# NAFEC TECHNICAL
# LETTER REPORT

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PRELIMINARY EVALUATION OF THE
PERFORMANCE OF ADVANCED AND
CONVENTIONAL AIRCRAFT WINDOWS
IN A MODEL FIRE ENVIRONMENT

by

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Approved by ______________________
JOSEPH M. DEL BALZO
Director, National Aviation Facilities
Experimental Center
Federal Aviation Administration
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# INTRODUCTION

## PURPOSE.

The effort described herein was a quick-reaction evaluation of the performance of advanced aircraft windows in a model fire environment. The purpose was to provide a timely response to a request by Dr. John Parker, Chief of the Chemical Research Projects Office at AMES Research Center. Under this request, advanced epoxy/polycarbonate windows provided by the National Aeronautics and Space Administration (NASA) would be tested in the National Aviation Facilities Experimental Center's (NAFEC) quarter-scale model of the C-133 aircraft fuselage. An additional purpose was to provide some preliminary information to be used in planning a broader project on aircraft windows in fiscal year 1981.

## BACKGROUND.

The Los Angeles crash of a Continental DC-10 provided documentation of the impact of an external fuel fire on a wide-body fuselage. The aircraft experienced significant melting of the aluminum skin along with destruction of the outer stretched acrylic windows in the vicinity of the melted skin. It should be noted that the outer stretched acrylic window is one of two or three windows separating the external environment from the cabin interior. Stretched acrylic is the material currently used for the windows because of many qualities, including the ability to withstand the many pressurization cycles involved in an aircraft's routine use. Nevertheless, the performance of windows in a fire is a factor in controlling the length of time the fuselage can shield the passengers inside from hazards emanating from an external pool fire.

As part of the NASA "FIREMEN" program, advanced laminated windows were evaluated wherewith the outer laminate would be a char-yielding material that could protect an inner-structural ply from an external fire for longer periods than a conventional acrylic window. Because of the success at NAFEC with model simulations of full-scale fires, a comparative evaluation of stretched acrylic windows with an epoxy/polycarbonate window could be performed on a quarter-scale fuselage model for rapid delineation of the performance to be expected in the full-scale environment.

## EXPERIMENTAL OBJECTIVE.

The experimental objective was to photographically and thermally determine the time and mode of failure of stretched acrylic and epoxy/polycarbonate windows as they were exposed to an 8-foot-square pool fire adjacent to a 4-foot-diameter model fuselage.

## DISCUSSION

### TEST CONFIGURATION.

The test bed used in this study was a quarter-scale fuselage built to simulate large-scale fire tests at NAFEC. The details of the fabrication of this test article are found in reference 1. In previous tests, the 1R door of the model was exposed to a variety of fire sizes under a range of wind conditions. For the window tests, the windows were mounted in a metal frame which was fastened over the 1R door. The 1R door itself measured 10 inches wide by 20 inches high, and the fuselage curvature in the vicinity of the door was flattened to accommodate the window frames.

The fuel pan adjacent to the 1R door was 8 feet square, and all tests were conducted with wind blowing the fire over the fuselage as shown in figure 1 Four tests were conducted in this manner, and these will be designated as tests 1 through 4. In test 1, a conventional stretched acrylic window was tested. In test 2, an epoxy/polycarbonate window was tested. For tests 3 and 4, an acrylic and an epoxy/polycarbonate window were cut into 4 equal pieces each, and the two types of windows were run side by side in each test. Forty gallons of fuel were used in all tests to allow steady burning of up to 4 minutes before the fire would gradually begin to decrease in intensity.

### WINDOW MOUNTING.

In tests 1 and 2, the windows were sandwiched between galvanized sheets separated by 1/4-inch fiberglass board. This arrangement is shown in figure 2 (left). In tests 3 and 4, the window segments were also sandwiched in the same fashion, but additional holes were cut in the mounting to accommodate two calorimeters for heat flux measurements. Also, in tests 1 and 2, the window was essentially clamped in place, while in tests 3 and 4, the window sections were fastened by bolts passing through the metal frame and the holes drilled in the windows. The arrangement for tests 3 and 4 is shown in figure 2 (right).

### INSTRUMENTATION.

The instrumentation for these tests included a motorized still camera, viewing the window from inside the model in tests 1 and 2, along with chromel/alumel thermocouples epoxied to the inside of the window. In tests 3 and 4, the instrumentation consisted of thermocouples epoxied to the inside surface of the windows and two calorimeters to show heat flux as a function of time. In all tests, windspeed was noted with a cup anemometer, and photographic documentation was accomplished with two movie cameras--one looking down the model length toward the end where the window was installed and one viewing the fire from outside the fuselage.

## RESULTS

Figure 3 shows the condition of the two full size windows after extinguishment of the fires in tests 1 and 2, respectively. NAFEC firemen started extinguishment when an observer noted burnthrough 108 seconds after the start of test 1 and 240 seconds after the start of test 2. Tests 3 and 4 were run for 113 seconds and 115 seconds, respectively, before extinguishment of the pool fire was started. The tests were halted when an observer could see the fire breaking through either of the window sections. Figure 3 also shows the window conditions for tests 3 and 4, respectively. The photographs show that the stretched acrylic windows failed by means of shrinking. The epoxy/polycarbonate window failed only in test 2 which was run for a considerable length of time. When the epoxy/polycarbonate window was exposed to fire, the outer ply formed a char which apparently served as an effective heat-blocking device.

Figures 4 and 5 shows backface temperature rises for test 1 and 2 along with corresponding photographs taken by the motorized still camera. The behavior of the windows during the fire can thereby be observed. The photographs shown in figure 4 are selected from sets of 35-mm color stills which were sequenced every 2 seconds during the test. The motorized still camera inside the fuselage viewed the fire through the window.

Noticeable speckling of the stretched acrylic window appeared at 28 seconds into the test. At 52 seconds the window darkened considerably, and at 104 seconds, the first breakthrough of the external fire was noted.

The epoxy/polycarbonate window first showed speckling at 30 seconds and darkened at 70 seconds. By 90 seconds the window was very dark and evidenced some stress cracks in the epoxy layer. From 90 to 190 seconds (when the camera stopped), the window was opaque and showed no signs of failure. Observations from the end of the fuselage indicate that the window failed at approximately 240 seconds. It should be noted that tests 1 and 2 were both run at 7 to 10 knots windspeed. Tests 3 and 4, however, were run at 12 and 3 knots, respectively. In both tests 3 and 4, the lower calorimeter on the window mount read 13 British thermal unit per square foot second ($Btu/ft^2$-sec), while the upper calorimeter read 16 and 15 $Btu/ft^2sec$, respectively.

The backface temperature-rise curves for tests 3 and 4 are shown in figures 6 and 7. For the first 40 to 60 seconds, the backface temperatures of both windows in a given test are equivalent. At this time, the backface temperature of the conventional window becomes higher.

The glass transition temperature ($T_g$) of acrylic will usually be around 230° F, while that of polycarbonate is around 300° F. When the backface temperature on either material approaches $T_g$, failure results.

## CONCLUSIONS

There are two major conclusions arising from the test results.

1. The state-of-the-art stretched acrylic windows fail by shrinking and falling out of place and not by burnthrough. Failure generally occurs around 100 seconds into a test.

2. The advanced epoxy/polycarbonate windows perform as designed and appear able to prevent significant fire penetration for at least 4 minutes. The failure mode involves gradual conductive heating through the epoxy char to the polycarbonate structural ply which then melts and falls away.

## RECOMENDATION

The principal recommendation is that the FAA perform more detailed evaluations of the performance of these char-forming advanced windows with regard to both resistance to fire and performance in routine use. Particular attention should be given to effects of moisture and aging on epoxy integrity.

## REFERENCE

Eklund, T. I., Preliminary Evaluation of the Effects of Wind and Door Openings on Hazard Development within a Model Fuselage from an External Pool Fire, FAA/NAFEC, Report Number NA-79-1-LR, February 1979.


TEST PREPARATION

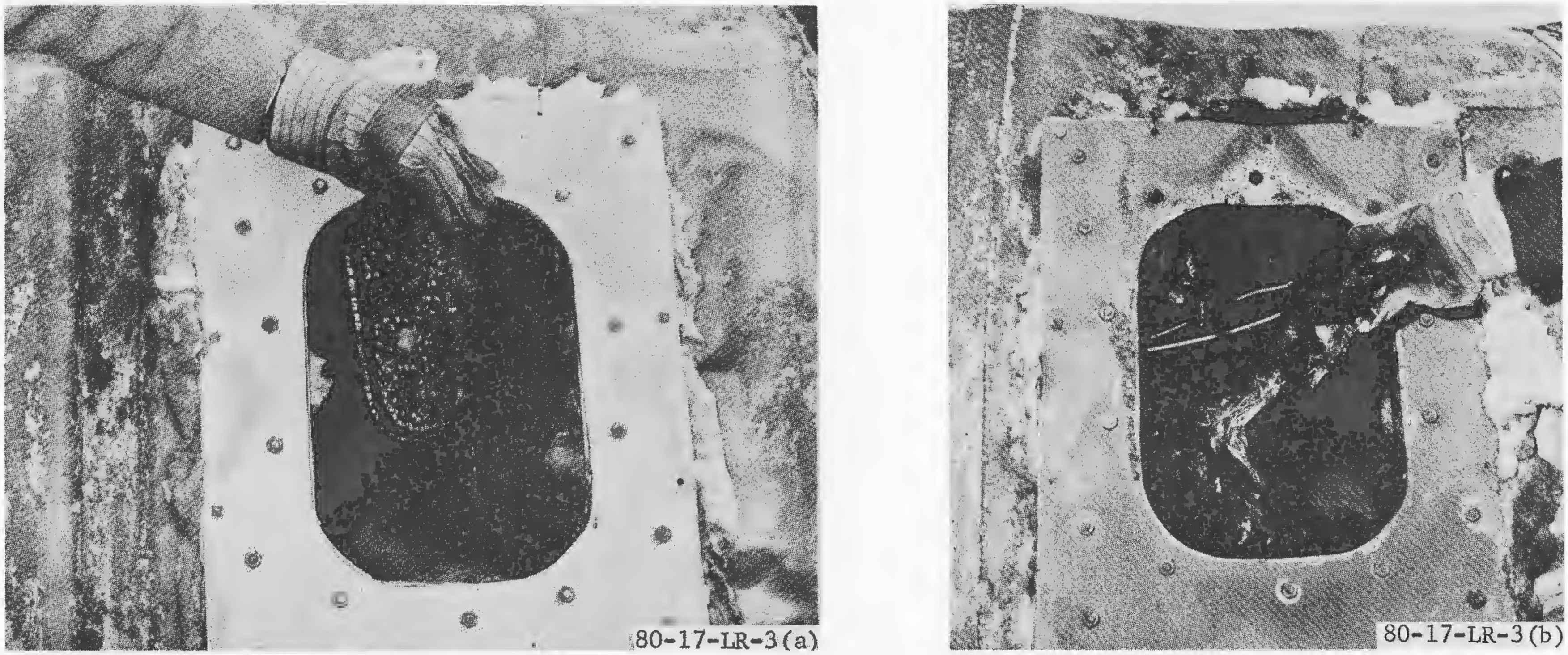

TYPICAL FIRE

FIGURE 1. TEST CONFIGURATION


WINDOW SEGMENTS WITH CALORIMETERS (TESTS 3 AND 4)


COMPLETE WINDOW (TESTS 1 AND 2)

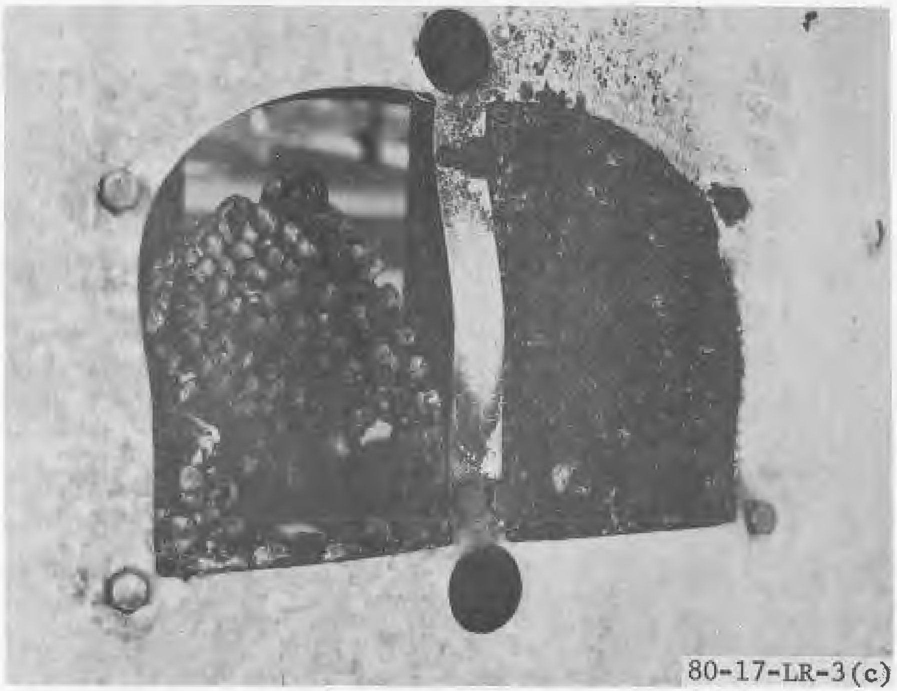
FIGURE 2. WINDOW MOUNTING




TEST 1

TEST 2

FIGURE 3. WINDOW DAMAGE (SHEET 1 OF 2)




TEST 3 (FRONT VIEW)


TEST 4 (REAR VIEW)

FIGURE 3. WINDOW DAMAGE (SHEET 2 OF 2)

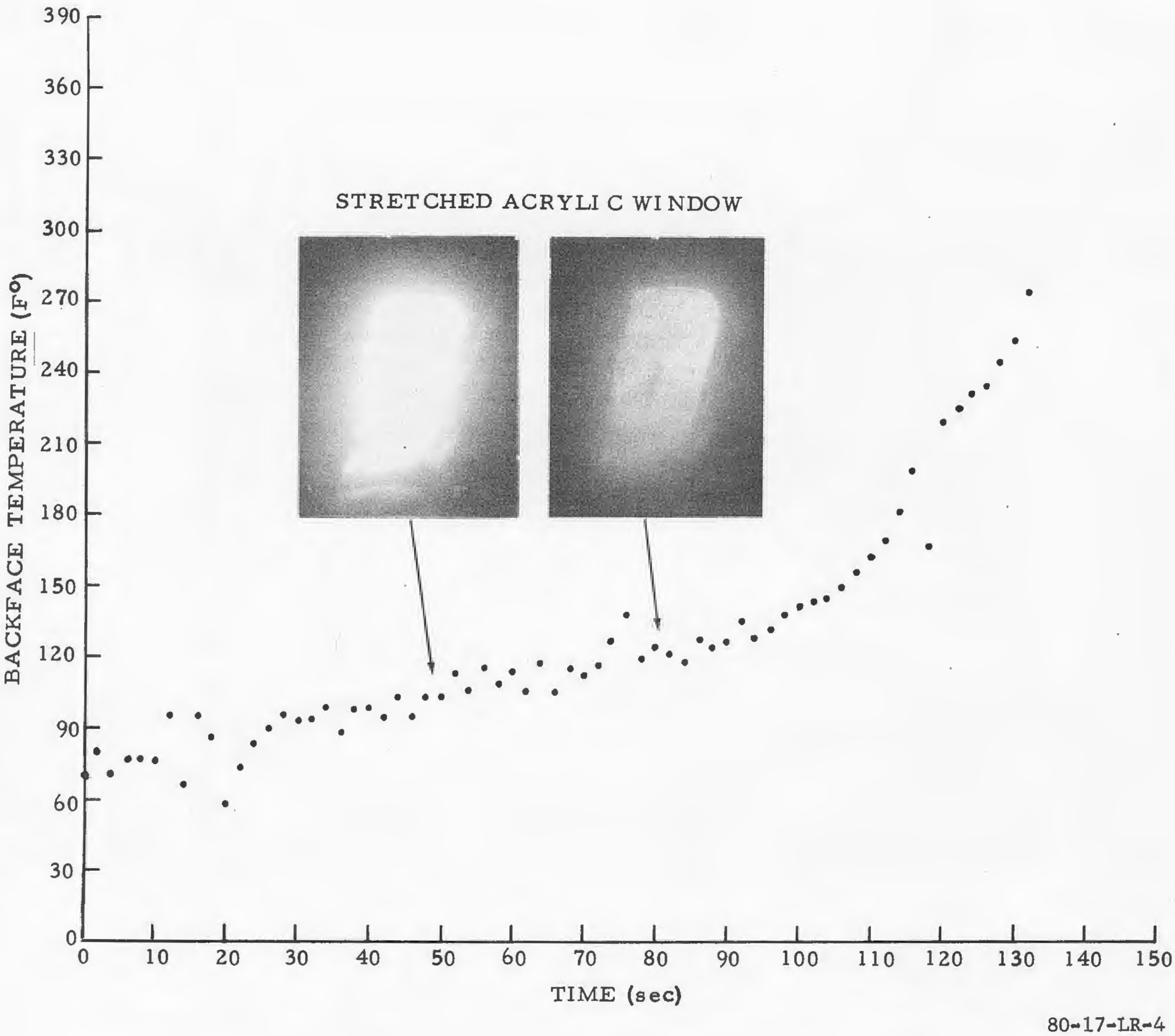



FIGURE 4. BACKFACE TEMPERATURE--(TEST 1)

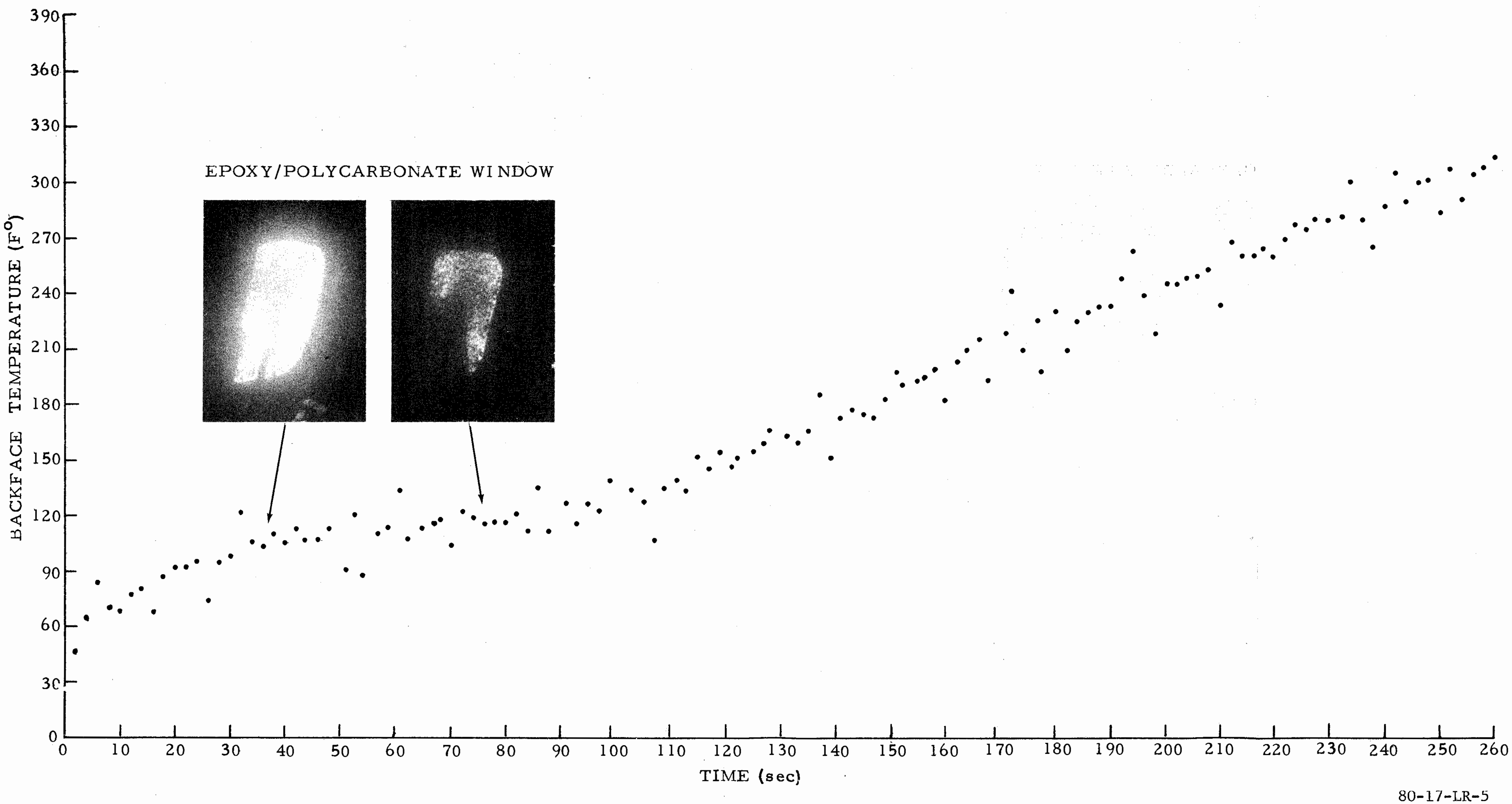
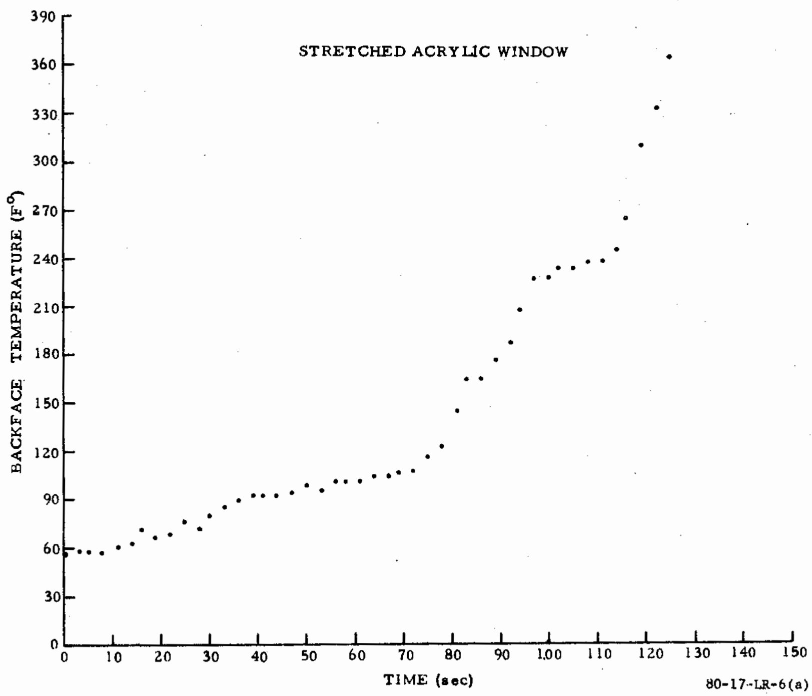



FIGURE 5. BACKFACE TEMPERATURE--(TEST 2)



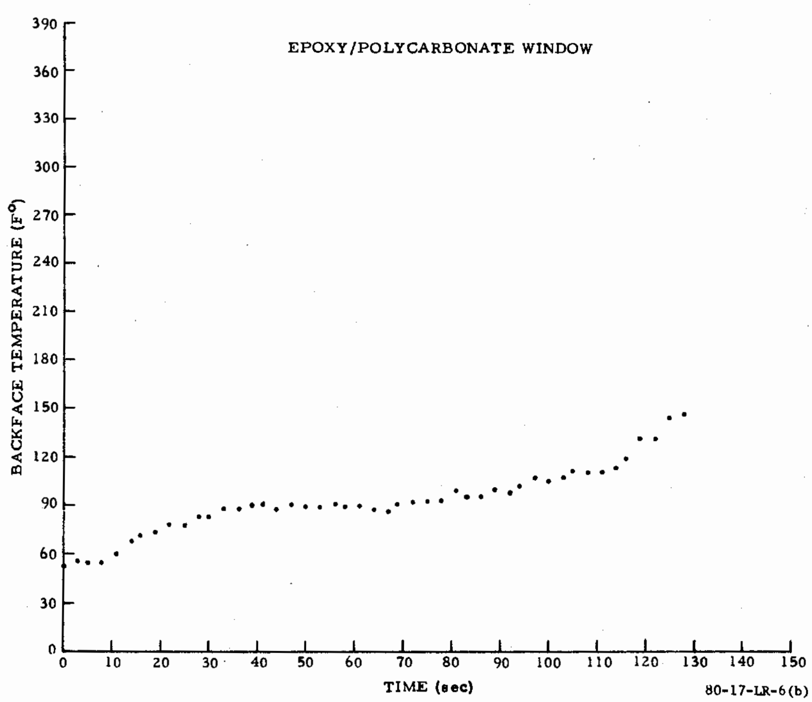
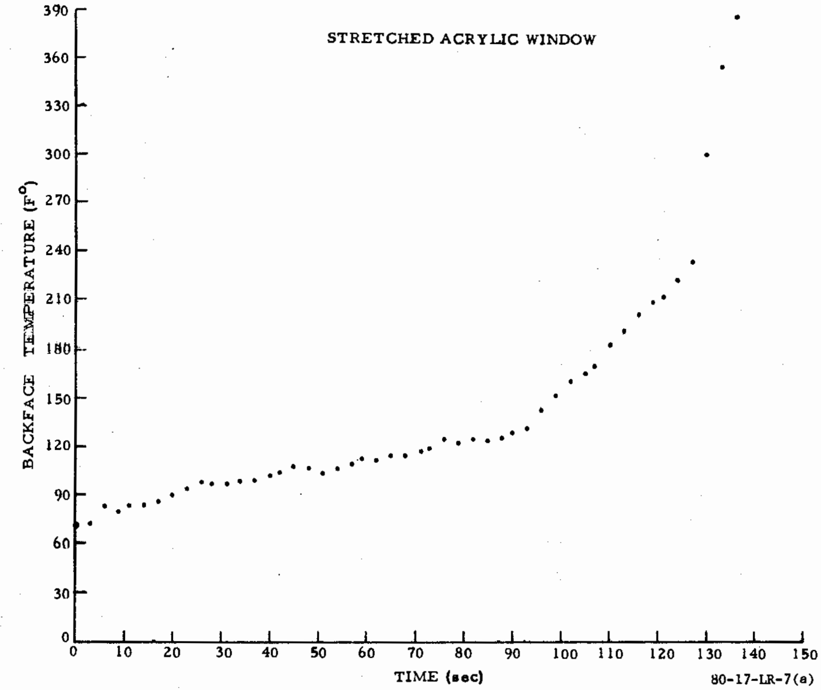




FIGURE 6. BACKFACE TEMPERATURE--(TEST 3)



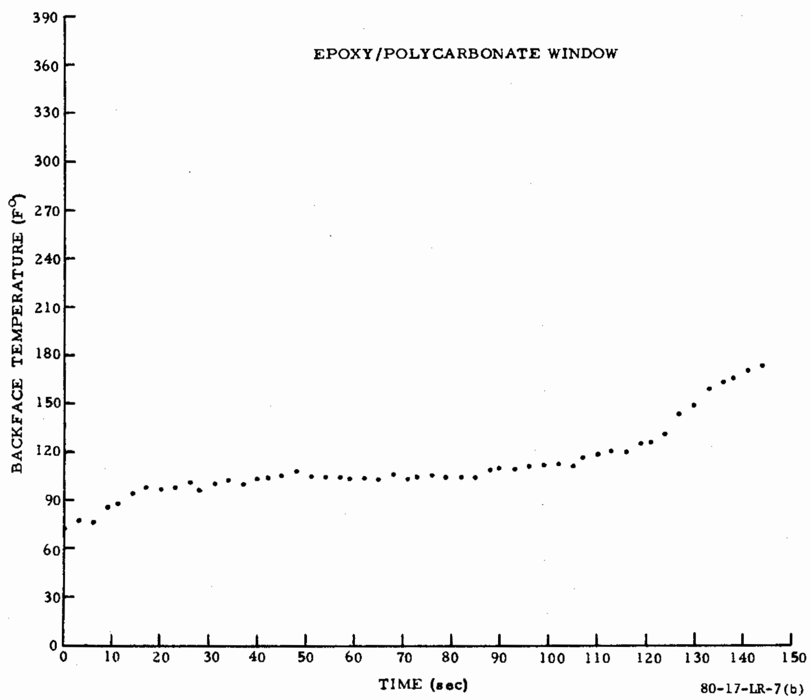




FIGURE 7. BACKFACE TEMPERATURE--(TEST 4)

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