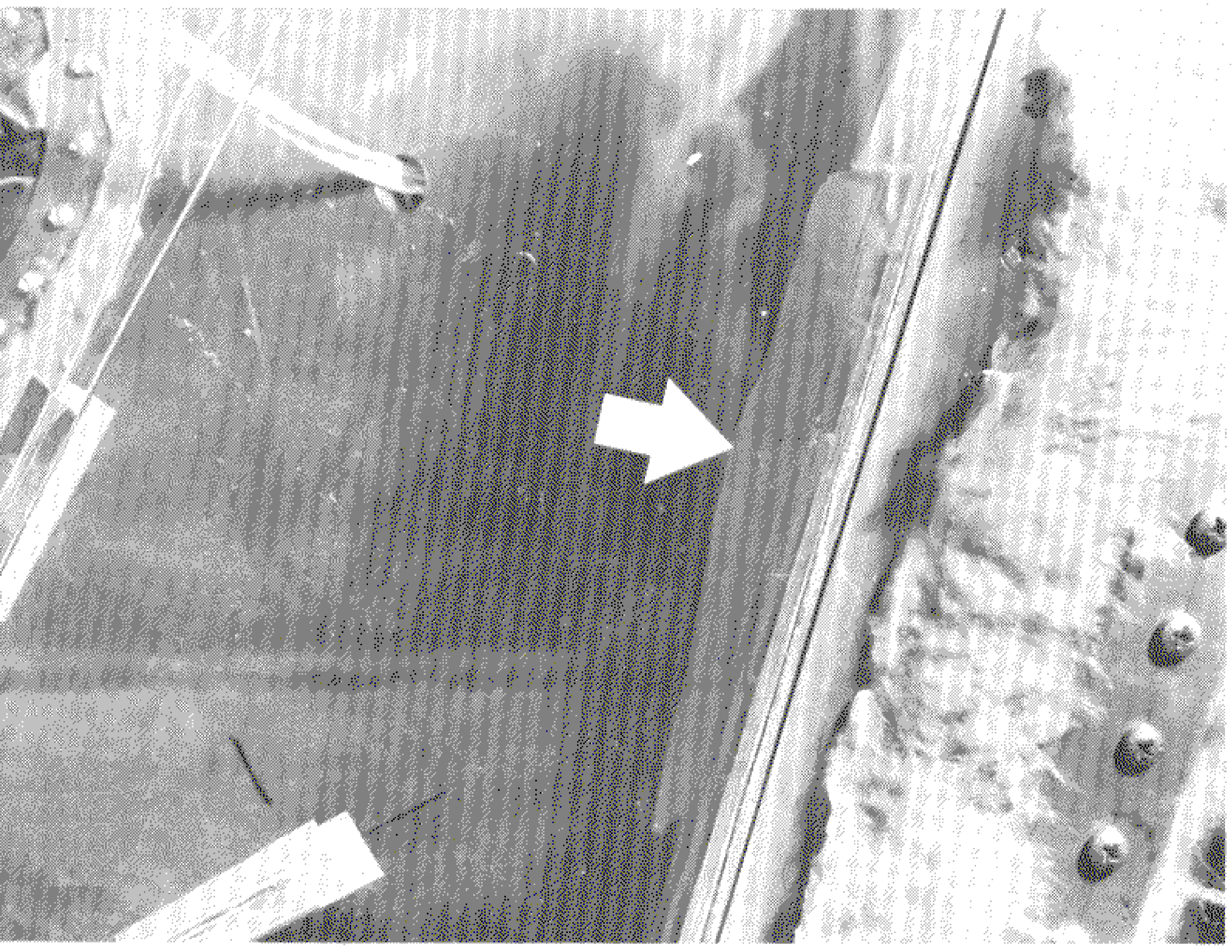


Figure 12. Delamination at Outer Ply-to-Vinyl Interface

Next, the panel was subjected to a series of pressure cycling fatigue tests. During these tests the pressure differential was raised from zero to 11.9 psi, then returned to zero again approximately 600 to 700 times per hour at temperatures representative of normal and extreme service conditions. The tests were stopped periodically to permit close inspection of the panel and to operationally check its conductive coating. A total of 20,000 pressure loading cycles were applied to the test panel.

After 4,000 cycles, slight delamination (see Figure 12) between the outer glass ply and the vinyl interlayer was observed around the periphery of the panel; peripheral delamination of a lesser degree also occurred between the inner (structural) glass ply and the vinyl ply. During the remainder of the pressure cycling tests there was no noticeable increase in delamination. The average extent of delamination between the outer glass ply and the vinyl ply was 0.4 inch from the parting medium, well within the allowable delamination limit of 2 inches all around the panel edge. A few small localized spots of delamination no larger than 1/4-inch were noted between the inner glass ply and vinyl at the panel edge, but these also fell well within the same delamination limit. Furthermore, it was observed that these delaminations had no effect on panel windshield heat operation, as was demonstrated by several power applications and frequent measurements of conductive coating resistance during the tests.

The last of the pressurization test series was the pressure creep test. The plan was to pressurize the test panel at 16.38 psi for four hours to determine the ability of the panel to withstand pressure loading for an extended period. Shortly after the start of the pressure creep test a large area of the vinyl ply separated from the inner (structural) glass ply, and within 9 minutes the outer glass ply fractured and the vinyl-outer glass ply combination bulged outward over the area shown in Figure 13. Despite this partial failure the inner structural glass ply remained intact and successfully withstood the full 16.38 psi for the four-hour test requirement.

The Lockheed research department evaluated the test results and concluded that the structural soundness of the windshield panel design had been successfully demonstrated, pointing out that the test panel withstood a total of 20,000 cyclic pressure loadings to 11.9 psi (more than twice maximum operating pressure) at high and low temperature extremes (+100°F and -65°F) as well as more representative service temperatures. This number of pressure loadings represented an estimated twenty years of aircraft operation, and the applied pressure loadings were substantially greater than any that will ever be encountered in actual service. Although some delamination occurred between the outer glass ply and the vinyl interlayer, it was considered to be well within acceptable limits and did not affect the electrical continuity or proper operation of the windshield heat conductive coating. Finally, while a partial failure of the test panel did occur, the panel still maintained three times maximum normal operating pressure for the full four-hour test period. Furthermore, the failure occurred during the *final* test of what was felt to be a very severe test program.

Similar tests were also performed on the acrylic windshield side panels and skylights. As was expected, panel deflections during the proof pressure tests were somewhat greater (particularly at higher temperatures) than those of laminated glass panels due to greater elasticity of the acrylic panels. After the panels were subjected to pressure cycling and pressure creep tests, examination revealed that they had withstood the complete test program without apparent effect.

When heated windshield side panels were scheduled to become the standard production installation with the introduction of the P-3C, further tests were required. During this test program the panel was heated to minimum and maximum operating temperatures and subjected to pressure cycling of 0 to 14.1 psi; next, protective features of the side panel heat control system were disabled and heating power was applied to the panel until the conductive heating film failed; this was followed by more pressure cycling tests. Finally, two pressure creep tests were performed to complete the test program. During the first creep test the panel installation maintained a pressure differential of 21.1 psi for four hours at -40°F, and during the second the same pressure differential was maintained for another four hours at +125°F. Even though minor delaminations occurred early in the test series and a large delamination occurred during the high temperature creep test, the panel was examined thoroughly at the conclusion of the test program and still found to be structurally sound (see Figure 14).

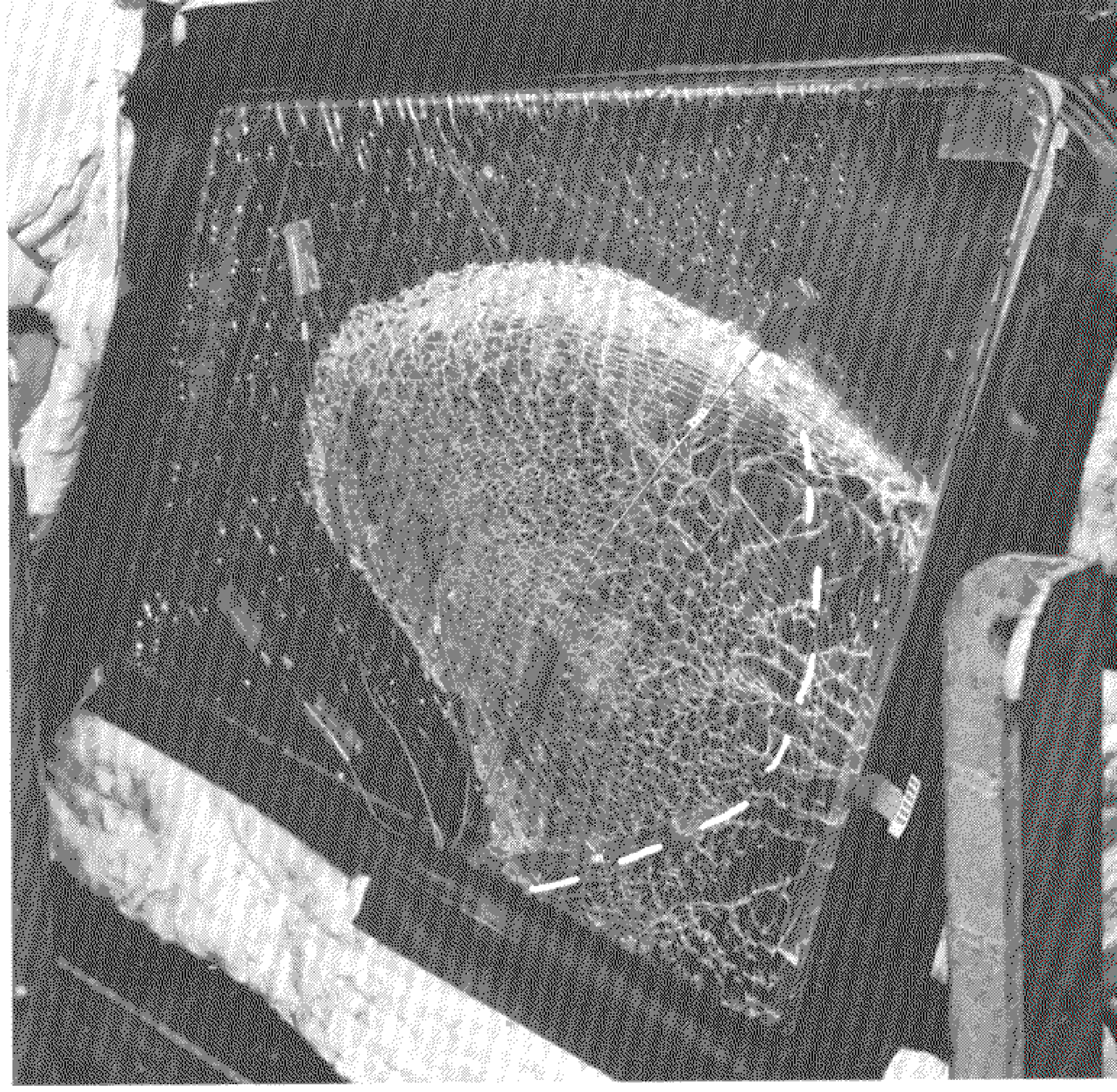
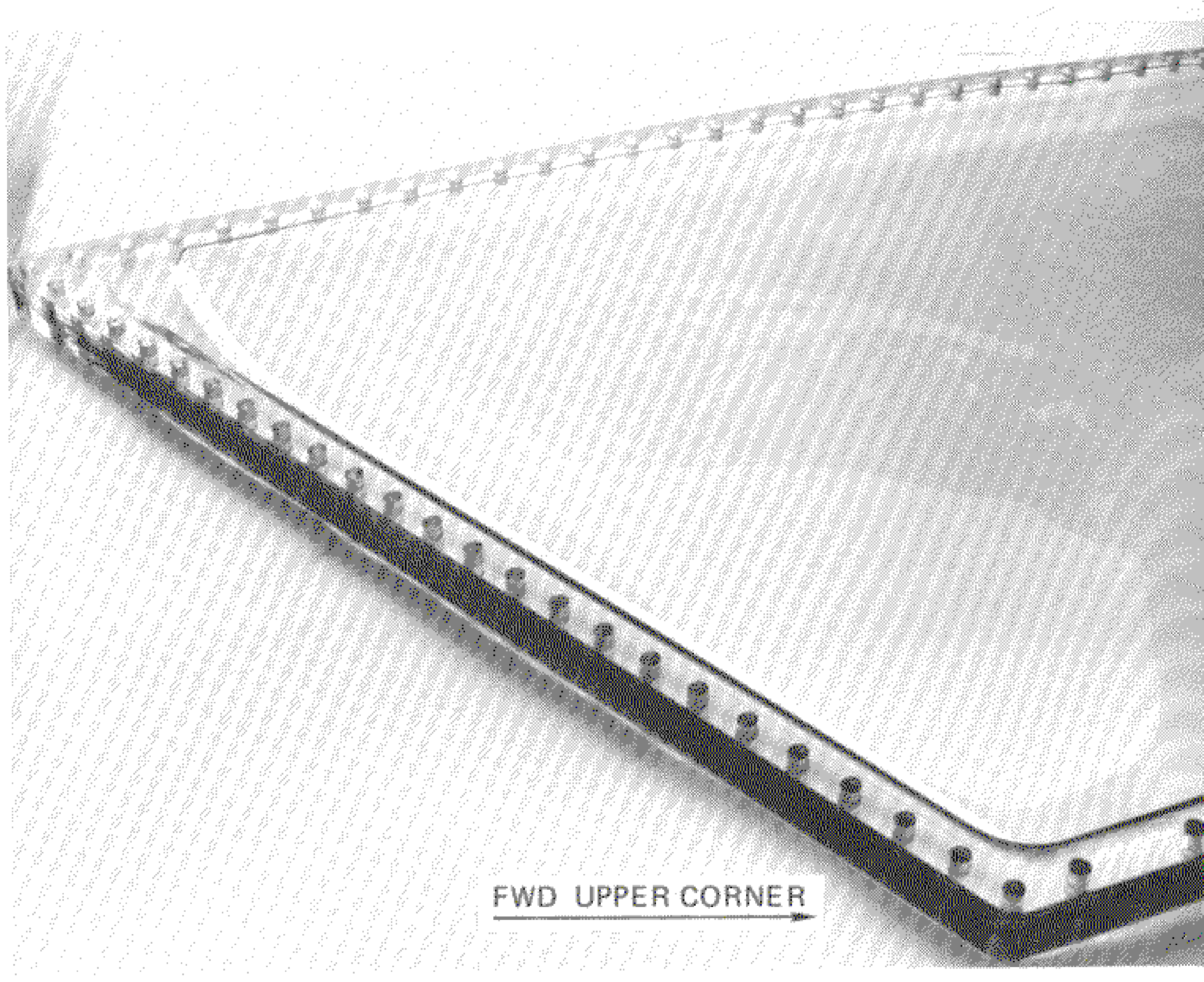


Figure 13. View of YP3V-1 Test Panel following 4-hour Creep Test at 16.38 psi. Vinyl-to-Main ply delamination occurred to the right of the dashed line; a thin layer of glass flaked off the main ply and adhered to the vinyl to the left of the dashed line.

Figure 14. Delamination of Heated Windshield Side Panel following High Temperature Creep Test

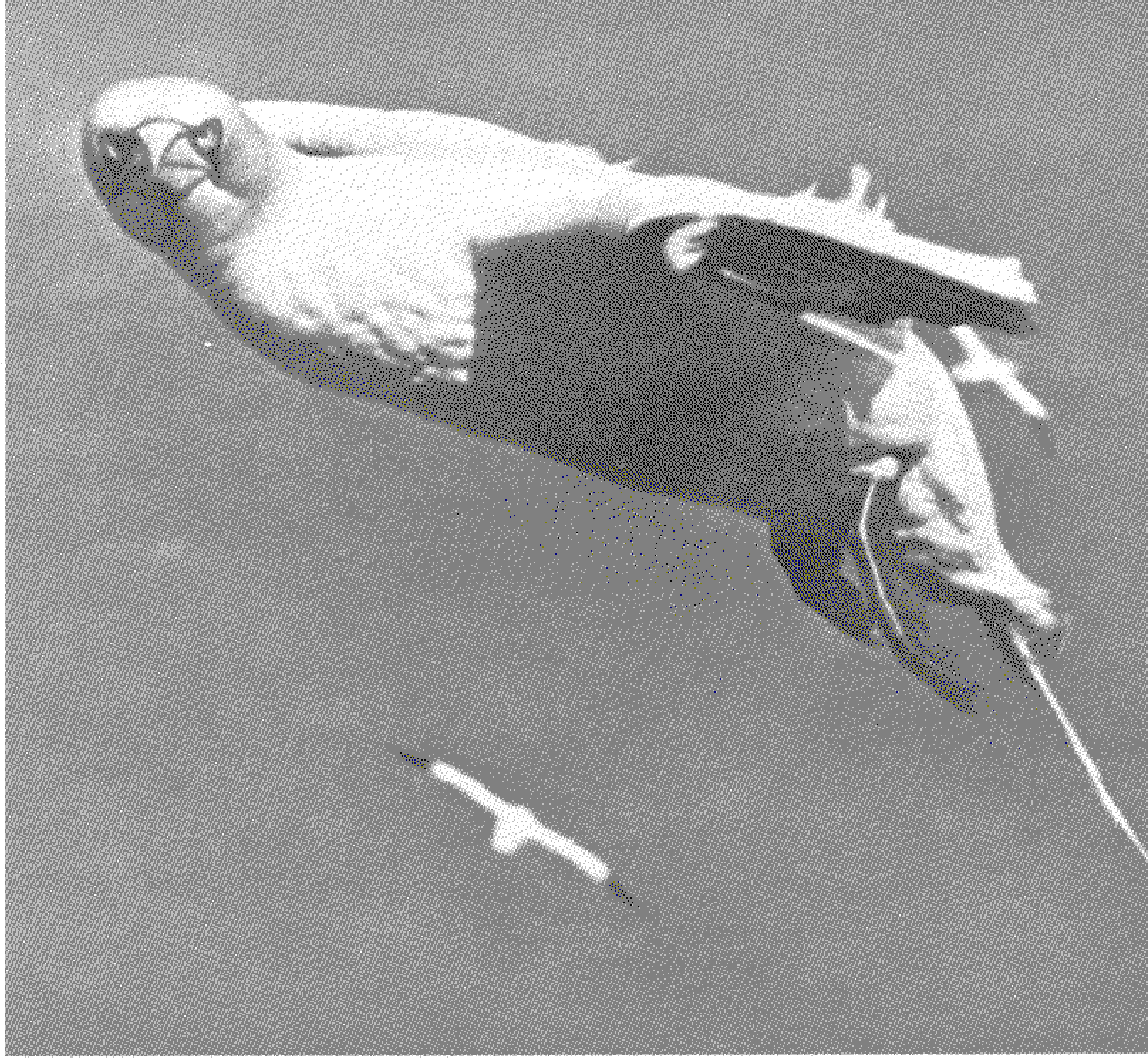


BIRD PROOFING Since most naval air stations are situated near the sea and the majority of naval flying operations are conducted near sea level, it is not surprising that naval aircraft experience a great number of bird strikes. At this point it might be interesting to review some bird strike statistics since they have a bearing on birdproof windshield design requirements, as well as on aircraft operational limitations.

Bird Strike Statistics Nearly twenty years ago an extensive survey revealed that over a twelve-month period some 300 bird strikes occurred during commercial operations in the United States – an average of almost one per day. Of the bird strikes reported in this survey, 89 or about 30 percent struck the windshields. In another survey conducted from August 1963 to January 1966, approximately 1,100 bird strikes were recorded during air transport operations, almost 23 percent of which occurred on windshields. A survey conducted by the U.S. Navy for the period 1966-1968 revealed that P-3 Orion aircraft experienced 47 bird strikes, only one of which involved the windshield. Although the results of this latter survey *could* be construed to indicate that P-3 windshields are not susceptible to bird strikes, it is more likely that they merely reflect a great deal of good fortune.

Statistics compiled several years ago indicated that in North and South America by far the greatest proportion of reported bird strikes involved species of birds which varied in weight from one to six pounds. Species included in this "medium bird" group are ducks, gulls, and buzzards. Pigeons, larks, robins, and sparrows fall into a "small bird" group which includes birds weighing less than one pound and which present little hazard to aircraft unless a migratory flock is intercepted. About 4 percent of the reported strikes involved birds heavier than six pounds. In this "large bird" group, eagles and geese can weigh as much as thirteen pounds while swans frequently exceed thirty pounds in weight. More recent data showed that of the bird strikes that were reported, about 37 percent were estimated as small birds, 30 percent as medium birds, 6.5 percent as large birds, and in 25 percent of the instances an estimate of the weight of the bird was not given.

Statistics show that approximately two-thirds of all bird collisions occur less than 2,000 feet above the local ground elevation, and about 95 percent occur at altitudes of less than 6,000 feet. Strikes above 10,000 feet are comparatively rare occurrences, but they tend to involve larger birds with the attendant increased threat to aircraft and crews. At least one bird strike was recorded at 25,000 feet. Ducks and geese have been reported at 20,000 feet, and a mallard duck was reported to have performed admirably on a treadmill in an altitude chamber at 30,000 feet.


SHELL AVIATION NEWS

Birdproofing Requirements During the years following World War II it became apparent that as aircraft operating speeds increased, aircraft windshields would also require more effective birdproof characteristics. Based to a large extent on bird strike reports, a civil airworthiness requirement was devised and stated essentially that the windshield and supporting structure should withstand the impact of a four-pound bird striking the windshield with a velocity equal to the V_{no} (Maximum Normal Operating) speed of the aircraft without penetration. The Lockheed L-188 Electra windshield installation complied with these requirements, and soon afterward the same philosophy was applied to the design of the P-3 windshield.

The parameters laid down in this requirement were governed to a certain extent by the state-of-the-art in windshield design, for it is not practicable to produce a windshield that can withstand all conceivable bird strikes under the most adverse conditions. However, according to the laws of probability, it would be unusual for an airplane complying with this requirement to be seriously compromised by a bird strike. Throughout the last twenty years this has been confirmed by operating experience.

BIRD MASS	BIRD DIMENSION	FOOT-POUND FORCE AT VELOCITY SHOWN (AIRCRAFT VELOCITY IN MPH)						
LB.	INCHES	(50)	(100)	(200)	(300)	(400)	(500)	(600)
1	3	332	1330	5320	12,000	21,000	33,000	48,000
2	4	500	2000	8000	18,000	32,000	50,000	72,000
4	5	800	3200	12,800	28,800	51,200	80,000	115,200
8	6.25	1280	5110	20,400	46,000	81,600	128,000	184,000
16	8	2000	8000	32,000	72,000	128,000	200,000	288,000

SHELL AVIATION NEWS

Table 2. Bird Impact Forces

A significant factor in windshield birdproofing test requirements is the test speed (V_{no}). As previously mentioned, the majority of bird strikes occur at the lower altitudes, which represent the climb and descent regimes of ordinary transport aircraft operation and a great deal more time in a patrol mission profile. The much higher V_{no} speeds of large turboprop and pure jet aircraft at lower altitudes presented quite a problem to the windshield designer, since the state-of-the-art had not yet progressed to the point where improved measures against bird strikes could be incorporated on these aircraft without making unacceptable compromises in visibility and weight. It followed that most of these turbine aircraft have had to accept certain operational restrictions to maintain the required degree of resistance to bird impacts. On the L-188 Electra (and subsequently the P-3 Orion), for example, forward windshield heat has to be on at all times to maintain the windshield in its required state of "birdproofness" under maximum operational conditions, whereas on the slower and larger piston-engined aircraft this measure has been left to the operator's discretion.

Subsequent birdproofing tests on L-188 panels permitted the windshield heat ruling to be relaxed on Electra aircraft so that flights with a "cold" windshield could be made with some operational restrictions. These modified procedures were also adopted for P-3 aircraft (see the "Operational Procedures" section).

The magnitude of bird impact forces that a windshield panel vinyl layer must withstand is reflected by Table 2 which was published in a recent issue of the *Shell Aviation News*. The data in this table are based on the assumption that the bird is accelerated to the speed of the aircraft in the time that the aircraft travels a distance equal to an arbitrarily selected "effective bird dimension." The impact force calculations were based on the premise that the aircraft structure did not yield; if the structure were to deform one "bird dimension" the forces would be one-half those shown. The figures in this table relate to hypothetical bird carcasses with no stiffness. In a real case the impact forces would be greater, because any tendency of the carcass *not* to spread would result in the acceleration taking place in a shorter distance than one "bird dimension."

Since impact energy varies directly with the square of impact speed, substantial gains can be made in reducing the bird strike hazard with relatively slight reductions in speed. This expedient might well be considered by flight crews when operating in localities where the larger species of birds are known to be numerous. For example, a reduction in speed to 70 percent of V_{no}, will enable the windshield to absorb the impact of at least an 8-pound vulture just as effectively as the windshield resisted the impact of a 4-pound bird at V_{no} speed under test conditions.

Birdproofing Tests The windshield installation on the L-188 Electra was subjected to FAA certification tests wherein 4-pound birds were shot against test panels mounted in fixtures which simulated the windshield installation. Based on the similarity of the L-188 and P-3 windshield installations, the test results were also considered applicable to

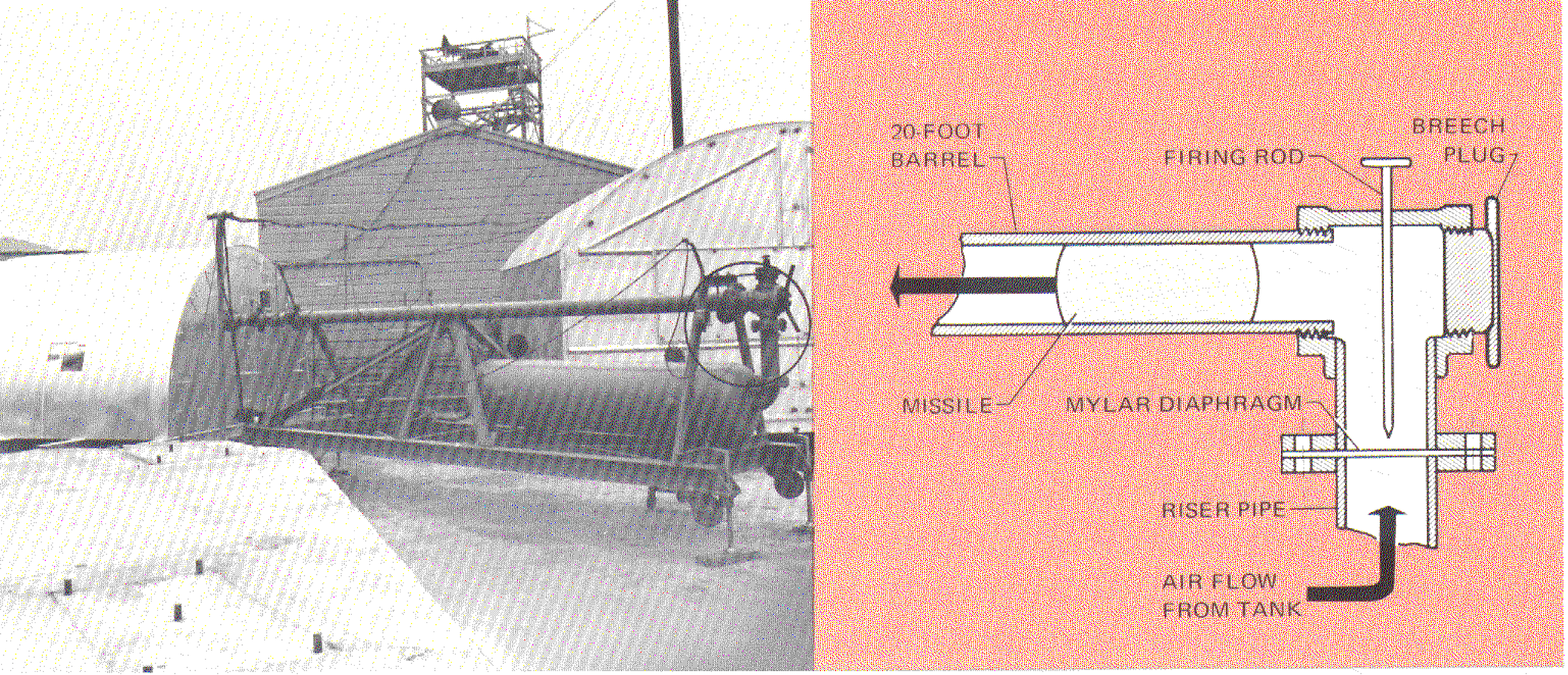


Figure 15. Facilities used during Birdproofing Tests on L-188 Electra Panels Showing Details of Gun Breech and Firing Mechanism

Orion aircraft. Some photographs related to typical tests are shown in the accompanying illustrations.

The gun (see Figure 15) used in these tests had a barrel 20 feet long with a honed bore five inches in diameter. The missiles were prepared, weighed, and loaded into the gun breech. A pressure vessel, connected to the breech by a riser pipe containing a pressure release mechanism, was charged with compressed air at a pressure (100 to 150 psi) that would produce the desired missile velocity. When the Mylar diaphragm was ruptured by the firing rod, air pressure was released suddenly into the gun to propel the missile against the test panel. The bird velocity in each test was determined just prior to impact by means of two photoelectric cells placed 24 inches apart near the muzzle. Effects of the impacts were photographed with a high-speed (3,000 frames per second) motion picture camera.

Figures 15 through 20 showing the gun, test enclosure, and some test results are self-explanatory with the accompanying captions. It should be noted that some of these tests were conducted with early experimental panels, the cross sections of which resembled the conventional three-ply birdproof panel configuration. Due to a combination of the size of the L-188 front panels and the high impact speeds involved, it was found that the stretched polyvinyl butyral ply did not retain all fragments of the shattered inner glass, some of which entered into the space behind the windshield with considerable force. This difficulty was eliminated by the addition of thin vinyl and glass safety plies on the inside of the panel, making five plies in all, which helped to retain the larger fragments of the thick structural glass. Early P-3A aircraft were not production equipped with windshield installations featuring these two additional plies, however these aircraft were modified to the current configuration through incorporation of P-3 Airframe Change No. 58 which replaced the existing forward panels with five-ply panels.

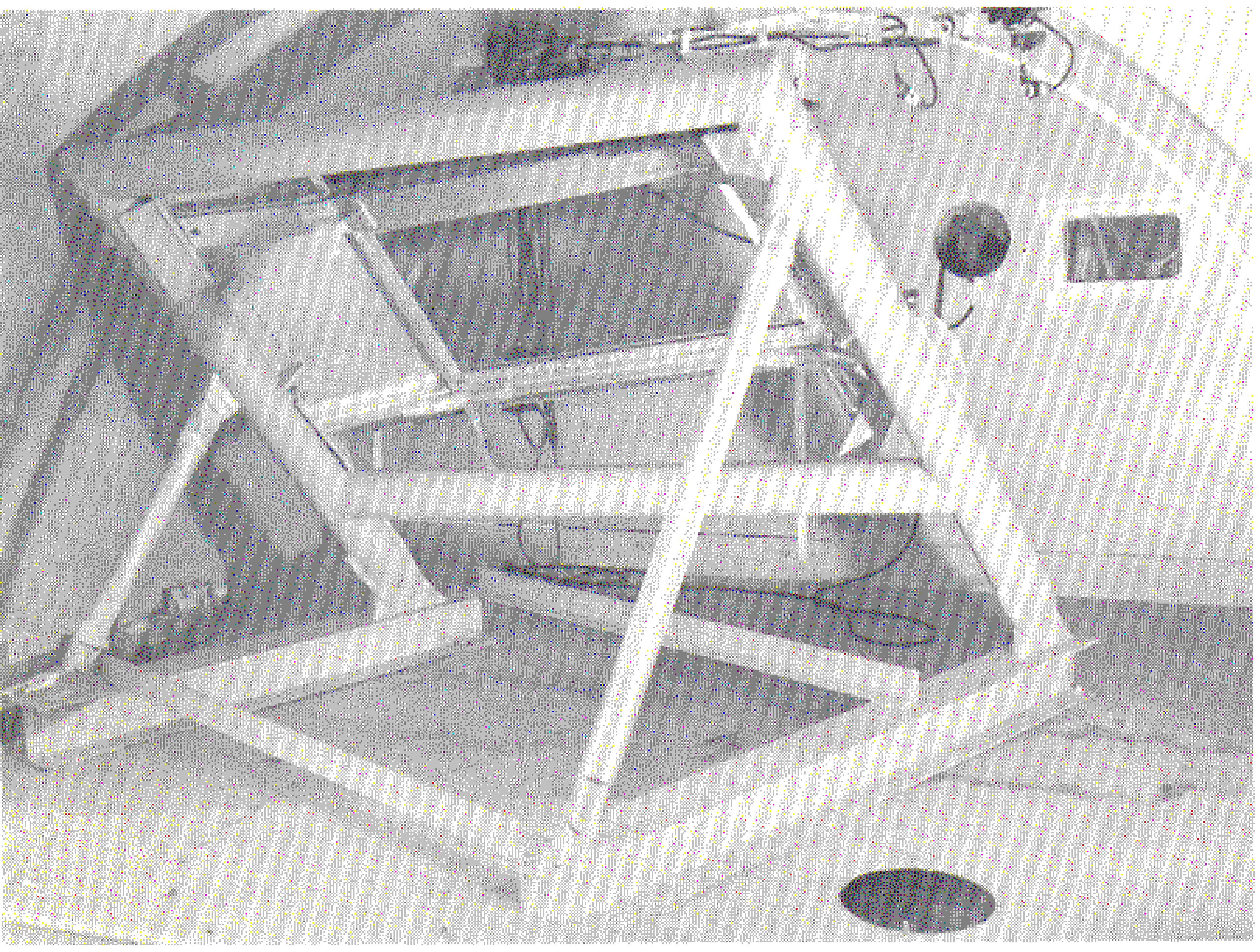


Figure 16. View Inside Test Enclosure Showing an L-188 Electra Pilot's Forward Windshield Panel Installed in Test Fixture

The ability of birdproof windshield assemblies to withstand the impact of bird strikes while still maintaining cabin pressurization integrity has been demonstrated by in-service incidents. A Super Constellation was making a landing approach when vulture weighing probably 12 or 13 pounds struck the 3-ply center windshield panel assembly. Both inner and outer glass plies shattered. The vinyl ply bulged inward approximately three inches, but did not rupture or pull away from the structure. The windshield heat had been selected to LOW for some time before the collision.

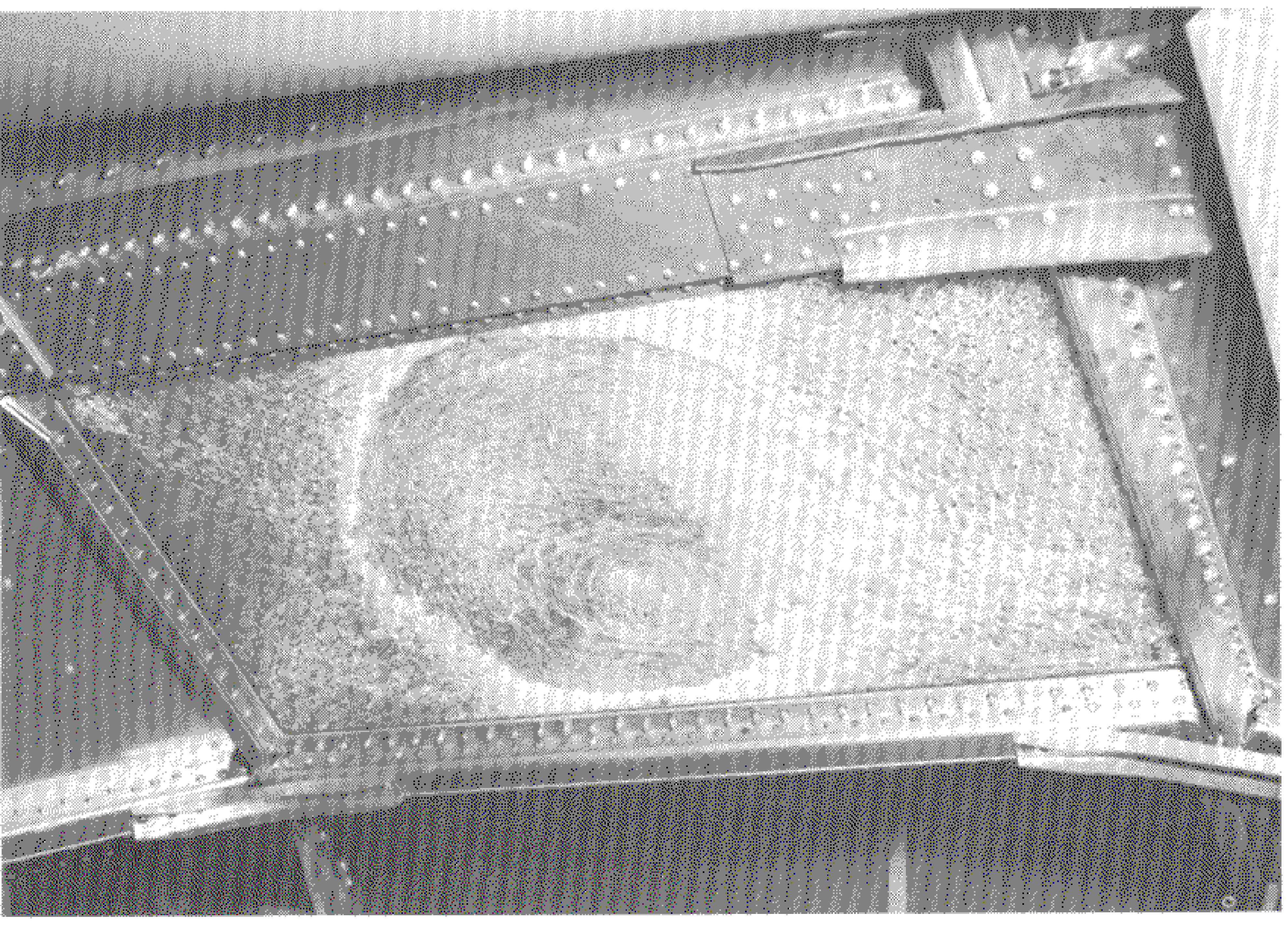


Figure 17. Heated Windshield Tests. Aft view of an experimental Electra 3-ply windshield panel after impact of a 4-pound bird at 380 knots (vinyl temperature 90°F to 100°F). Note that glass fragments from the center of the panel's main ply were not retained by the vinyl ply.

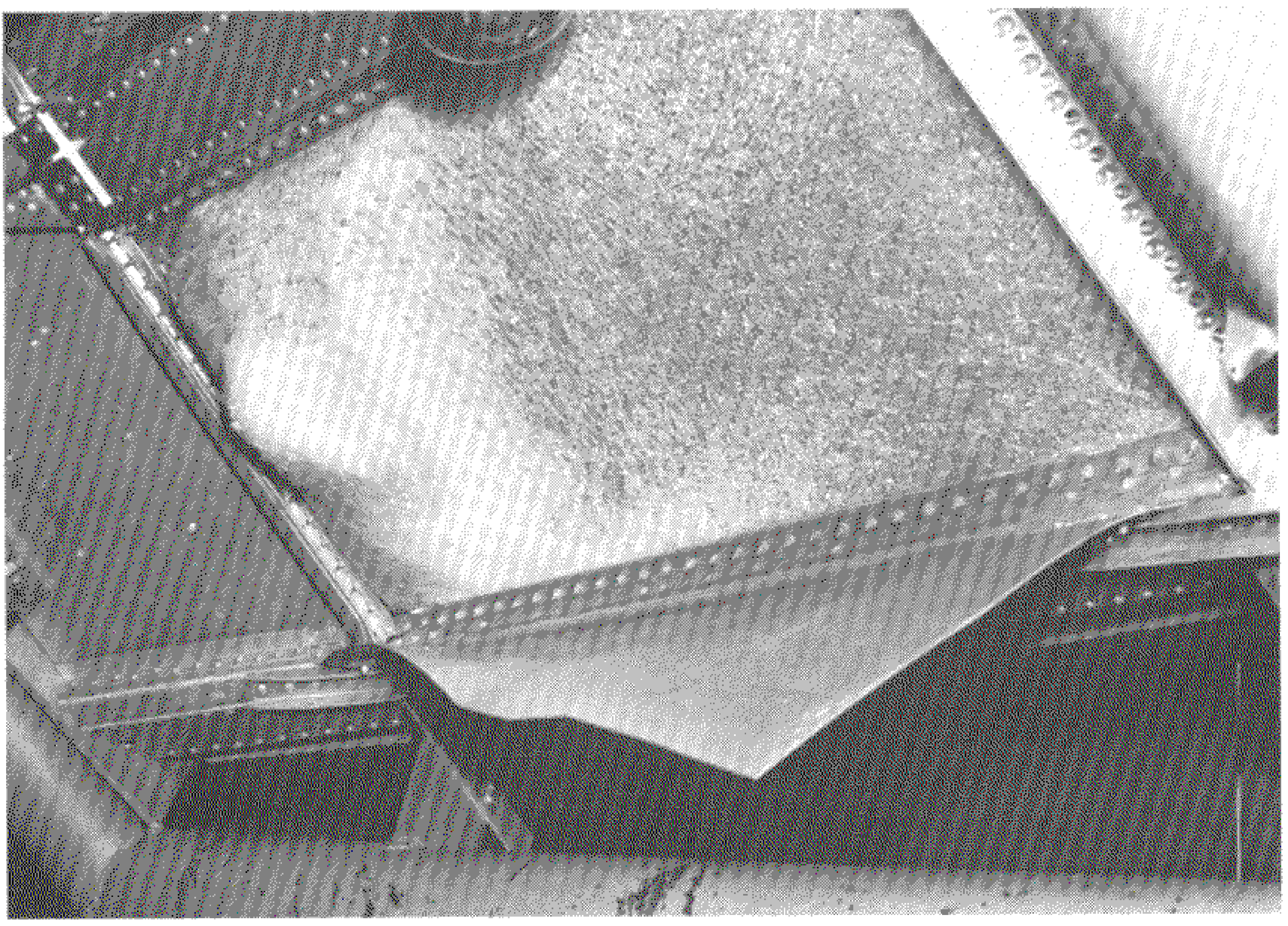


Figure 18. Heated Windshield Tests. Aft view of production-type Electra 5-ply windshield panel after impact of a 4-pound bird at 350 knots (vinyl temperature 90°F to 100°F). Note that the additional vinyl and glass protective plies retained all of the main ply glass fragments.

Figure 19. Cold Windshield Tests. Front view of production-type Electra 5-ply windshield panel after impact of a 4-pound bird at 256 knots (vinyl temperature 22°F). Note how cracks radiate from point of impact at top right-hand corner.

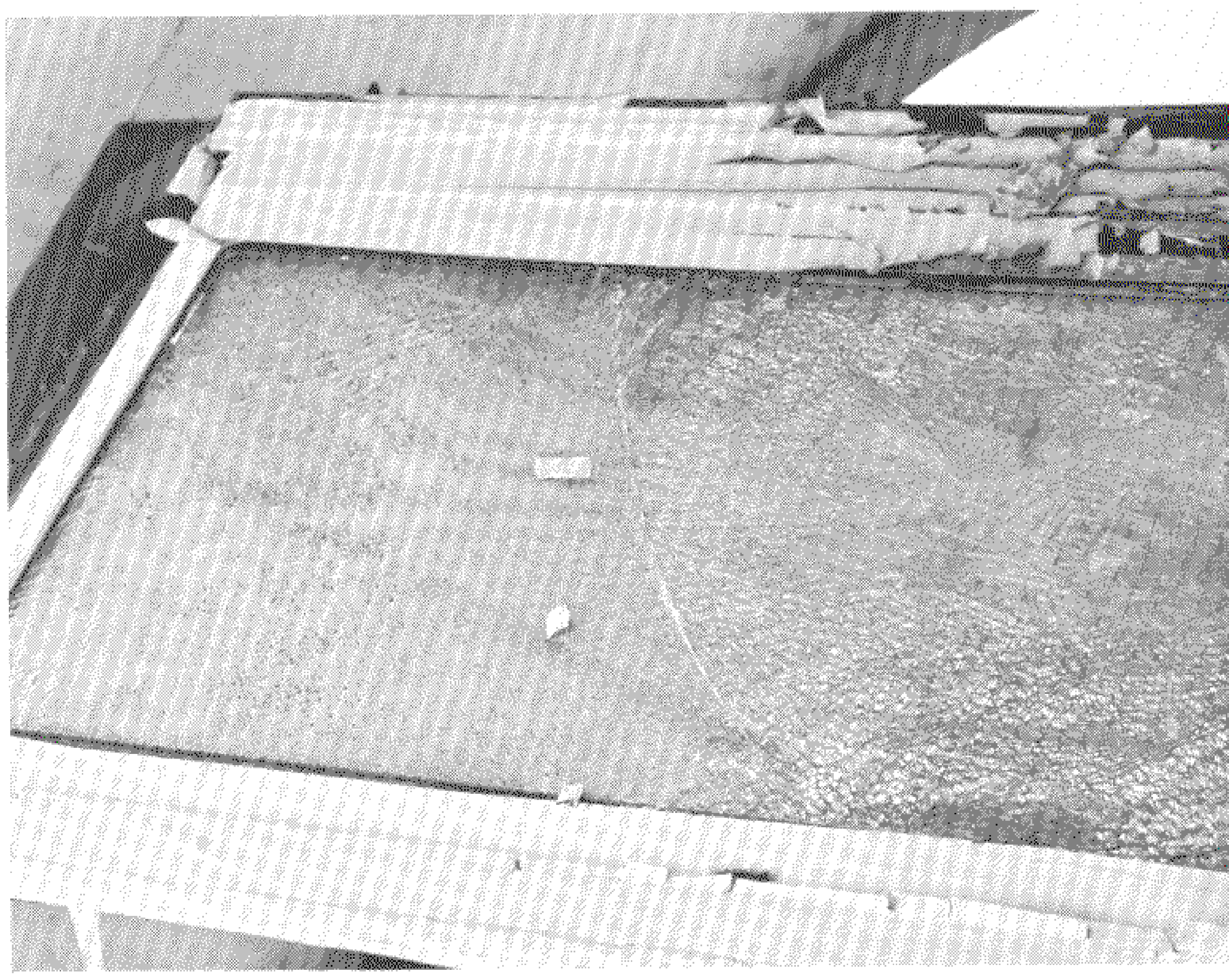


Figure 20. Cold Windshield Tests. Front view of production-type Electra 5-ply windshield panel after impact of a 4-pound bird at 251 knots (vinyl temperature 46°F). All glass plies cracked, but vinyl was undamaged. Note how, compared with Figure 19, this panel is opaque due to cracking of the fully-tempered main glass ply.

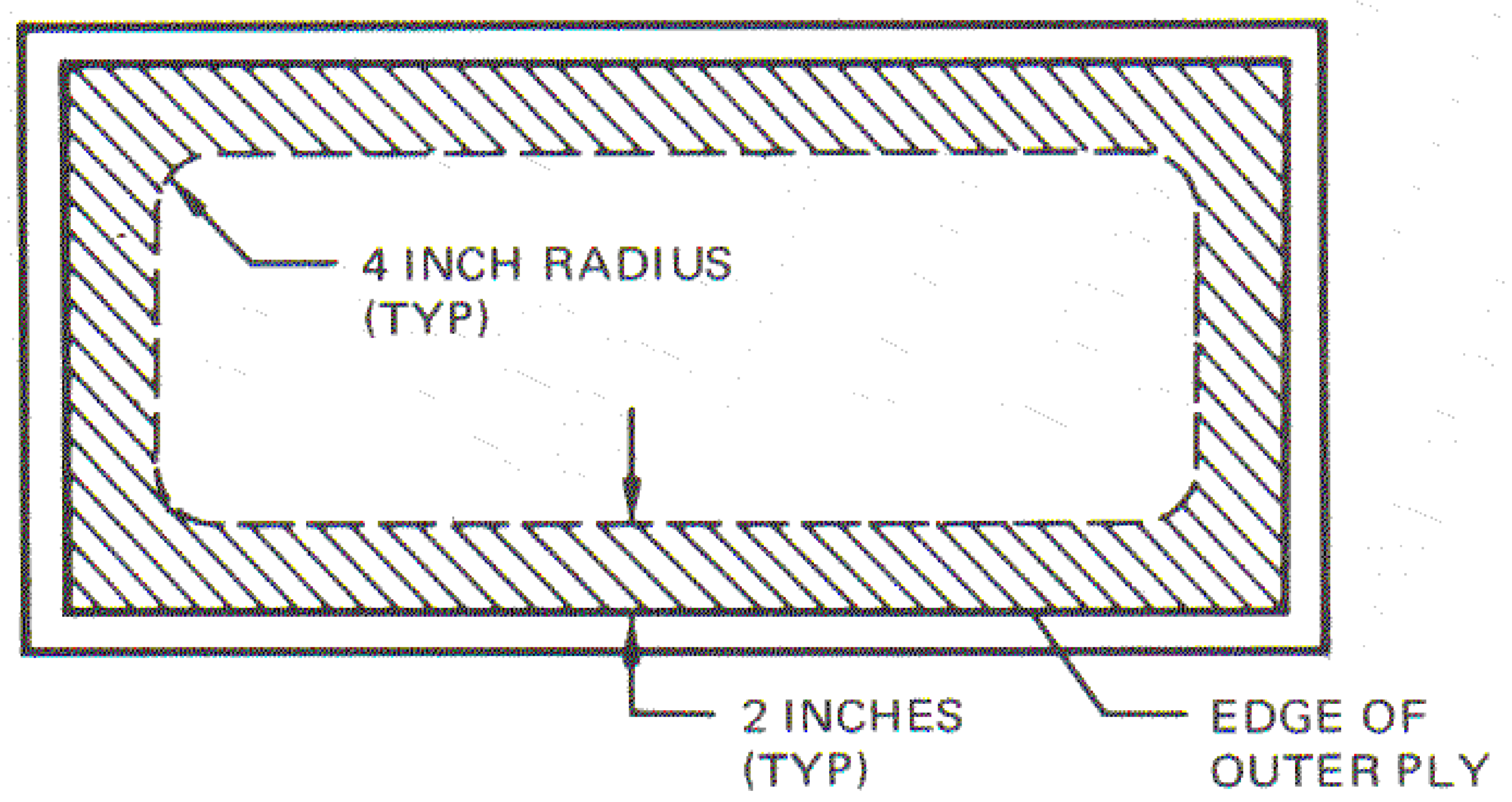
SERVICE PROBLEMS

Many of the problems associated with windshields are difficult to explain fully without previous detailed examination of panel construction, physical properties of the components, electric circuitry, etc., of each windshield system. Therefore, this section has been placed after these discussions so that greater advantage can be realized from the background material.

DELAMINATION Although undesirable, some separation of the panel plies is not harmful structurally and can be allowed within the limits shown in Figure 21, provided that it does not unduly affect the optical qualities of the panel.

There are many factors acting on a panel which tend to produce delamination. The most obvious (and one that is unavoidable) is pressurization loads on the inside surface of the panel, which have their maximum effect at the edges of the bond between the outer glass (or acrylic) ply and the adjacent interlayer. However, it is the physical properties of a vinyl interlayer in relation to those of glass which are the basis for most of the delamination and other service problems. Figure 22 illustrates delamination in a windshield panel along with other damage.

Figure 21. Laminated Glass Windshield Panel Delamination Limits. Delamination permitted within shaded area.



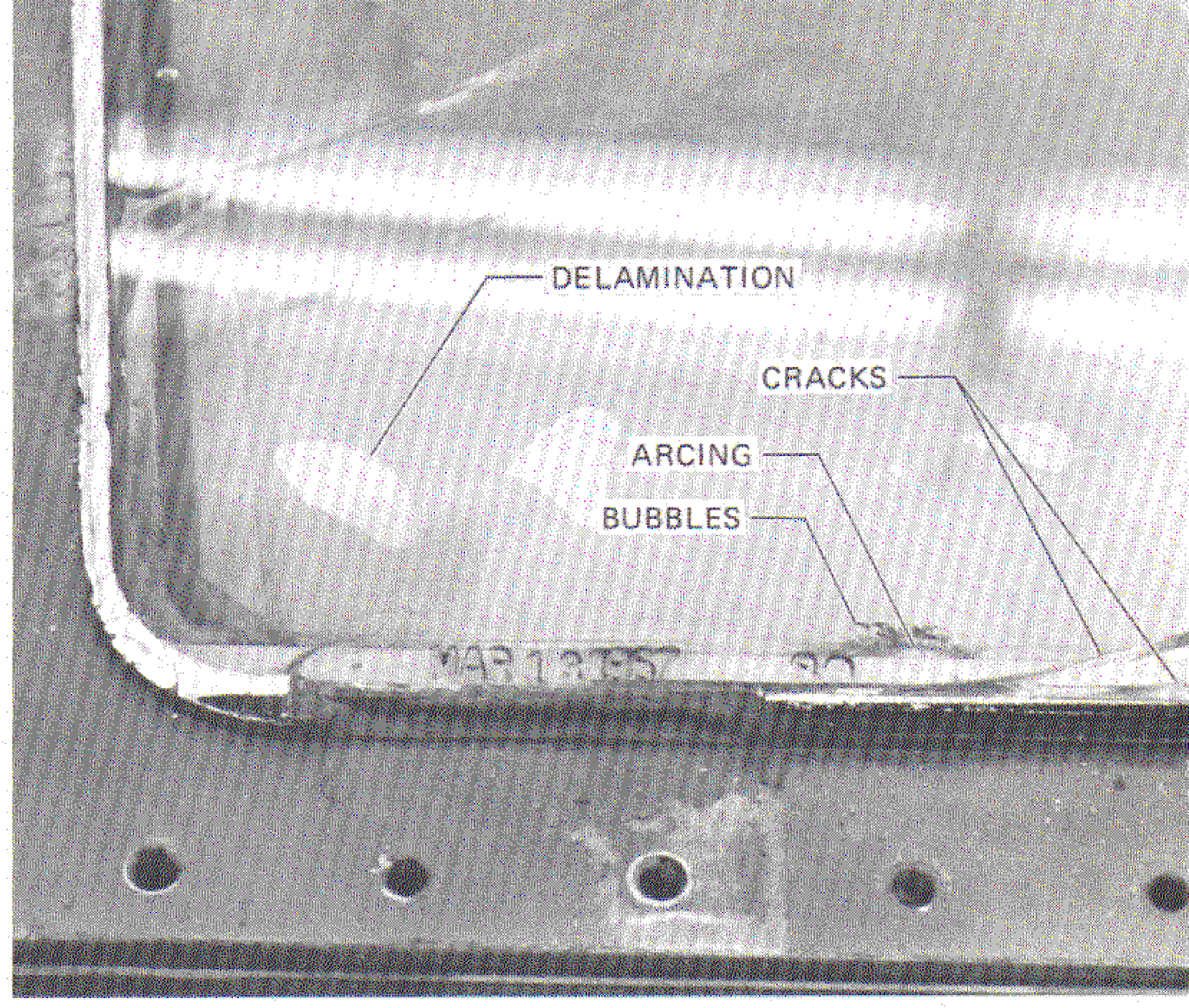


Figure 22. Forward Windshield Panel Damage Delamination, Arcing, Bubbles, and Cracks

As can be seen in Figure 6 the conductive coating or heating element is located between the outer glass and vinyl plies where, with the addition of the parting medium, it is both protected and electrically insulated. Electrical heating applied between these two substances would present no problems were it not for the fact that vinyl has a coefficient of expansion approximately 10 times greater than that of glass. At temperatures where the vinyl is in a plastic or semiplastic state, relative expansion of the vinyl and glass presents no difficulties, but at extremely low temperatures where the vinyl hardens the shrinkage difference between vinyl and glass can cause what is sometimes referred to as "cold delamination." This is no more than a separation of the plies, but it can be distinguished from delamination due to other causes.

For instance, at the interface between the outer glass ply with the conductive coating and the adjacent ply of vinyl, the vinyl-to-conductive coating bond increases in strength at low temperatures so that separation or cold delamination is more apt to occur between the conductive coating and the glass rather than between the conductive coating and the vinyl. Another distinguishing feature of damage from extreme cold is that in addition to delamination, the strength of the bond is sufficient to actually pull conchoidal-shaped chips of glass from the surfaces of the glass plies that are not protected by the parting medium. Such damage to the glass ply with the conductive coating can cause arcing and local overheating when the panel is again heated.

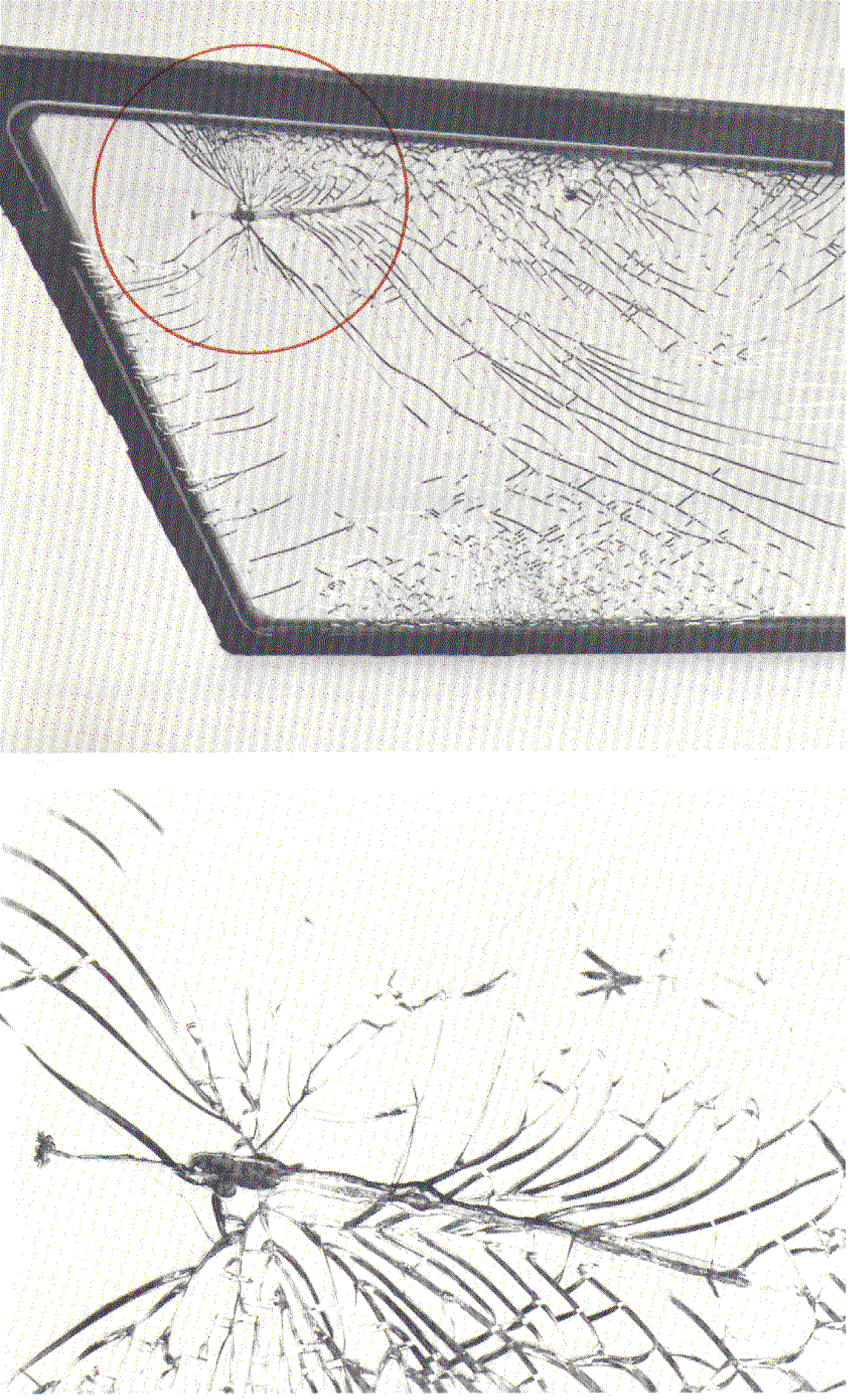


Figure 23. Forward Windshield Panel Damage -- Arcing and Cracked Outer Glass Ply. Note overheat damage to vinyl ply

It should be pointed out that although delamination can occur without any contributing factor other than extreme cold, such low temperatures are unlikely to be encountered in service. However, it is obvious that a laminated windshield is most vulnerable when at a moderately low temperature, consequently delamination, arcing, and local overheating usually occur when excessive heat is applied under these conditions and the panel is subjected to thermal shock. Vinyl has a thermal conductivity approximately one-fifth that of glass, a fortunate circumstance in itself, which serves to direct most of the heat generated in the conductive coating to the outer surface of the panel where it is needed most. However, this also means that the sudden application of excess heat to a cold panel, such as selecting HIGH power rather than LOW, will compound what is already an uncertain situation. The glass will heat before the vinyl, increase the thermal stresses between the glass and the vinyl, and will almost certainly cause delamination, chipping, or even cracking of the outer glass ply.

Much work is being done to minimize, and eventually to eliminate, delamination and its associated problems. In the meantime it should be emphasized that knowledge of laminated aircraft windshield design and manufacture has not yet progressed to the point where delamination in service is unexpected. However, it is also apparent that delamination problems can be reduced considerably by strict adherence to the recommendations for windshield maintenance and operation, which will result in a consequent improvement in the service life of these components.

ARCING The appearance of arcing in a windshield panel usually indicates that there is a breakdown in the conductive coating. Where chips or minute surface cracks are formed in the front glass plies, simultaneous relief of surface compression and internal tension stresses in the highly tempered glass can cause the edges of the crack and the conductive coating to part slightly and form a gap in the coating. Arcing is produced where the current jumps this gap, particularly if these cracks are parallel to the bus bars. Where arcing exists there is invariably a certain amount of local overheating which, depending upon its severity and its location, can cause further damage to the panel including cracking of the outer glass ply as shown in Figure 23. Arcing in the vicinity of the thermistor is a problem of potentially greater magnitude since it could upset the panel heat control system as well by damaging the thermistor. In the event that arcing occurs in the windshield panels, HIGH power should not be used and the pilot should consider operation of the aircraft with the windshield heat system de-energized.

Before leaving this subject, we might quote one field report submitted several years ago by an operator of another type of aircraft: ". . . flashes of electrical charges danced back and forth between the layers of the windshield panel. The charges would start from any edge of the panel and spread in jagged streaks, much like the limbs of a tree, then disappear. There didn't seem to be any relationship to the position of the thermistor or contacts . . ." This effect is not necessarily evidence of deterioration of the panel, but is more likely to be associated with static buildup on the panel.

TONG MARKS Slight impressions are left in the surfaces of tempered and semitempered glass panels during manufacture (see Figure 24). These impressions are made when the panes are held by tongs while they are in a semiplastic state during the tempering process. Tong marks have adverse effect on the structural integrity of a glass pane, and from an optical standpoint they are undesirable. For these reasons strict controls are applied during panel manufacture to confine tong marks within certain specified areas at the edges of the panes. Tong marks are apparent only on the outer glass plies of P-3 laminated glass windshield panels, since the fully-tempered structural ply is effectively shielded by vinyl and glass plies on both faces.

DISCOLORATION AND HALO EFFECT The electrically-heated windshields are transparent to directly transmitted light, but they have a distinctive color when viewed by reflected light. This color is due to the stannic oxide conductive coating on the inner surface of the outer glass ply, and may vary between panels by different manufacturers even though the panels have the same part number. This is the explanation for the varying colors such as light blue and yellow tints in heated windshield panels.

As an example of the type of unusual problem that can be encountered in windshield design, discrepancies were noticed on some L-188 Electra windshield panels which were not harmful except that they impaired vision at night. Bright lights viewed through the panels were accompanied by an unusually large halo. After some preliminary investigation, this phenomenon was finally traced to the vinyl interlayers of these panels which showed a characteristic "orange peel" formation when viewed from a certain angle. The vinyl plies in these panels had been procured from two different sources and, although each material was acceptable when used by itself, they were incompatible when used in the same panel. The resultant orange peel formation caused internal diffusion of the light which caused the halo effect at night but which could not be detected by normal inspection methods. The problem, however, was of short duration and manufacturing controls preclude its reappearance.

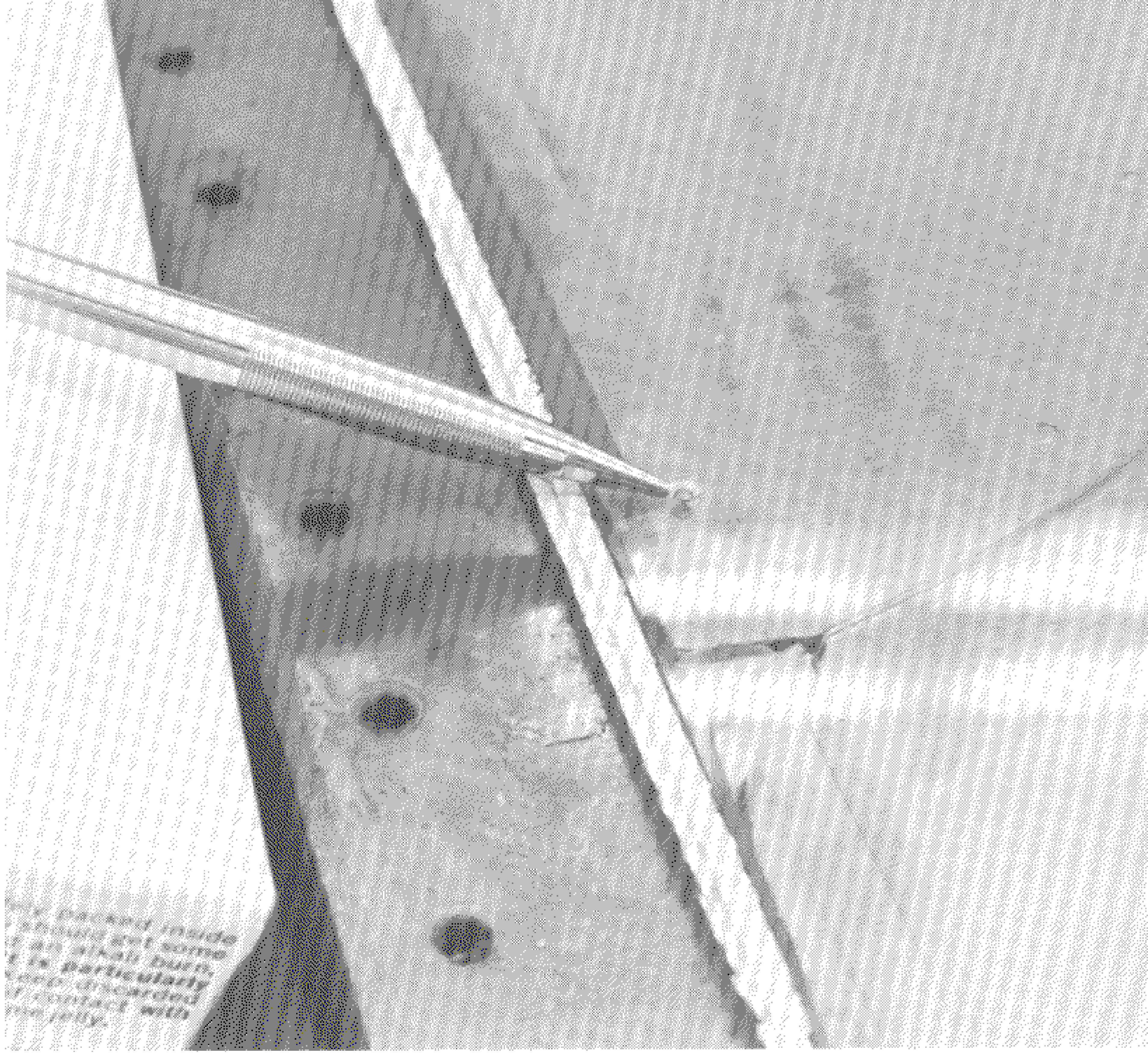


Figure 24. Tong Mark in Forward Windshield Panel

WINDSHIELD SCRATCHES Windshield damage from scratches is more common on the pilot's and copilot's forward windshield panels due primarily to the action of windshield wipers on these panels. Any grit trapped by a wiper blade is converted immediately into an extremely effective glass cutter when the wiper is operated. The best solution to scratches on these panels is a preventive measure provided by cleaning the windshield wiper blades as frequently as possible. Incidentally, operation of a windshield wiper on a dry panel is an unforgivable sin and considerably increases the chances of inflicting surface damage.

Assuming that visibility is not adversely affected, scratches or nicks in the inner and outer plies of a laminated glass panel are permitted to a maximum depth or width of 0.010 inch and to a maximum length of five inches. Since the thicker center glass ply is the principal load-carrying member of the panel this more tolerant view can be taken of damage to the inner and outer glass plies, for such damage would not compromise the safety of the aircraft. Nevertheless, the practice of polishing out nicks and scratches in the inner or outer glass plies in an attempt to improve visibility is not recommended. This is because of the unpredictable nature of the residual stress concentrations set up in the manufacture of tempered glass.

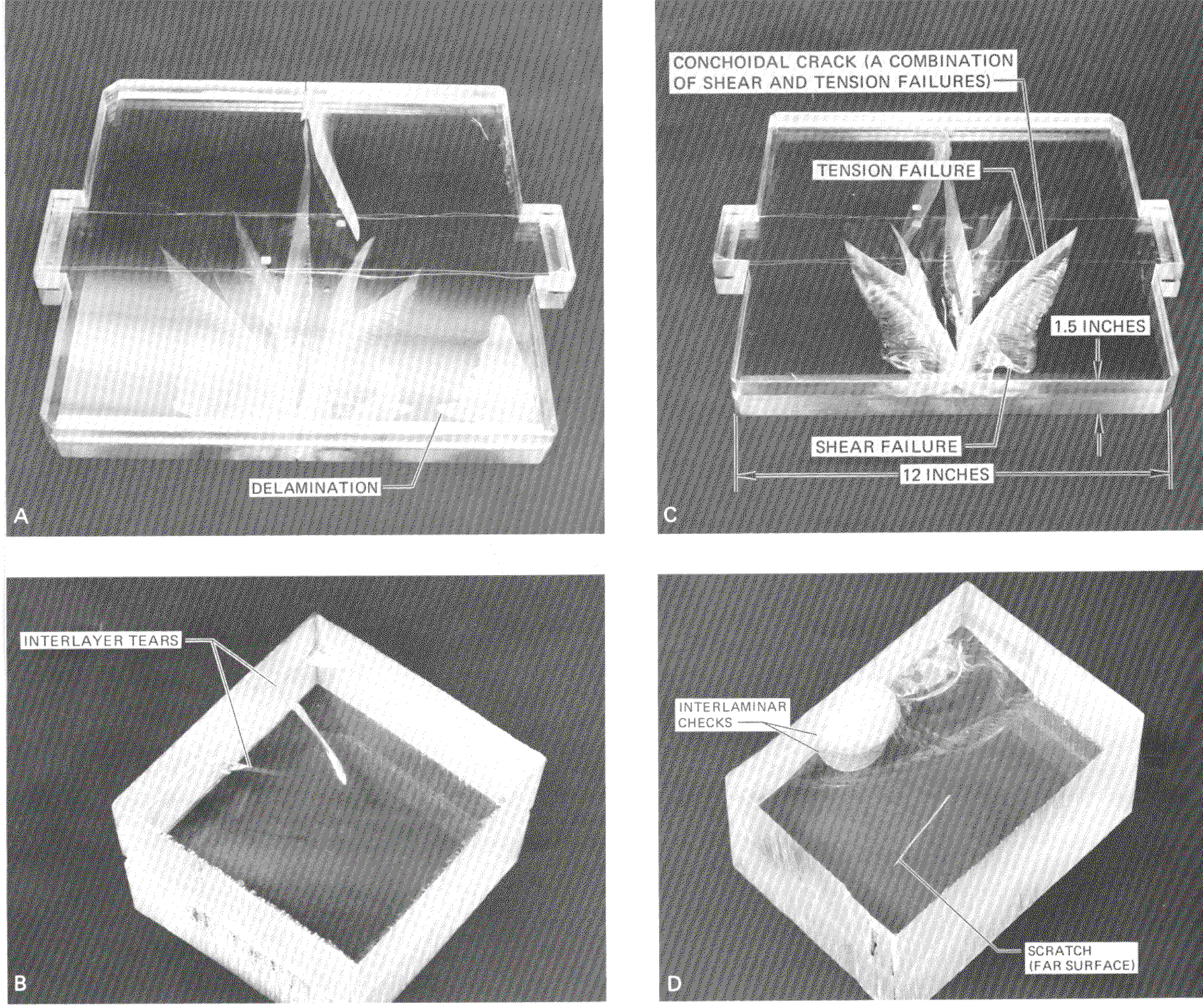


Figure 25. Windshield Side Panel Test Specimens showing Delamination, Interlayer Tears, Cracks, and Interlaminar Checks

Tempered glass is stronger than ordinary annealed glass only by virtue of the compression stresses in the glass surface which have to be overcome before failure can occur from tension stresses in the core. Therefore, polishing away any appreciable surface layer can destroy this balance of internal stresses and may even result in immediate failure of the glass. Attempts to rework deeply scratched panels have so far been unsuccessful in regard to maintaining optical clarity; but more important than this, as was previously stated, the structural reliability of the glass after such rework cannot be assured, and therefore the glass manufacturers and Lockheed do not recommend this practice.

ACRYLIC SIDE PANEL SERVICE PROBLEMS

Delaminations, bubbles, and the presence of cracks have been the most frequently reported service problems with the acrylic side panels, and for the most part these problems can be attributed to the same factors affecting the service life of laminated glass panels. However, the tendency to employ similar guidelines for both forward and side panel serviceability has resulted in the premature replacement of several acrylic side panels.

From the standpoint of appearance, delaminations or bubbles (Figure 25A) in an acrylic side panel may be objectionable, but they do not affect structural soundness of the panel. Thus, notwithstanding the presence of delaminations or bubbles, a side panel can remain in service as long as visibility of the flight crew is not unduly impaired. The same holds true if "tears" are present in the cast-in-place panel interlayer (see Figure 25B). Since the interlayer is not a primary load-carrying segment of the panel structure, neither the number nor the length of tears in the interlayer is of structural significance. Tears are usually perpendicular or nearly so in relation to the panel faces, and have been mistaken for cracks in the structural plies. When viewed from the flight station, scratches on the side panel outer surface may be mistaken for tears.

Cracks (Figure 25C) in the side panel stretched acrylic plies are a matter of greater concern, but to the best of our knowledge damage of this nature has not occurred under service conditions. However, during laboratory tests severe direct contact of objects with side panels has produced cracks in the acrylic plies. Of the damage produced, shear failures tended to be parallel to the panel faces while tension failures tended to be perpendicular to the panel faces. Shear and tension forces in combination produced conchoidal cracks. Interlaminar checks (Figure 25D) or cracks have occurred in acrylic plies during service, but they can be distinguished from shear cracks because they are invariably initiated at the edge of the panel and are relatively shallow in penetration. At the conclusion of the side panel test program, the results were evaluated and damage limitations were established.

If a crack or tear is found in one of the acrylic plies of a side panel, the damaged area should be examined thoroughly and determination of panel serviceability should be made in accordance with the NAVAIR 01-75PAA-2-2 Maintenance Instruction Manual. If the serviceability of the panel cannot be determined, further inquiries should be directed to the local P-3 service representative or to the Lockheed-California Company. If cracks are noted in any windshield panel during flight, the operational procedures in Section V of the P-3 NATOPS Flight Manual should be followed. The fail-safe design of the windshield affords ample protection as long as these procedures are followed.

Acrylic side panels, unlike the laminated glass forward panels, can be reworked by polishing to remove scratches and crazing provided that the pane thickness after rework is at least the minimum shown in Table 3 and the total area of rework does not exceed 25 percent of the surface. Crazing originating at the inner or outer face of the panel must be removed, the rework being subject to the above limits. If these limits are exceeded the panel must be replaced. The depth of scratches or crazing can be measured with an optical depth micrometer, a brief discussion of which is included later in this section. Acrylic ply thickness can be determined by comparative measurement of a calibration standard and the affected ply with an ultrasonic measuring device similar to the Model 102B digital caliper manufactured by Branson Instruments, 5925 Noble Avenue, Van Nuys, California 91401.

Table 3. Thickness Limitations For Rework of Acrylic Windshield Side Panels

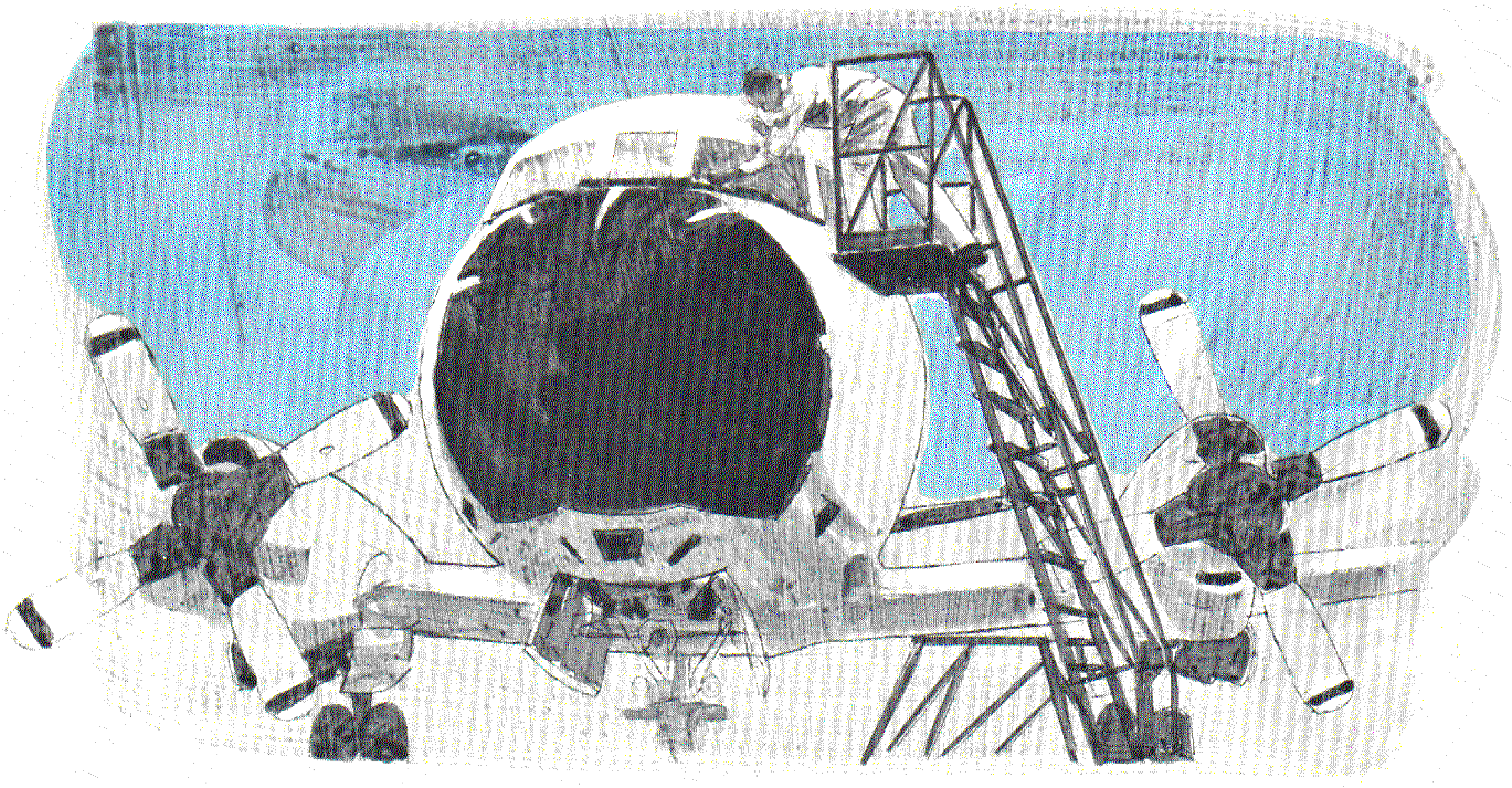
		P-3A AND B AIRCRAFT NOT INCORPORATING AFC NO. 200		P-3A AND B AIRCRAFT INCORPORATING AFC NO. 200		ALL P-3C AIRCRAFT	
		INNER PLY	OUTER PLY	INNER PLY	OUTER PLY	INNER PLY	OUTER PLY
NOMINAL THICKNESS OF PLY BEFORE REWORK		0.660 INCH ±10%	0.660 INCH ±10%	0.660 INCH ±10%	0.125 INCH ±0.020	0.660 INCH ±10%	0.660 INCH ±10%
MINIMUM ALLOWABLE THICKNESS OF PLY AFTER REWORK	4-INCH SQUARE AT CENTER OF PANEL	0.575 INCH MINIMUM	0.575 INCH MINIMUM	0.575 INCH MINIMUM	0.090 INCH MINIMUM	0.589 INCH MINIMUM	0.589 INCH MINIMUM
	REMAINDER OF PANEL	0.565 INCH MINIMUM	0.565 INCH MINIMUM	0.565 INCH MINIMUM	0.090 INCH MINIMUM	0.579 INCH MINIMUM	0.579 INCH MINIMUM

Instructions for removal of scratches and crazing by polishing are presented in the NAVAIR 01-75PAA-2-2 Maintenance Instruction Manual, Section III. Slight optical distortion will result from such polishing of panel surfaces, but the degree of distortion may be minimized if the polishing is done with utmost care and the reworked area is feathered smoothly to blend into the surrounding undamaged surface.

An optical micrometer kit (FSN 6625-831-5532-966A1), manufactured by the Custom Craft Division of Monogram Industries, Culver City, California 90230, is suitable for determining the depth of scratches, cracks, and delaminations in windshield panels (see Figure 26). The optical micrometer can be used on flat, convex, or concave surfaces of panels, whether they are installed on the airplane or not. Essentially, it is a microscope supported on small legs rather than by the more familiar base mounting. When focused on any particular spot, the distance from the lens to the spot can be read from a micrometer scale on the barrel of the instrument. The depth of a scratch or crack in a windshield panel can be determined from readings of the measurements to the surface of the panel and to the bottom of the scratch. The difference between the two readings is equal to the depth of the scratch or crack.


Figure 26. Optical Micrometer Kit

When reading *into* or *through* a transparent material with an optical micrometer, an error is induced into the measurement by the refraction of light as it passes through the material. This error is corrected by multiplying the micrometer reading by the refraction index of that particular material. For example, 1.5 is the refraction index of the stretched acrylic plastic plies of the side windshield panels. Thus, if the depth of a flaw within an acrylic ply is measured as 0.204 inch, the reading is multiplied by 1.5 which gives the actual depth of the flaw as 0.306 inch.

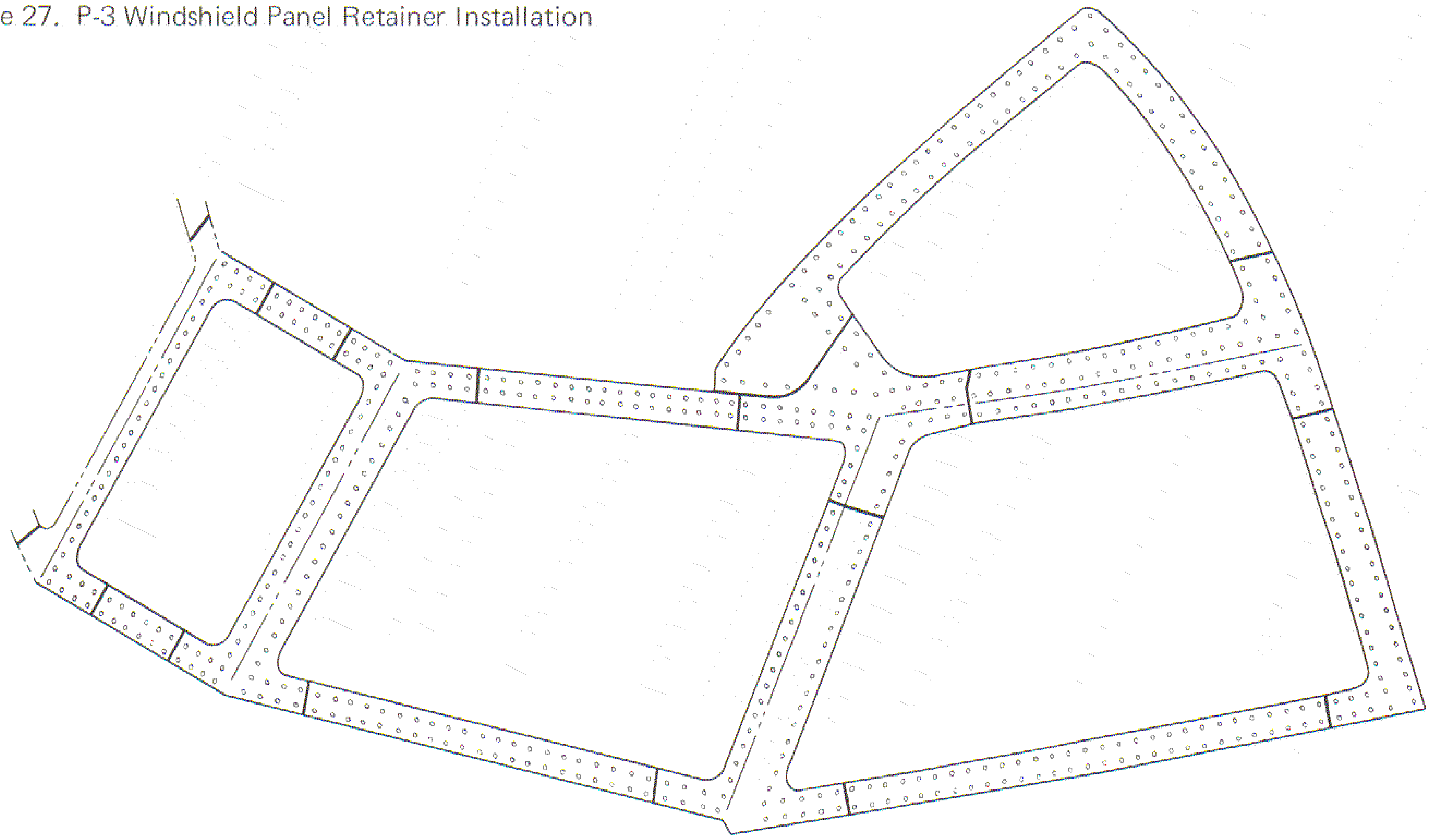


WINDSHIELD PANEL REPLACEMENT

The maximum service life of a windshield panel can be realized only if it has been installed properly. Each panel is designed to withstand pressurization loads far greater than those it will encounter in service, but if the prescribed installation procedures are not practiced excessive loads may be applied to the panel. Frequently the result is abnormal delamination, and on occasion structural failure of one or more plies of a panel. Care must be exercised to ensure that gaps or voids between the periphery of the panel and the airframe mounting surfaces are adequately filled and that the installation is properly sealed in order to prevent the penetration and entrapment of moisture. Moisture penetration between the outer glass ply and the adjacent interlayer may cause arcing in the conductive coating and precipitate electrical or structural failure of the panel. Less spectacular but equally important, moisture entrapment may lead to corrosion of aircraft primary structure.

The P-3 Orion windshield panels are installed from the outside of the aircraft and are secured to the aircraft structure by attachment screws and retaining strips. Synthetic sponge rubber seals and LAC C-40-769, Type I low adhesion sealing compound* are used in the factory production windshield installation to maintain pressure integrity of the aircraft at the windshield frames. Sealing compound conforming to Specification MIL-S-8784, Class B-1/2 is used for subsequent replacement installations and repair. Figure 27 shows that several of the windshield panel retaining strips are used to secure more than one panel, and that removal of just one windshield panel requires

Figure 27. P-3 Windshield Panel Retainer Installation



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*LAC C-40-769, Type I sealing compound conforms to all requirements of MIL-S-8784, Class B-1/2 except for its gray color; red is a specification requirement. The two colors thus provide ready identification of areas of previous repair. For further information on sealants, refer to Orion Service Digest Issue 15, pp. 21-23.

the removal of a considerable number of attachment screws from adjacent panels. Stress requirements dictated that these particular retainers be made common to adjacent panels, thus necessitating this extra work in windshield replacement. All this elaborate design is to simplify as much as possible the task of panel replacement, while still conforming to the philosophy of performing most of the work from outside the flight station – an area that is a notorious bottleneck on most aircraft during maintenance periods.

The center and forward windshield panels are all installed in the same manner, and although the side panel and skylight panel installations do have individual peculiarities, their installation procedures also are basically the same as those of the forward and center panels. Detailed instructions for windshield panel removal and installation are defined in NAVAIR 01-75PAA-2-2, Section III. However, the following abbreviated outline may provide the reader with a better grasp of windshield removal and installation methods.

PANEL REMOVAL

1. Remove the sun visor track, remove or disconnect the equipment mounted on the window frame trim covers of the affected panel, then remove the trim covers.

2. Cut or disconnect the lead wires from the defective panel, if applicable.

3. Prior to removal of either the left or right forward panel, remove the appropriate windshield washer spray manifold and cap the line.

4. Remove the screws from the panel retainers, then remove the retainers. Pry the retainers loose with the aid of one or more plastic chisel-type tools, using a method similar to that employed for removing an automobile tire from the rim. If sufficient Resin Release "N" (Specialty Resins Co., 2801 Lynwood Rd., Lynwood, California 90262) was used in the previous installation, the retainers should come away with ease.

5. Cut through the old sealant around the panel perimeter with a sharp plastic cutter. Preserve as much of the old sealant as possible in place in the window frame for reuse as filler.

6. Remove the windshield panel. Again, if sufficient Resin Release "N" has been employed during the previous installation, the panel should be removed easily. A suitable tool used as a lever will be found helpful in stubborn cases. Apply constant pressure on one corner of the panel and it should break loose in a peeling action.

7. After the panel begins to break loose, caution should be used in case it pops out of the frame. Note that the center panel weighs 24.4 pounds, a forward panel 57.8 pounds, a side panel 54.2 pounds, and a skylight about 20 pounds.

PANEL REINSTALLATION The following procedure assumes that the windshield frame is bare although a maximum amount of sealing material was left in the frame when the defective panel was removed to save time and material in replacement panel installation.

1. Verify the integrity of protective material on interior and exterior surfaces of the new panel to make certain that the panel is not damaged or scratched.

2. Clean the structural frame thoroughly. The surfaces should be free of all foreign matter such as chips or drill cuttings. Use petroleum base cleaner (KUL, manufactured by Kelite Products Co., or equivalent) to remove grease from these areas.

3. Reprotect the frame where necessary with a coating of zinc chromate primer.

4. Prior to installing seals or sealant on the center or forward panels, position the panel in the frame and determine the contour (panel and frame flatness) mismatch. The measurement must be made from inside the flight station. If the contour mismatch is greater than 0.06 inch, shim the frame to prevent application of undue stresses to the panel.

5. Install grommets in acrylic panel mounting holes. Apply MIL-T-50036 Talc to the exterior surface of each grommet to facilitate installation.

6. Install AMS 3197 synthetic sponge rubber seals on the panel and/or window frames, as

applicable. Use MIL-A-1154 Bonding Adhesive to secure seals to the center and forward panels and to the frames; use MIL-A-5092, Type 1 Rubber Base Adhesive to secure seals to acrylic panels. The lead wires of center and forward panels must be pulled through their respective holes in the seal before the seal is mounted on the panel.

7. Install the panel in the frame carefully. With center and forward panels, first place a strip of AMS 3197 synthetic sponge rubber on the bottom side of the frame, then position the panel in the frame. Be certain that the panel lead wires are routed through their respective holes in the frame structure and into the conduits.

8. Fill gaps around the panel sides with AMS 3197 synthetic sponge rubber strips to align the panel with mounting holes in the frame, but do not cement the rubber strips in place.

9. Apply Resin Release "N" compound to exterior mounting surface of center or forward panels.

10. Apply MIL-S-8784, Class B-1/2 Sealing Compound (MIL-S-8802, Class B sealing compound is an acceptable substitute) with a flat tool over the frame structure to fill the gaps and voids around the periphery of the panel. Also apply the sealant over the exterior mounting surfaces of the center and forward panels.

CAUTION

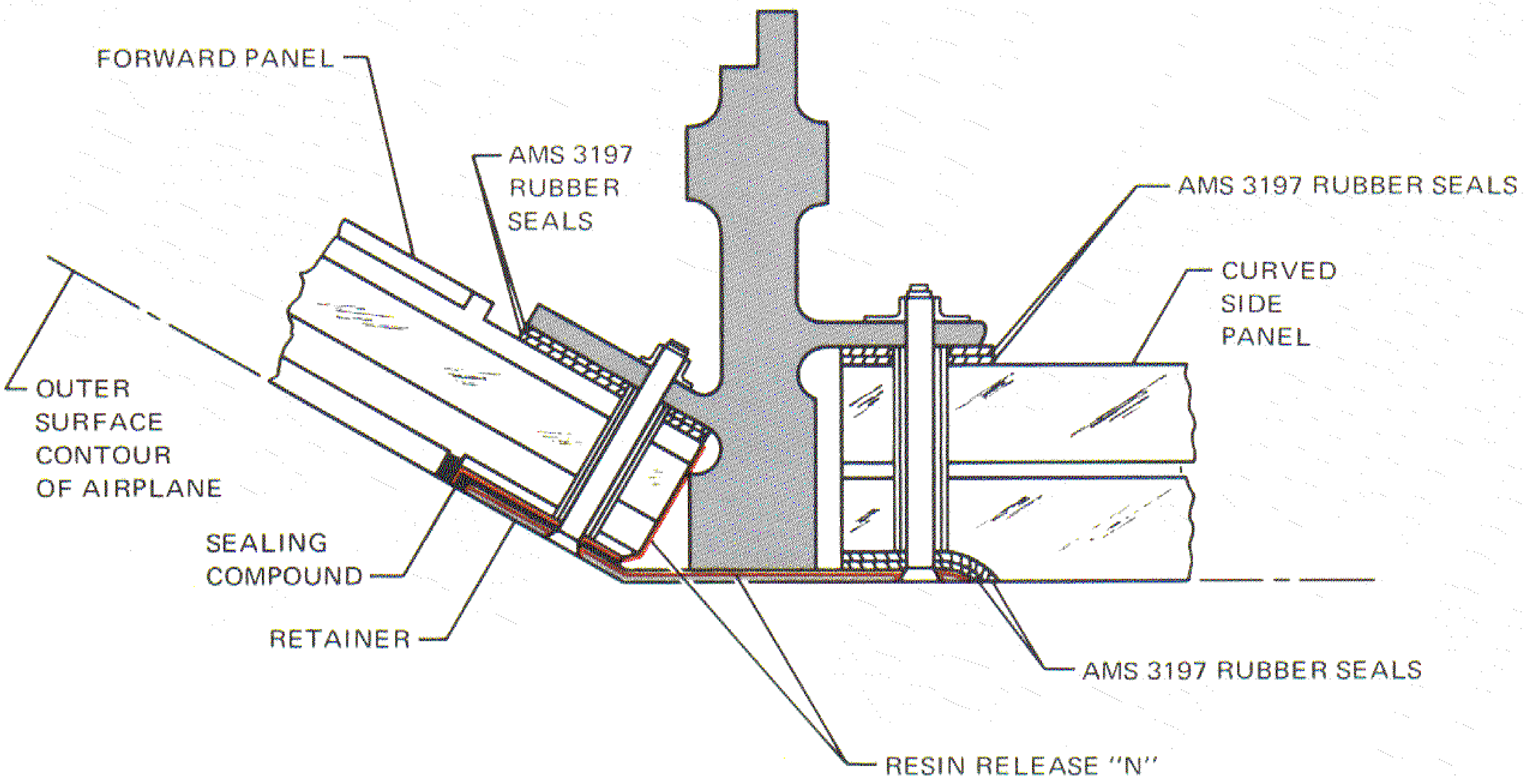
Use only MIL-S-8784, Class B sealing compound or MIL-S-8802, Class B sealing compound for windshield panel installation. The class A compounds of these specifications contain solvent that is incompatible with plastic glazing materials.

11. Apply Resin Release "N" compound to inside and outside surfaces of the panel retainers.

12. Assemble the retainers with the window frame as soon as possible, and install all screws loosely. The screws must be installed while the sealant in the panel installation is still wet. On heated windshield panels, be certain that the protective covering has been removed from the panel outer surface in the areas where the bonding clips contact the panel, and that the bonding clips have positive grounding contact with the panel upon completion of the installation.

13. Tighten the screws that attach the retainer *only to the fuselage structure* to between 25

Figure 28. Sealing P-3 Windshield Panels



and 40 inch-pounds torque value as specified in NAVAIR 01-1A-8.

14. Tighten the screws that attach *both* the retainer *and* the panel to the fuselage structure progressively until the retainers meet flushness requirements and, for laminated glass panels, until sealant extrudes at all edges of the retainers near the glass. These screws may be tightened up to a *maximum* of 20 inch-pounds. It may be necessary to substitute screws of greater length to ensure that the screws extend a minimum of two threads through the respective plate nuts. Do not overtighten screws failing to meet flushness requirements; check for improper countersink or too much sealant. If air leaks appear at the screws during cabin pressure check, remove the screws, apply more sealant, then replace them.

15. Remove excess sealing compound from the fuselage and windshield surfaces carefully with a putty knife. Clean the retainers and adjacent metal surfaces with MEK (methyl-ethyl-ketone), Federal Specification TT-M-261.

16. Connect all lead wires from the electrically heated panels. For the center and forward panels, perform windshield heating system checkout procedures specified in NAVAIR 01-75PAA-2-2.4; NAVAIR 01-75PAC-2-13.1 provides instructions for the functional check of the heated side windshield panel system on P-3C aircraft.

17. Install the windshield trim and removed equipment.

18. Clean windshield panels with mild soap and water.

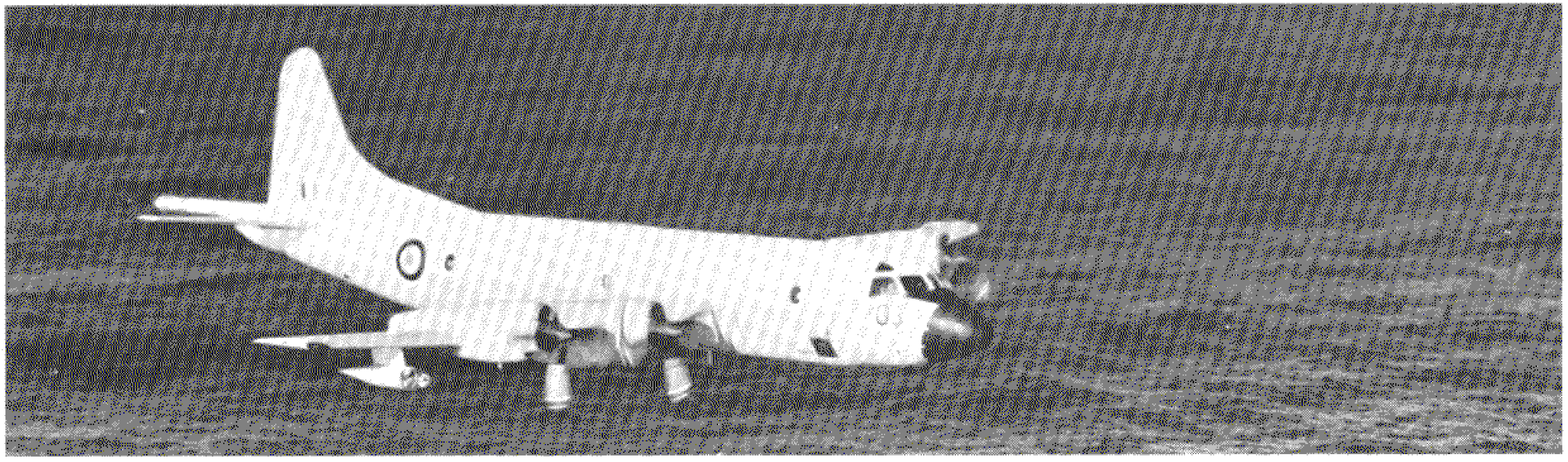
In addition to the foregoing installation procedure, the following notes also have relevance to proper panel installation procedures.

Note 1. No solvents, primer, paint, or emulsified cleaners should be allowed to contact the narrow vinyl buffer strip at the edge of the windshield glass. If any cleaning material of this nature must be used in the area of the windshield panels, masking must be applied not merely to the glass itself, but also must cover the vinyl buffer strip. Do not attempt to use solvent of any kind in this area to remove paint.

Note 2. Do not attempt to use a substitute for Resin Release "N." Operators of commercial aircraft have attempted to substitute some petroleum base products and found that they were incompatible with the vinyl in the windshield.

Note 3. Extreme care should be taken when tightening the screws that extend through the windshield. Overtightening the screws will lead to early delamination of the panel plies, and in extreme cases may even extrude the vinyl from the edges of the panel. However, a slight amount of delamination may occur at the edges upon installation of a new windshield panel. This is sometimes unavoidable and is due to the slight misalignment that can exist between the panel and the windshield frame.

Note 4. As mentioned in the "Windshield Temperature Control" section, each center and forward windshield panel is graded into one of three resistance ranges and identified as RA, RB, or RC. The rating determines the transformer terminal (A, B, or C) to which the panel should be connected during installation. Thus, a panel with the resistance rating of RA should be connected to terminal A of the transformer, etc.



WINDSHIELD OPERATIONAL PROCEDURES

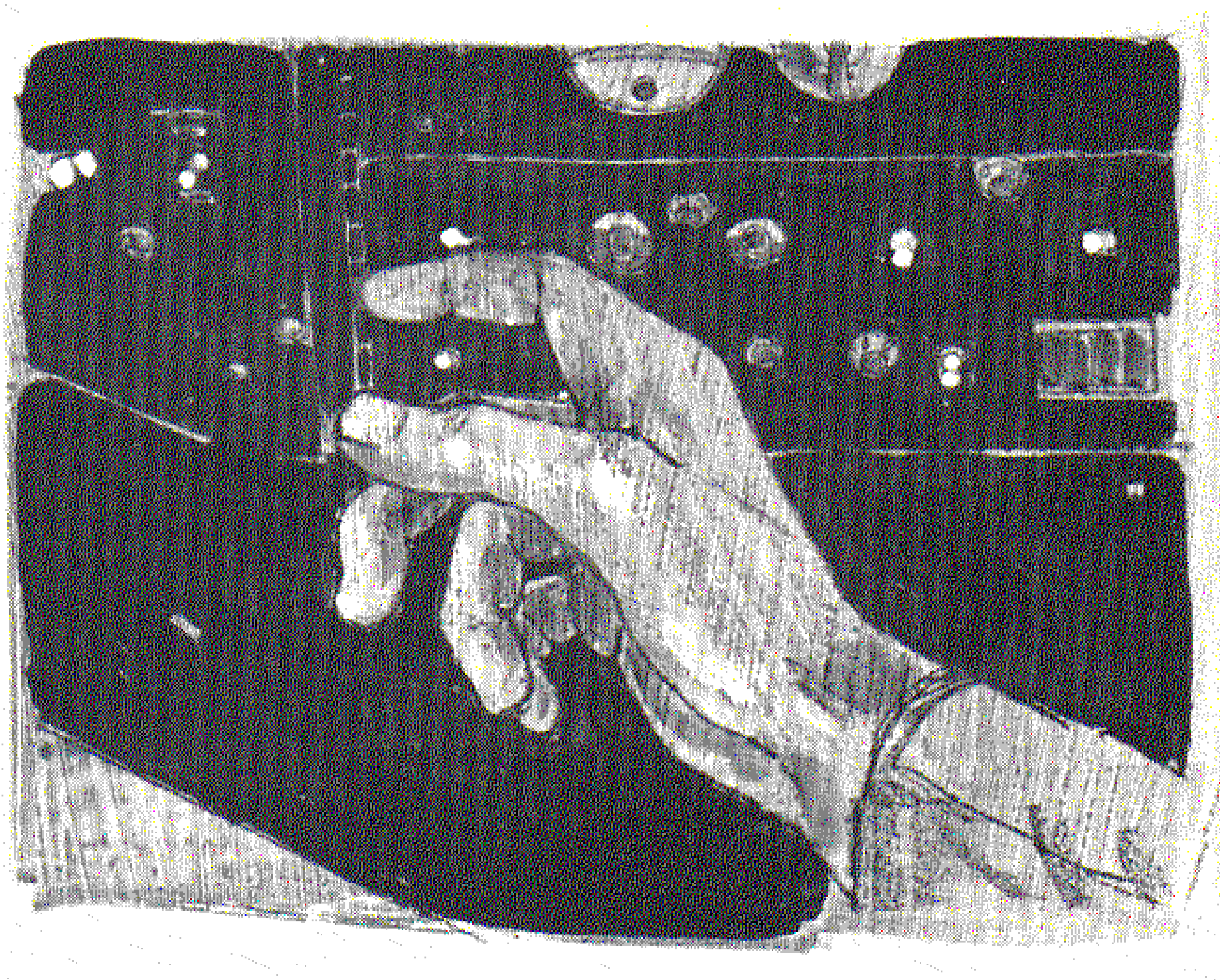
Reference should be made to the P-3 NATOPS Flight Manual for the procedures to be followed during normal and emergency operation. Comments in this section are restricted mainly to emphasize items that have proven to be troublesome in service. For example, the limitations laid down regarding the use of HIGH power is one of the primary factors affecting the service life of the windshield panels. Normal (LOW) power should always be selected before HIGH power in order to prewarm the panels and avoid possible panel damage, particularly at low ambient temperatures.

If the windshield heat is selected to HIGH power when on final approach, it should be selected to LOW immediately upon landing unless the outside air temperature is below 0°C (32°F). In any event, the aircraft should not be parked with the windshield heat switch in the HIGH position. This lessens the chances of applying maximum heat to a cold windshield when the aircraft electric system is subsequently energized, a circumstance which has caused numerous panel failures in service.

Normal (LOW) power, which is equivalent to about 40 percent of the HIGH power output, is recommended for all operating conditions except as specified below. These are also the only conditions in which HIGH power should be used, assuming prior warm-up at LOW power.

1. When ice begins to form on the windshield panels.
2. When icing is anticipated at outside air temperatures near the low end of the icing range between 0° to -25°C (plus 32° to -13°F).
3. At altitudes of 10,000 feet or less when descending into areas where birds are likely to be encountered and the outside air temperature is below 0°C (32°F).
4. At altitudes of 10,000 feet or less when descending into areas of high temperature and high humidity.
5. At any time in flight for antifogging purposes.

Operation of the windshield heating system CYCLING lights is a useful guide for determining when to operate the systems in HIGH. Increased severity of icing conditions is indicated by more frequent illumination of the CYCLING lights. Thus, if the lights indicate that the systems are cycling rapidly during LOW mode operation, HIGH should be selected. It is standard operating procedure to leave the system constantly in LOW, selecting HIGH only when required by icing conditions.



Occasional reports have been received of instances where the outer glass ply of an electrically-heated windshield cracked when the system was switched on to LOW power. This has occurred after the airplane has been subjected to extremely cold conditions of approximately -40°F or below. Although these may be isolated cases in which the resultant thermal shock has combined with a minute defect in the surface of the glass to produce the damage, nevertheless it would seem to be advantageous to preheat the windshields with hot air from ground heaters or some similar device before switching on electric power to the windshields. If this method of preheating is impractical, electric heating can be performed with little likelihood of the panel being subjected to thermal shock by manually cycling windshield heat between OFF and LOW. Apply heat for a few seconds at a time with pauses of about a minute between applications until the panel no longer feels cool to the touch, then allow its heat control system to assume normal operation. In most cases this would involve use of the system OVERRIDE switch.

P-3C aircraft are also equipped with electrically heated windshield side panels that are normally energized throughout the flight as an antifogging measure. Each side panel heating system is controlled by an ON-OFF toggle switch and an automatic control unit. Adjacent to each toggle switch is a side panel FAIL light which illuminates if either the system power relay or overheat control relay is in the energized position when the control switch is in the OFF position. This signal light does *not* indicate failure of a heated side panel system while the control switch is positioned ON.

ARCING IN ELECTRICALLY HEATED PANELS The presence of arcing in a panel may not necessitate cutting off power to the panel. However, once arcing occurs, panel deterioration usually progresses until the panel fails through overheating. Consequently, it is recommended that power to an affected forward panel be selected to LOW or left in LOW. In any case, the system may be turned off at the pilot's discretion.

OPERATION WITHOUT WINDSHIELD HEAT P-3 aircraft may be dispatched with part or all of the forward windshield electric heating systems unserviceable or selected OFF, provided the following conditions are satisfied:

1. Indicated airspeed must not exceed 240 knots below an altitude of 10,000 feet. (Birds are less likely to be encountered at higher altitudes, and normal speed limitations apply above 10,000 feet.)
2. The aircraft must not be dispatched into known or anticipated icing conditions.

Although expediency may dictate dispatch of a P-3 aircraft with its forward windshield heating systems unserviceable or selected OFF, as previously pointed out it is recommended that the electric heating be selected LOW under all operational conditions except when it is necessary to use HIGH. This allows a windshield panel to maintain optimum birdproof characteristics and also prevents it from being "cold soaked" for long periods under very low temperature conditions.

OPERATION WITH DAMAGED WINDSHIELD PANELS The cracking of a windshield panel in flight can be somewhat disconcerting, and when this occurs at higher altitudes the natural reaction is to descend as fast as possible so that cabin differential can be reduced and thereby relieve the pressurization load on the affected panel. However, such emergency measures are not necessary unless panel failure has already resulted in rapid depressurization. Each situation should be quickly evaluated to determine the extent of the damage, the action to be taken, and the changes in flight plan to be made, if any.

The following operational procedures were established for P-3 aircraft after consideration of the pertinent birdproofing requirements, and many other factors, some of which are listed at the end of this section. Nevertheless, the NATOPS Flight Manual for the aircraft must be considered as the final authority in questions concerning operational procedures.

Center and Forward Windshield Panels

1. Turn off the heating power to the affected panel.
2. If possible, determine which of the glass plies is cracked and proceed as follows:
    a. If outer ply of glass is cracked – Continue mission but do not exceed 240 knots below 10,000 feet. Replace the panel before the next flight.
    b. If middle (structural) ply of glass is cracked – Reduce speed to 240 knots, reduce cabin differential pressure to 2.0 inches Hg (1 psi), and make a normal descent to 10,000 feet or less. Maintain these conditions during balance of mission. Replace the damaged panel before the next flight.

Note

There are no restrictions during flight with the inner glass ply (fragmentation shield) cracked, although from an optical standpoint it could be a cause of annoyance.

   c. If it is not possible to determine which ply of glass is cracked, or if both the outer and middle plies are cracked, follow the procedures in step 2.b.

3. Crewmembers in the flight station must don their helmets and position the visors down.

Windshield Side Panels

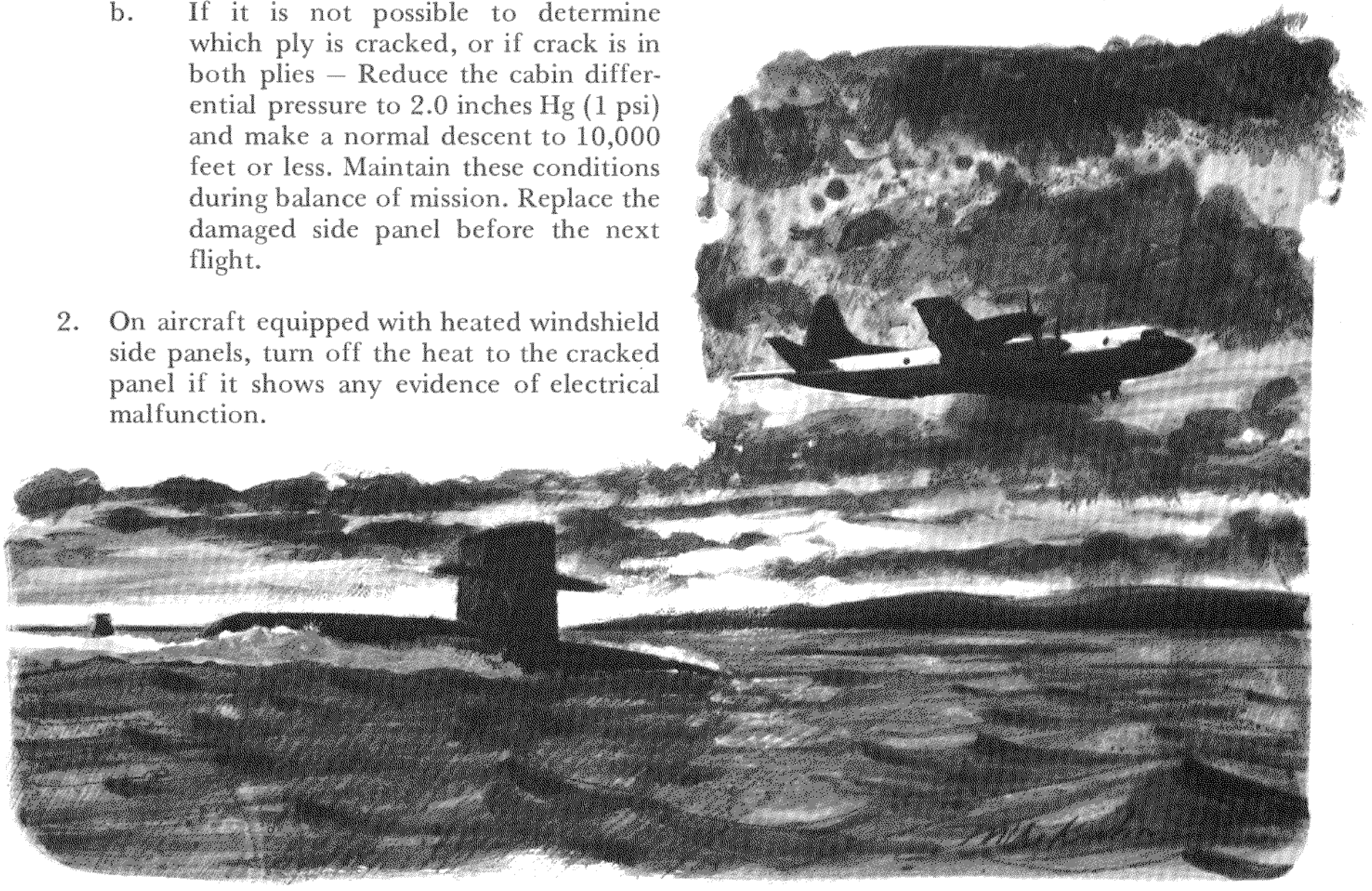
The following procedures are based on the most recent recommendations by Lockheed Engineering for flight operations of P-3 aircraft with cracked windshield side panels. It is anticipated that during the next P-3 NATOPS conference, Lockheed will recommend that the existing operating procedure be revised accordingly.

1. If possible, determine if crack is in only one (either inner or outer) or both acrylic plies and proceed as follows:
   a. If only one ply is cracked – Continue mission. Replace the damaged panel as soon as practical.
   b. If it is not possible to determine which ply is cracked, or if crack is in both plies – Reduce the cabin differential pressure to 2.0 inches Hg (1 psi) and make a normal descent to 10,000 feet or less. Maintain these conditions during balance of mission. Replace the damaged side panel before the next flight.
2. On aircraft equipped with heated windshield side panels, turn off the heat to the cracked panel if it shows any evidence of electrical malfunction.

When a ground inspection is performed on a cracked windshield side panel that has a cast-in-place interlayer, it may be discovered that the "crack" is not in either of the acrylic panes, but rather is a "tear" in the interlayer. There are no restrictions during flight for side panels with tears in cast-in-place interlayers, although optically it could be a cause of annoyance.

Skylights and Cabin Windows The skylights and cabin windows are constructed of two panes of stretched acrylic plastic, separated by an airspace that is vented through the inner pane into the flight station or cabin. If a skylight or cabin window cracks during flight, determine if the crack is in the inner or outer pane and proceed as follows:

1. If inner pane is cracked – Continue mission. Replace the panel as soon as practical.
2. If outer pane is cracked – Reduce cabin differential pressure to 2.0 inches Hg (1 psi) and make a normal descent to 10,000 feet or less. Maintain these conditions during balance of mission. Replace the damaged panel before the next flight.



CONCLUDING COMMENTS The following points, many of which have already been presented, are pertinent to this discussion and formed the basis for establishing the preceding operational procedures with cracked birdproof windshield panels. Figure 29 shows a section through a typical birdproof panel consisting of two thick glass plies (A and C) separated by a layer of vinyl (B). The additional thin vinyl and glass protective plies (D and E) form the fragmentation shield on the center and forward windshield panels.

1. The thick "structural" glass ply (C in Figure 30) is the principal load carrying member. The other two glass plies (A and E) have basically a protective function, although in practice they do carry some of the pressurization and aerodynamic loads. Also, to some extent, they act as a backup should the structural ply fail.

2. The birdproof panel is fail-safe by virtue of the thick vinyl ply (B) which is capable of withstanding pressures well in excess of the maximum cabin pressure differential.

3. Cracking of the thick structural glass ply (C) is the only eventuality requiring a change in flight plan and a reduction in cabin pressure.

4. To the best of our knowledge, cracking of a structural glass ply in a birdproof panel has never occurred in service except as a result of impact.

5. When fully tempered structural glass plies (C) were shattered during laboratory tests, a complete loss of visibility through the test panels invariably resulted. It is apparent that the occurrence of such a failure in flight would make it difficult to determine if the outer glass ply is still intact. The emergency procedures are therefore applicable whether the structural ply only is cracked, or whether it is cracked in combination with one or both of the other glass plies.

6. If either of the less highly tempered non-structural glass plies (A or E) crack, vision may or may not be seriously affected.

7. Electric heating should be discontinued if either the outer (A) or the structural glass ply (C) cracks. When the outer glass ply cracks the conductive coating on the inner face of the ply will inevitably sustain some damage, and further damage due to arcing and hot spots should be avoided. When the structural glass ply cracks, whether the outer glass ply is also damaged or not, the panel will be stiffer and stronger if the vinyl ply (B) is allowed to cool.

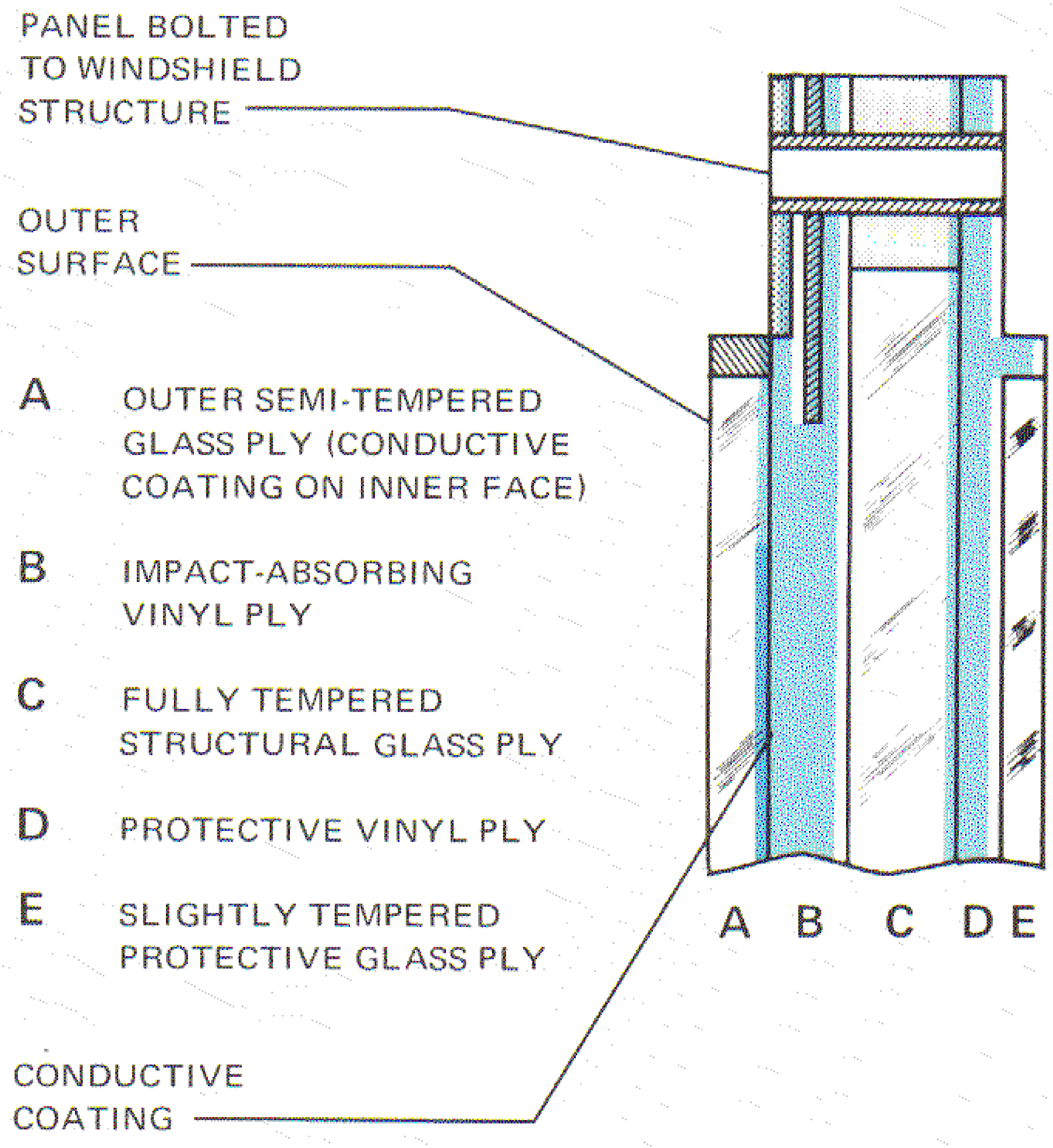


Figure 29. Five-Ply Birdproof Windshield Panel Section

8. Cracking of the inner glass ply (E) does not necessitate discontinuation of heat to the panel or imposition of flight restrictions.

9. There would appear to be certain advantages to maintaining some positive cabin pressure differential in the event that the structural glass ply (C) is cracked in flight. This would counterbalance to some extent the aerodynamic load on the more vulnerable forward windshield panels. The recommended pressure differential is 2.0 inches Hg (1 psi).

▲▲

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