Exposure of Nacelle Panels of the Re-Engined KC-135R Aircraft to a Standard Burner Flame

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April 1984

DOT/FAA/CT-TN84/12

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16. Abstract

One 15-minute fireproof test using a standard Federal Aviation Administration (FAA) fire test burner or a modification thereof, was conducted on each of four panels representative of portions of the re-engined KC-135R nacelle installation. Included were panels representative of those used for the fan cowl, fan duct, and firewall. Of these test samples, the panel representative of the firewall sustained complete flame penetration; those representative of fan cowl panels sustained penetration by the test flame into the aluminum honeycomb sublayer; and that representative of the fan duct panel sustained no visible exterior damage other than warping.

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EXECUTIVE SUMMARY

This project effort was in response to a United States Air Force (USAF) request for assistance in determining the fire protection characteristics of various nacelle components under FAA/USAF Agreement No. CT-168.

One 15-minute fireproof test using a standard Federal Aviation Administration (FAA) fire test burner or a modification thereof, was conducted on each of four 20-inch by 20-inch test samples representative of portions of the re-engined KC-135R nacelle installation. Included were test samples representative of materials used for the fan cowl, fan duct, and firewall. The elastomeric silicone ablative material, which was used in the fabrication of the fan cowl and firewall test samples (the fan duct sample had no ablative), is also used on certain domestic and foreign commercial fixed-wing and rotary-wing aircraft.

The sample representative of the firewall sustained complete flame penetration; those test samples representative of the fan cowl sustained penetration by the test flame into the aluminum honeycomb sublayer; and the test sample representative of the fan duct sustained no visible exterior damage other than warping and discoloration.

INTRODUCTION

PURPOSE.

The purpose of this test program was to expose specially prepared, fireproof rated engine nacelle panels typical of those used in the re-engined KC-135R program to the flame of a standard FAA fire test burner.

BACKGROUND.

The tests described herein were conducted by the Fereral Aviation Administration (FAA) Technical Center, Atlantic City Airport, New Jersey, for the United States Air Force (USAF) (Wright-Patterson AFB, Ohio) under FAA/USAF Agreement No. CT-168. The project effort was undertaken in response to an Air Force request for assistance in the certification of fireproof materials used in the re-engine installation of the KC-135R/CFM56-2-B1 aircraft nacelle.

The 20-inch by 20-inch test panels, fabricated by the Boeing Co. for these tests, were representative of the fan cowl and upper bifurcation; the fan duct outer barrel; and several firewalls located throughout the nacelle. The MA25S (an elastomeric silicone ablative) used in the fabrication of the fan cowl and firewall of the KC-135 is also currently used in the engine installations of a number of commercial and military fixed-wing aircraft and rotorcraft, both foreign and domestic. For this test program, the MA-25S was tested as a fire hardening material relative to the KC-135R only.

Panels identical to those described herein, were tested by the Boeing Co., and the results are contained in their document No. D458-40071-7. The method of fireproof testing as described in this document involved mounting the test panel horizontally at a distance 4 inches above the face of a 6-inch diameter propane burner.

The burner was adjusted to produce a 2000° $\pm$50° F flame at this position by regulation of the burner cooling airflow. The burner used for the tests conducted by the FAA Technical Center is described in the Test Equipment Description section of this report and was fired with Jet A fuel.

Although the Boeing Co. tests and the tests described herein by the FAA Technical Center used a different apparatus to provide the fire environment (propane burner versus standard FAA burner), it was not the objective of this project to compare test methods. As requested by the USAF, and with an Air Force representative present to witness all tests, FAA Technical Center personnel exposed the four Boeing fabricated test panels to the flame of a standard FAA fire test burner, or a modification thereof, for 15 minutes. The results of the FAA tests are documented herein, and they differ substantially from the results of the Boeing tests. Although some commentary is contained in the body of this report, it is left to the judgement of the USAF as to which test method should be used to determine the suitability of these materials for use in their intended aircraft enviornment. The four panels were returned to Wright-Patterson Air Force base by the Air Force representative, immediately upon completion of the FAA tests.

TEST EQUIPMENT DESCRIPTION.

The fire source for these tests was a standard FAA burner; a modified Carlin Model 200 CRD oil burner described in FAA Report RD-76-213. This burner was used in the testing of Sample No. 1 (EX-4133-3) only. Based upon mutual agreement between FAA Technical Center and Wright-Patterson AFB personnel, the standard burner was modified. The original 6-inch by 11-inch oval extension horn was replaced with one which had a 4-inch by 8-inch oval flame exit. This resulted in the burner flame being concentrated over a smaller area. A comparison of the flame characteristics for the standard and modified standard burners is shown in the appendix. Jet A fuel was used in the burner for all tests.

Each test sample was instrumented with two chromel-alumel thermocouples: one at the center of the rear face, the other 6 inches away but in line with the long axis of the burner extension horn. For test specimens, EX-4133-2, -3, and -4, the thermocouples were secured with short sheet metal screws. For test specimen Ex-4133-5, the thermocouples were first secured with high temperature fiber glass tape, and then over each taped thermocouple was placed a curved aluminum strip which was held in place by wedging it between a metal bar behind the specimen and the specimen itself. This arrangement provided positive spring-loaded contact of the thermocouple against the rear face of the test specimen until such time that the specimen began to sag, due to increasing temperature. At some point during the test, there was sufficient sagging so that the spring-loaded effect of the aluminum strips became ineffective. Sheet metal screws were not considered as a method for thermocouple attachment for sample EX-4133-5 because of its construction. With the absence of the honeycomb, the use of sheet metal screws could have compromised its fire integrity.

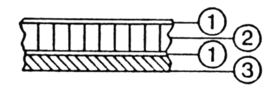
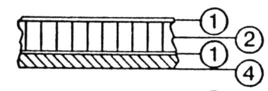
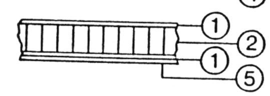
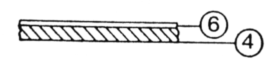
A single chromel-alumel, stainless steel sheathed Ceramocouple™ was used to record flame temperature. Before each test, this thermocouple was placed 1/4 inch from the specimen surface that would be exposed to the flame. During the course of the tests where the test samples were mounted horizontally, the Ceramocouple began to droop toward the burner, and thus, at the tests' end, the thermocouple was not at its original location. All data were recorded using an Accurex Autodata Ten/10 calculating data logger.

The test specimens are described in table 1. Test samples No. 1 (EX-4133-3) and No. 2 (EX-4133-2) were identical except for the thickness of the MA-25S fire protective coating. The specific details of fabrication for all test samples are described on Boeing Co. drawing EX-4133 titled, "Fire Proof Materials Test Panel Kit TCP 468-55 (KC-135R)."

TEST DESCRIPTION.

Test specimen No. 1 (EX-4133-3) was mounted in a frame in a vertical position and placed in front of the burner which was oriented horizontally (figure 1). The placement of the burner, relative to the test specimen was such that the flame impinged at the center of MA-25S coated surface. The distance between the end of the burner extension horn and the test specimen was 2 inches. In FAA Report No. FAA-RD-76-213, a distance of 4 inches from the end of the burner extension nozzle was the point at which all data were recorded. As noted in this FAA report, the standard burner does not, in fact, produce a uniform and constant 2000° F flame at a distance 4 inches from the extension horn. Therefore, a distance of 2 inches

TABLE 1. TEST SAMPLE INFORMATION

BOEING ID.	TEST NO.	WGT. (LB)	AREA DENSITY (LB/FT2)	USAGE	CONFIGURATION
EX-4133-2	2	4.389	1.580	Fan Cowl	
EX-4133-3	1	4.771	1.717	Fan Cowl	
EX-4133-4	4	4.437	1.597	Fan Duct	
EX-4133-5	3	3.375	1.215	Fire Wall	

NOTES

1. 0.040 Stock 2024-T62 Aluminium
2. 0.5 Aluminum Honeycomb BMS4 Type 6-40N
3. 0.094 MA-25.S
4. 0.125 MA-25S
5. 0.005 CRES 321SS
5. 0.063 Stock 2024-T81 Aluminum

was selected, rather than 4 inches, to more closely compare to the 2000° F reported during the Boeing tests of these same panels as noted in their Document No. D458-40071-7.

Test specimens 2, 3, and 4 were mounted horizontally and placed above the burner which was oriented vertically upward (figure 2). For these latter three tests, the 6-inch by 11-inch oval extension horn was replaced with one which produced a smaller flame impingement area. The modification produced a burner flame diffused over an oval area, 4 inches by 8 inches, rather than a 6-inch by 11-inch area. This modification resulted in the temperature more closely approaching the 2000° F target temperature. See figure 3 for the comparison of flame impingement area relative to the sample size for the standard and modified standard burner. For the method of thermocouple attachment for samples 1, 2, and 4, refer to figure 4. The duration of all tests was 15 minutes, including test No. 3 (EX-4133-5), during which the specimen failed prior to the end of the 15-minute period. For the purpose of these tests, failure was defined as the complete penetration of the test sample by the burner flame. Figures 5 through 8 show the test specimens before exposure to fire.

DISCUSSION OF TEST RESULTS

The summary of test results is given in table 2. Figures 9 and 10, respectively, depict typical tests in progress for vertically and horizontally mounted samples.

For test No. 1 (EX-4133-3), the time-temperature relationship indicated by the thermocouples secured to the rear of the test specimen and the thermocouple in the flame is shown in figure 11. The center back-surface thermocouple indicated a higher temperature than did the one 6 inches toward the panel edge. Note that the flame temperature recorded during this test, using the standard burner at a distance of 2 inches, generally fell between 1650° and 1750° F. Complete penetration of the test specimen by the burner flame did not occur. However, as shown in figure 12, the MA-25S had cracked with some portions falling away, thus exposing the underlying aluminum sheet. The exposed aluminum sheet was then penetrated by the flame prior to the end of the test, as is evidenced by the aluminum honeycomb which is visible at the center of the photograph. Figure 13 shows the rear surface, i.e., the surface not directly exposed to fire, of sample No. 1 with the heat affected zone shown by the light area in the middle of the photograph.

Figure 14 shows the temperature data for test No. 2 (EX-4133-2). Figures 15 and 16 show the front and rear surfaces of this test sample after testing. This panel was the first of the remaining three samples to be subjected to the flame of the modified standard burner i.e., that with the smaller flame impingement area. Center and edge temperatures were somewhat higher than in test No. 1 which is probably due, in part, to the thinner coating of MA-25S (0.094 inches versus 0.125 inches for the -2 and -3, respectively). Note that the flame temperature recorded during this test, using the modified standard burner at a distance of two inches, generally fell between 1925° and 1975° F. This higher flame termperature as compared to test No. 1 is another probable factor contributing to the higher recorded sample temperature. The results of test No. 3, shown in figure 17, were similar to those of test No. 1. The MA-25S cracked and exposed the underlying aluminum sheet which eventually was penetrated by the burner flame, thus exposing the inner aluminum honeycomb construction. At approximately 1 1/2 minutes into the test a loud "pop" was heard. This was also noted in Boeing report No. D458-40071-7 and was attributed to the ignition of the out-gassing fumes of the bonding agent.

TABLE 2. SUMMARY OF TEST RESULTS

TEST NO.	BOEING ID.	SAMPLE TEST POSITION	TEST DURATION	FAILURE/ TIME (MIN:SEC)	BURNER (2)
1.	EX-4133-3	VERTICAL	15 MIN.	NO	STD
2.	EX-4133-2	HORIZONTAL	15 MIN.	NO	MOD. STD.
3.	EX-4133-5	HORIZONTAL	(15 MIN.) (1)	YES/7:15	MOD. STD.
4.	EX-4133-4	HORIZONTAL	15 MIN.	NO	MOD. STD.

NOTES:

(1) Test continued for the 15 minute duration although flame penetration of the test sample occurred at 7:15.

(2) MOD. STD. - modified standard burner provided a 4" x 8" oval flam area; STD - standard burner provided a 6" x 11" oval flame area.

Figure 17 shows the temperature data for test No. 3 (EX-4133-5). This test sample, which was described as firewall material, indicated the highest center temperature and was the only sample to be completely penetrated by the burner flame. The flame penetration was visually observed near the center of the panel at the mid-point of the 15-minute test, i.e., 7 minutes 15 seconds. The panel center thermocouple plot in figure 17 shows no sharp temperature rise at the time of flame penetration, since the flame penetration did not occur at the exact location of the thermocouple on the rear surface of the test sample. The test was continued for the entire 15 minute duration. The flame temperature recorded during this test generally fell between 1800° and 1875° F. Figures 18 and 19 show the front and rear surfaces of sample No. 3 after testing. The area which was penetrated is seen at approximately the center of each of these figures.

Figure 20 shows the temperature data for test No. 4 (EX-4133-4). The flame temperature generally fell between 1825° and 1875° F. This was the only sample tested that did not have a coating of MA-25S. In place of the MA-25S was a thin stainless steel sheet (0.005 inches). See table 1 for the sample configuration. Figures 21 and 22 show the front and rear surfaces after testing. Note that on the rear surface (figure 22) the heat affected zone, as indicated by the lighter colored area, is larger than that of the other three samples. It is surmised that this was due to the absence of the MA-25S coating, which provided an insulating layer. Note, also, that the edge thermocouple indicated the highest temperature of the four samples. At approximately 2 minutes into the test, a loud "pop" was heard similar to that noted during the testing of sample No. 2 (EX-4133-2).

There was no load exerted on any of the samples during testing. Therefore, no definite statements can be made relative to the panels structural characteristics at elevated temperature. The panels, as used in the K-135R engine nacelle installation, are reportedly structural members in addition to being heat barriers. The temperatures indicated by the thermocouples secured to the rear surface of the test specimens would necessarily result in a degradation of physical properties as compared to that at ambient nacelle operating temperature. Among the four samples tested, the edge thermocouple indicated temperatures ranging from 650° to 825° F and the center thermocouples indicated temperatures ranging from 925° to 1125° F. This could conceivably result in physical strength properties in the heat affected areas of less than 10 percent of those at room temperature. This does not include the additional loss of structural integrity due to the penetration of the MA-25S and aluminum sublayer by the burner flame as in sample No. 1 and 2.

Because of the construction, the front and rear aluminum liners of the honeycomb sandwich contribute to the panel's overall structural strength. The penetration of one or both of these liners could tend to degrade the panel's structural integrity over and above that degradation due to elevated temperatures alone.

The following information was extracted from the seventh edition of the "Standard Handbook for Mechanical Engineers:"

TYPICAL TENSILE PROPERTIES OF ALUMINUM ALLOY 2024-T4 AT ELEVATED TEMPERATURES

Alloy and Temper	Property	Temperature, F 75°	300°	400°	500°	700°
2024-T4	T.S.	68000	46000	27000	14000	5000
	Y.S.	44000	38000	21000	9500	3500
	EL.	22	22	25	45	100

The alloy (2024) shown in this table is the same as that used by Boeing to cover the front and rear faces of the honeycomb. The exact temper of the aluminum sheet, -T62, was not listed in this publication. The items listed in the "Property" column are defined as follows: T.S.-tenisle strength, psi; Y.S.-yield strength, 0.2 percent offset, psi; EL.-elongation in 2 inches, percent. This table is presented only to illustrate the degradation of certain physical properties of an aluminum alloy at elevated temperatures. No attempt is made to relate this information directly to the possible degradation in structural integrity of the KC-135R nacelle panels while undergoing fireproof testing.

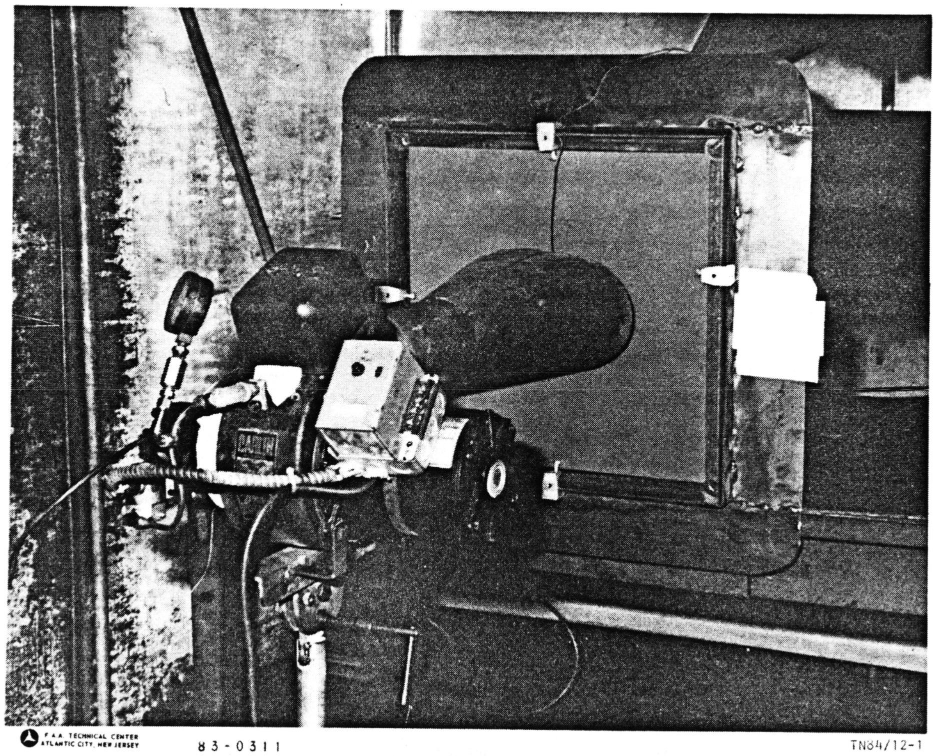


FIGURE 1. TYPICAL TEST SET-UP WITH SAMPLE MOUNTED VERTICALLY/ BURNER HORIZONTAL

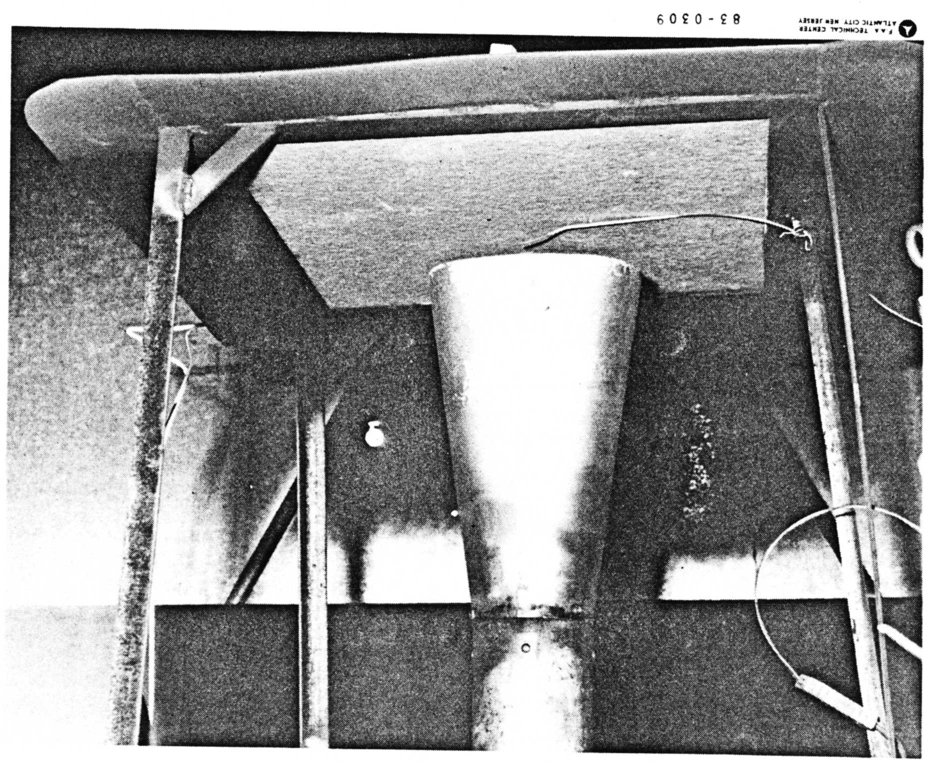


FIGURE 2. TYPICAL TEST SET-UP WITH SAMPLE MOUNTED HORIZONTALLY/ BURNER VERTICAL

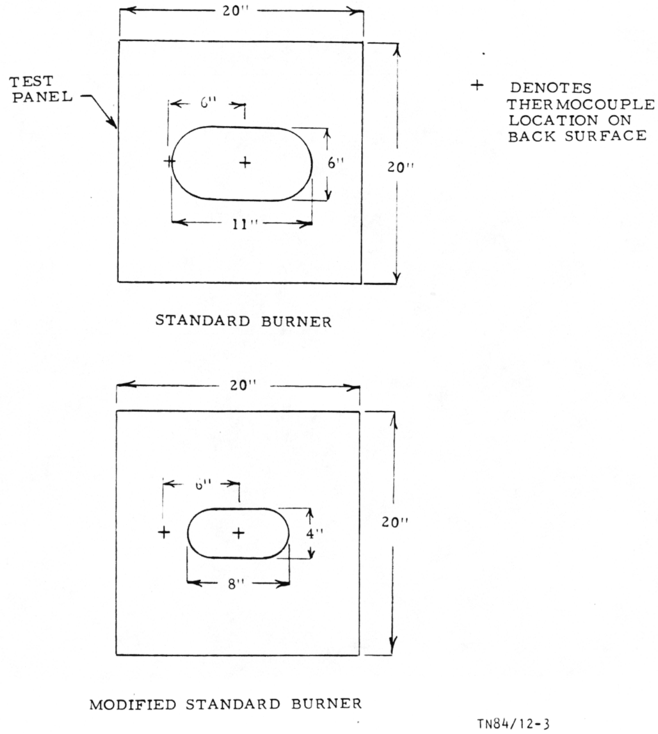


FIGURE 3. NOZZLE PROFILE FOR STANDARD AND MODIFIED STANDARD BURNER RELATIVE TO TEST PANEL

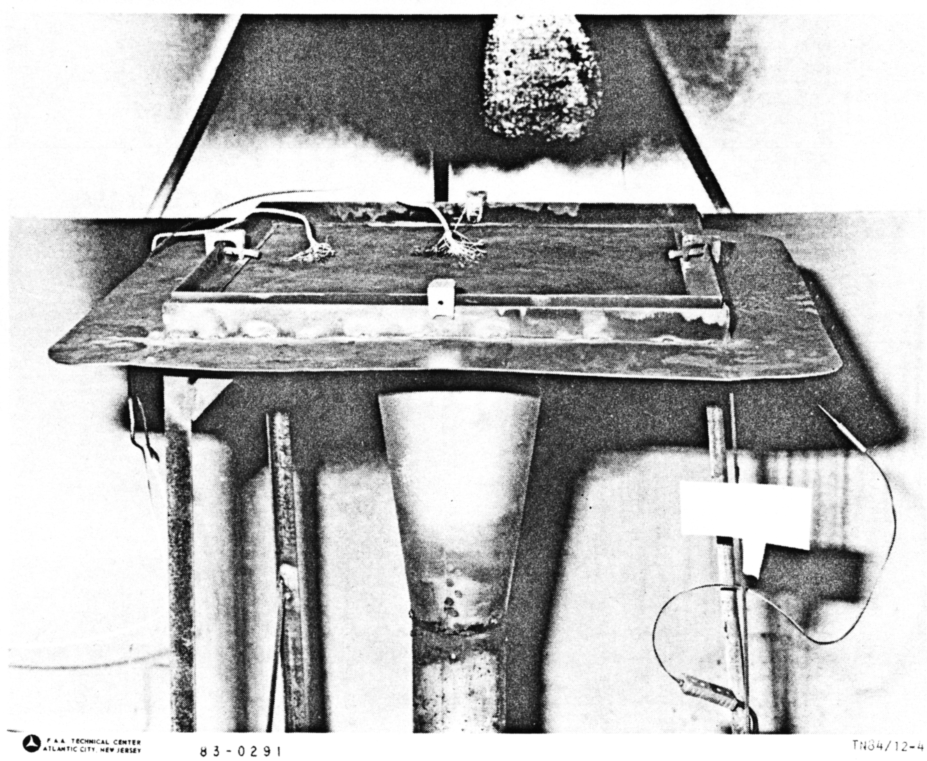


FIGURE 4. REAR OF TEST SAMPLE SHOWING THERMOCOUPLE INSTALLATION

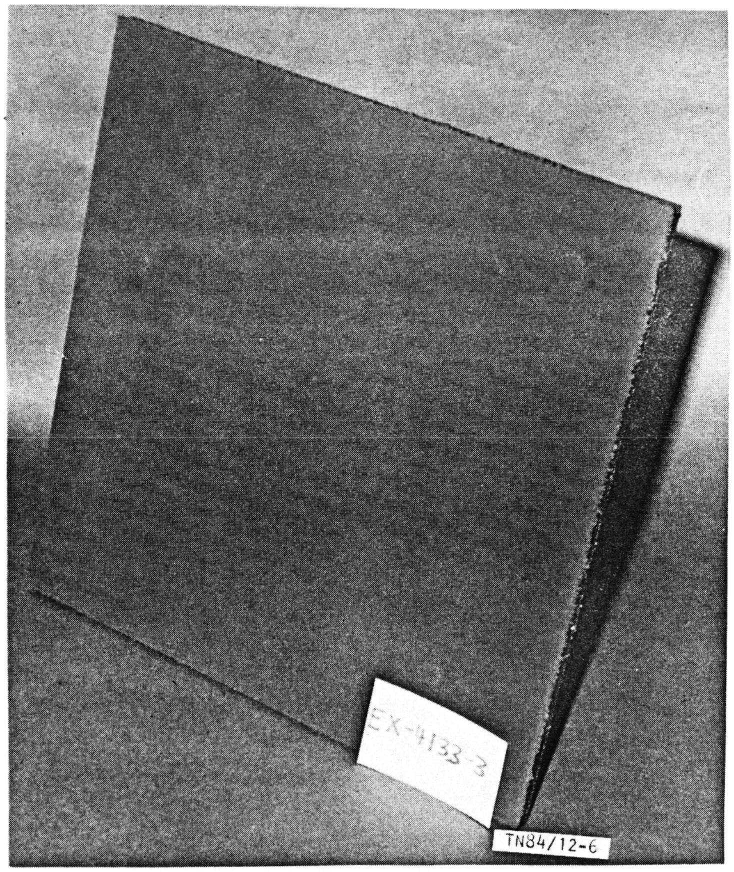


FIGURE 5. TEST SAMPLE NO. 1 (EX-4133-3) BEFORE TEST

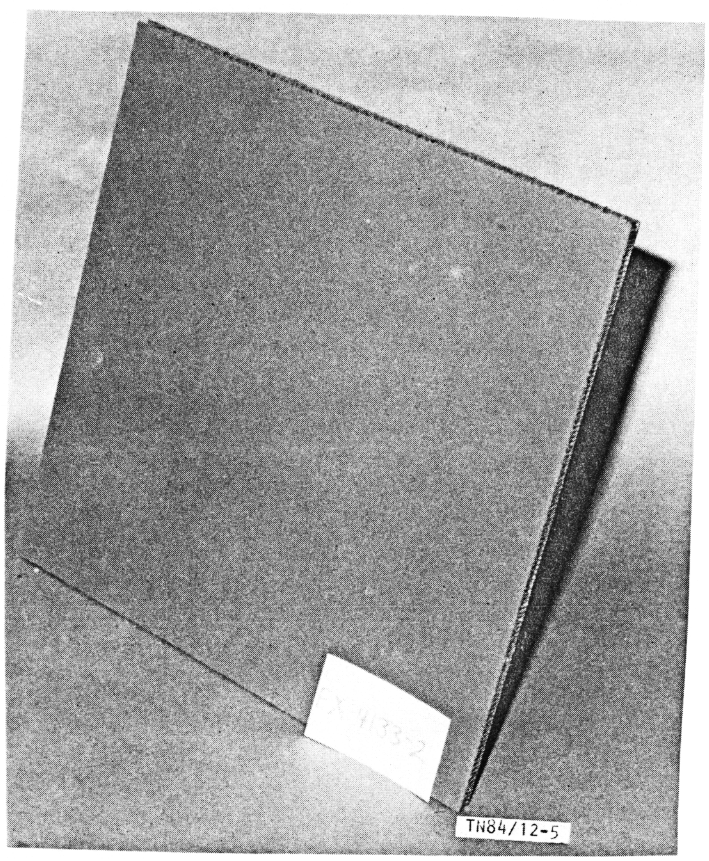


FIGURE 6. TEST SAMPLE NO. 2 (EX-4133-2) BEFORE TEST

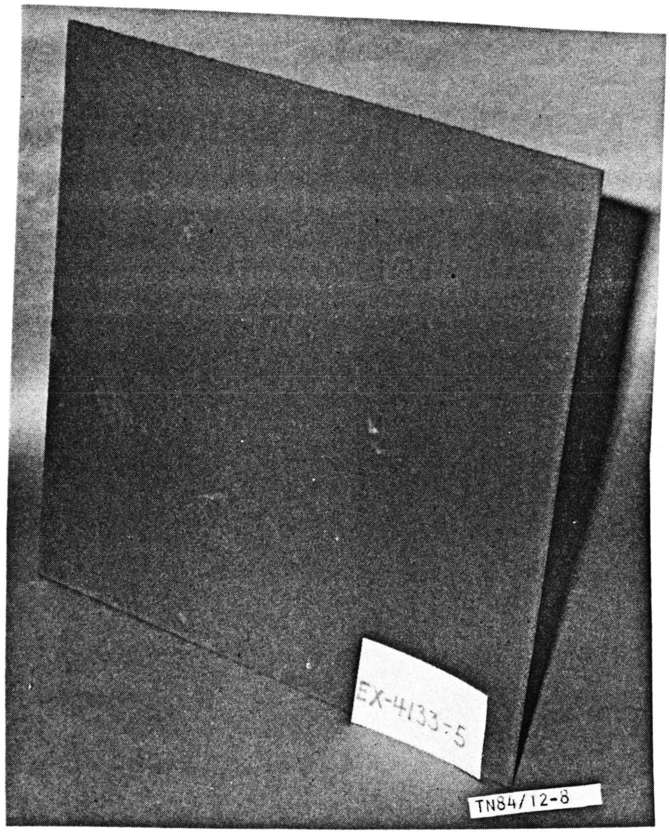


FIGURE 7. TEST SAMPLE NO. 3 (EX-4133-5) BEFORE TEST

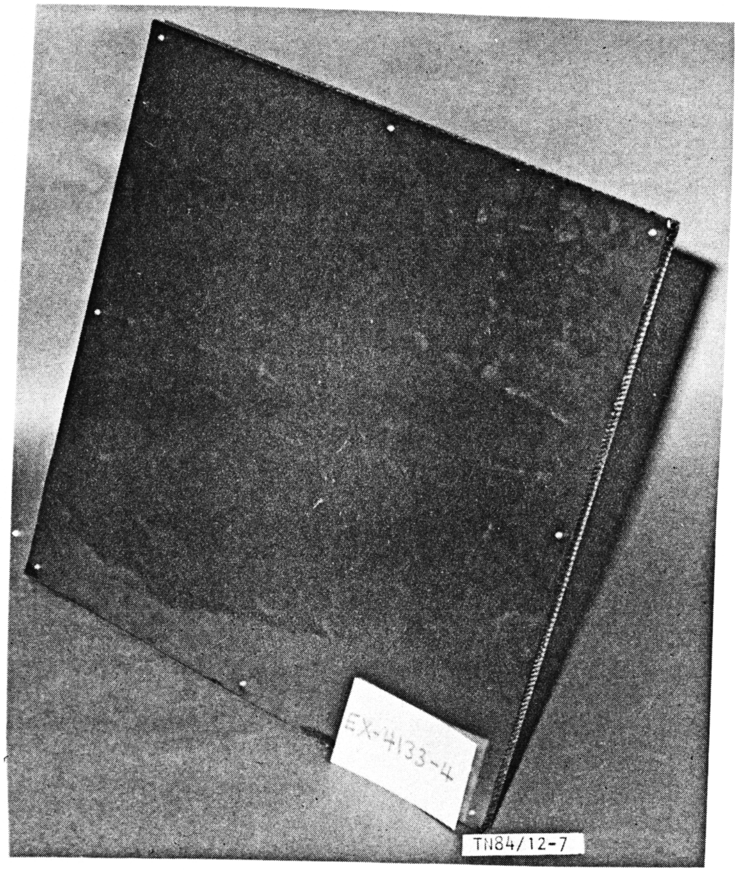


FIGURE 8. TEST SAMPLE NO. 4 (EX-4133-4) BEFORE TEST

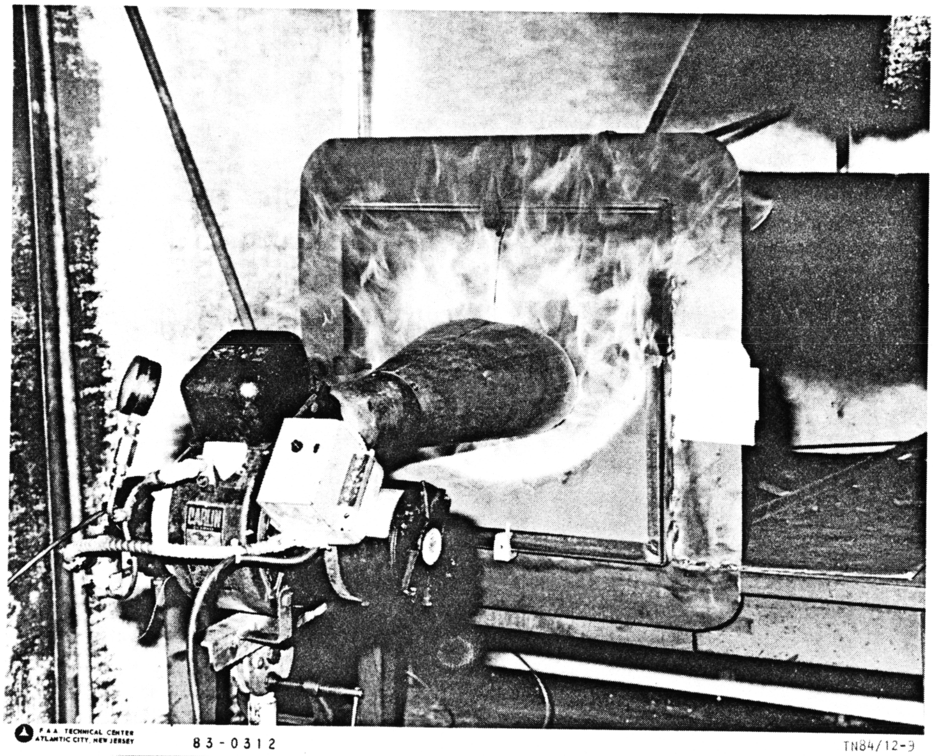


FIGURE 9. TYPICAL TEST WITH SAMPLE MOUNTED VERTICALLY/BURNER HORIZONTAL

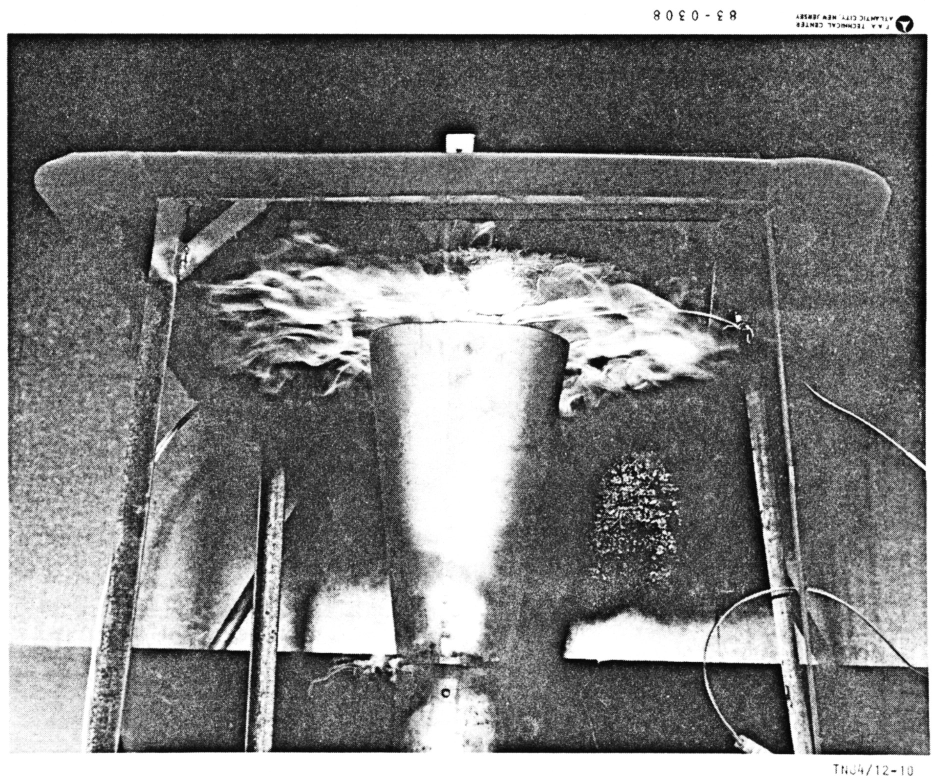


FIGURE 10. TYPICAL TEST WITH SAMPLE MOUNTED HORIZONTALLY/BURNER VERTICAL

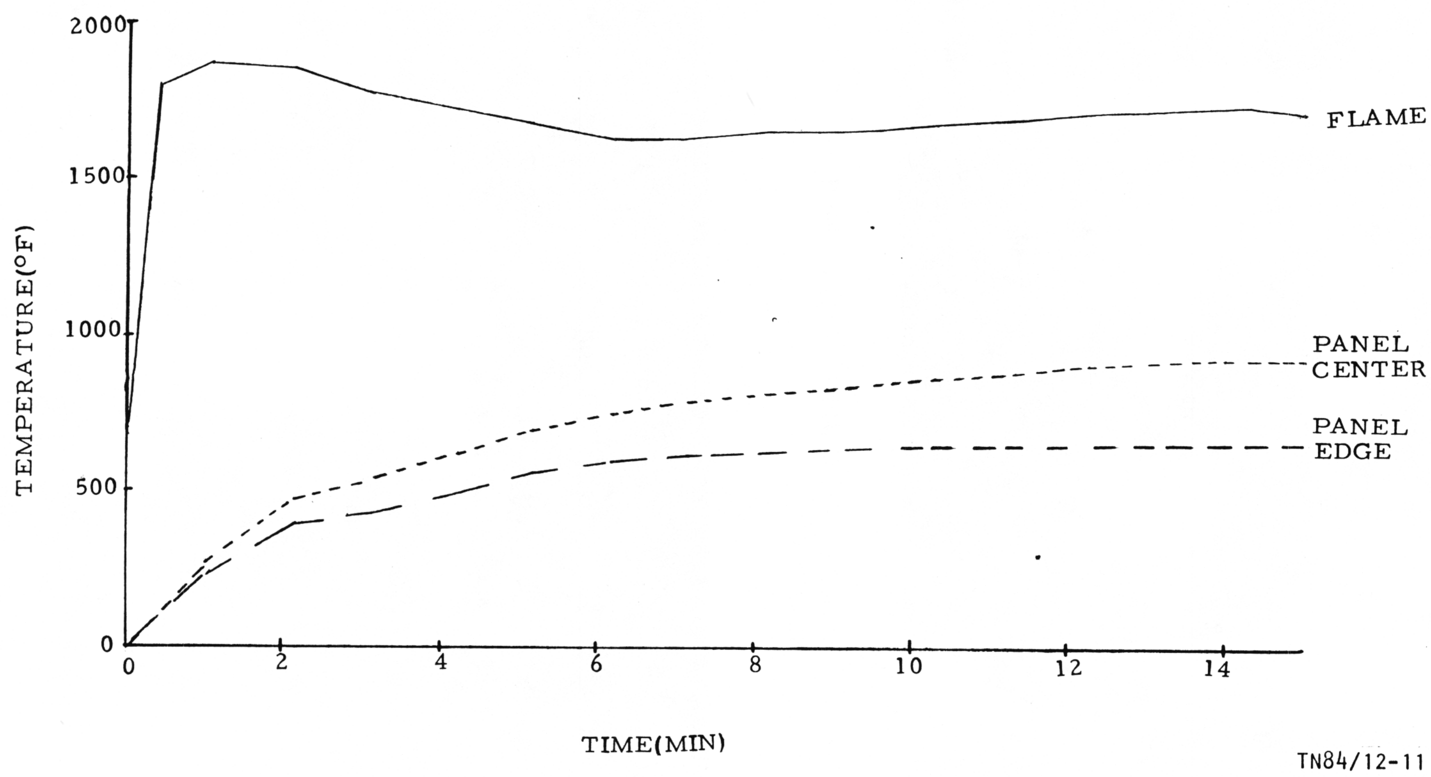


FIGURE 11. TIME-TEMPERATURE PLOT FOR SAMPLE NO. 1(EX-4133-3)

FIGURE 12. FRONT OF TEST SAMPLE NO. 1 (EX-4133-3) AFTER TEST

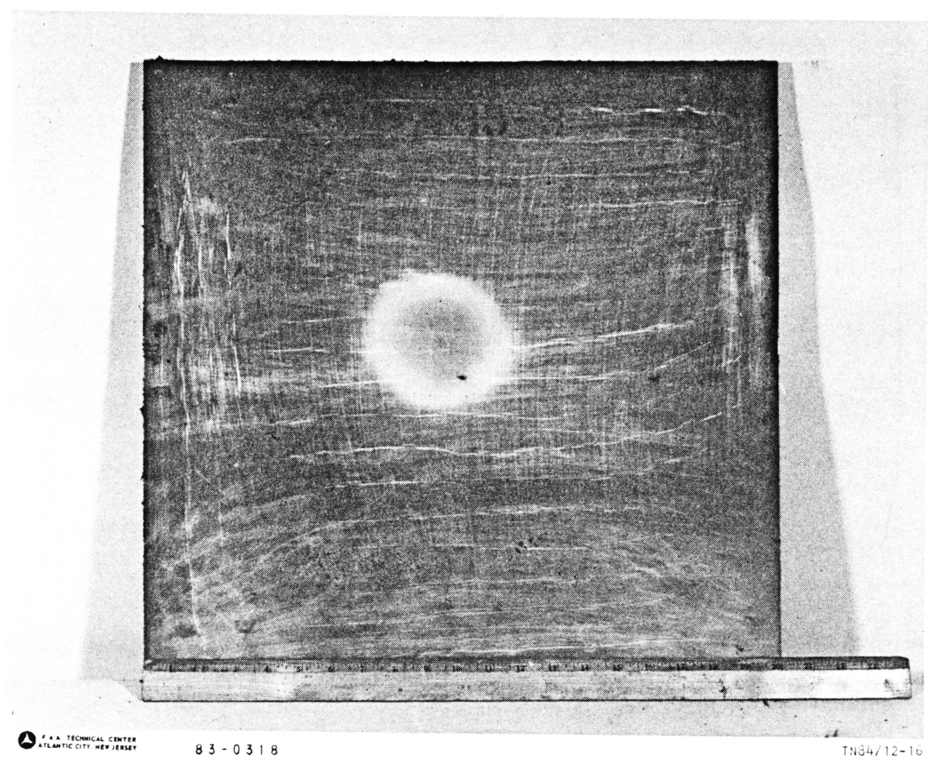


FIGURE 13. REAR OF TEST SAMPLE NO. 1 (EX-4133-3) AFTER TEST

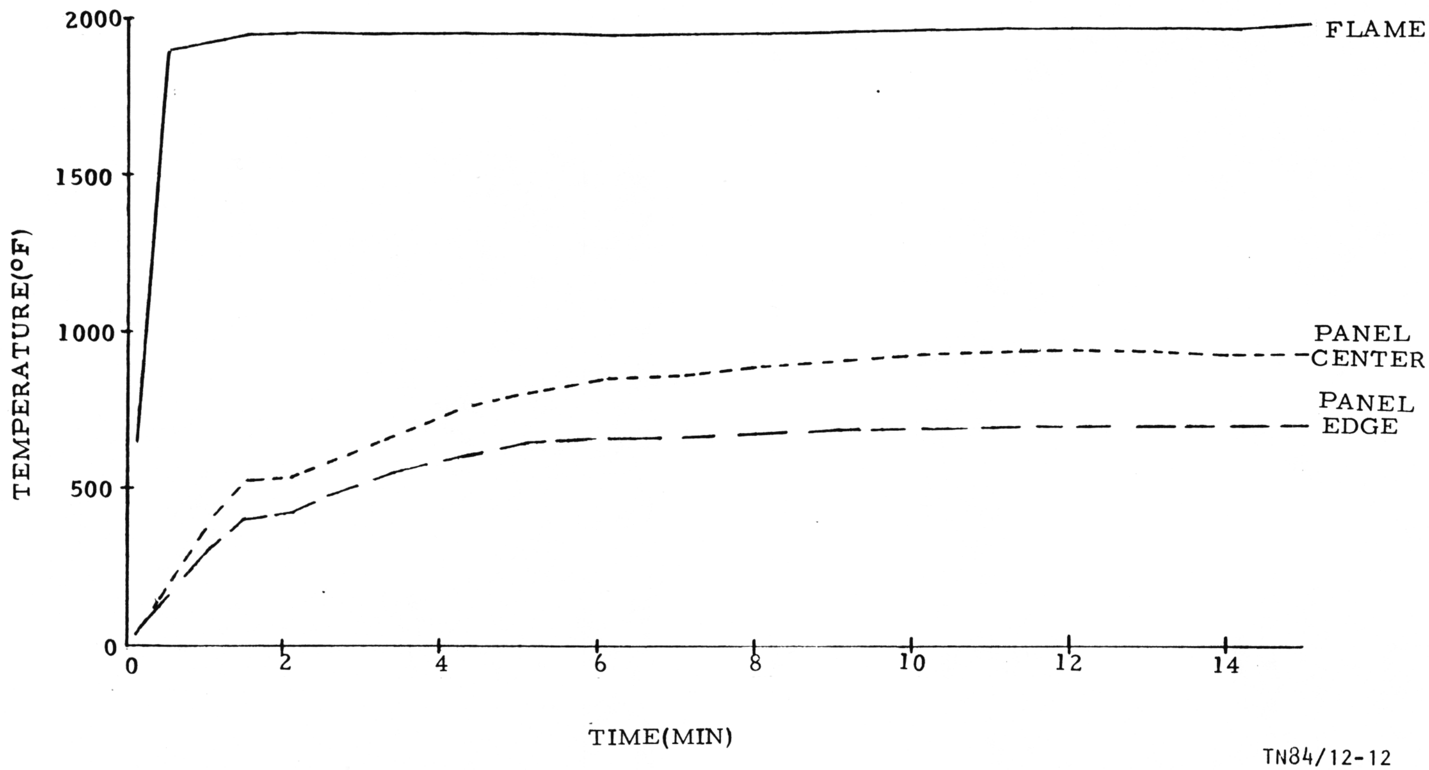


FIGURE 14. TIME-TEMPERATURE PLOT FOR SAMPLE NO. 2(EX-4133-2)

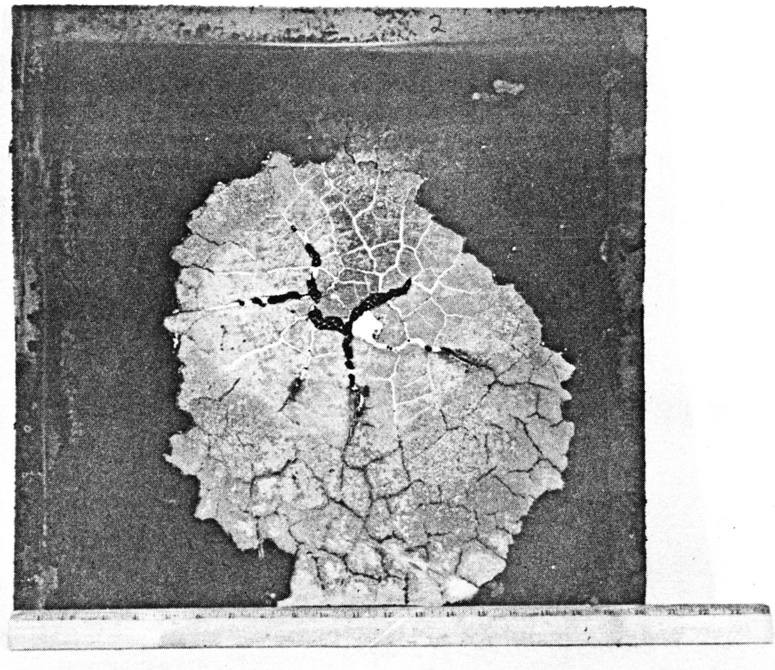


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FIGURE 15. FRONT OF TEST SAMPLE NO. 2 (EX-4133-2) AFTER TEST

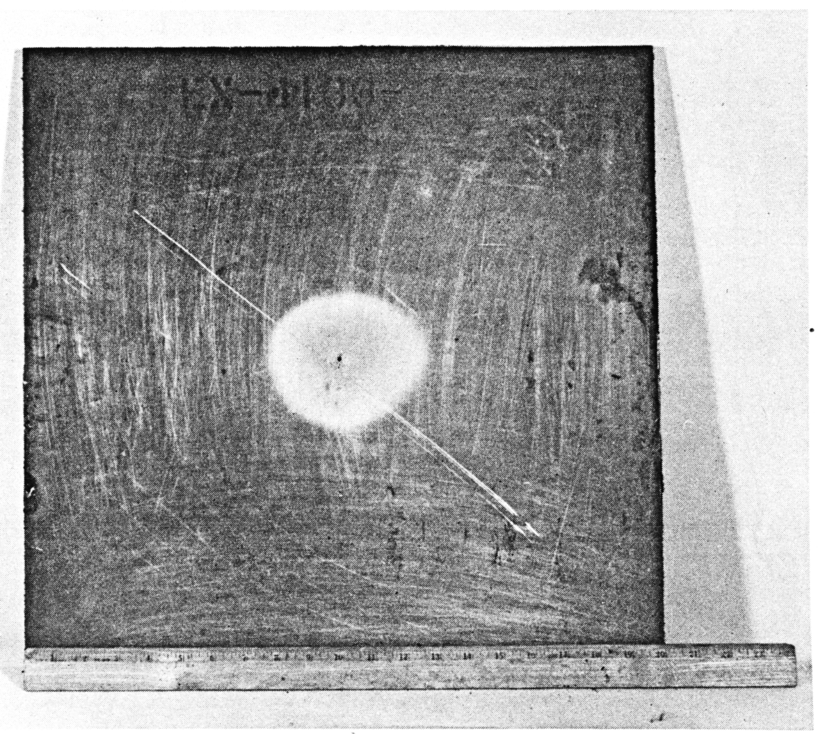

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FIGURE 16. REAR OF TEST SAMPLE NO. 2 (EX-4133-2) AFTER TEST

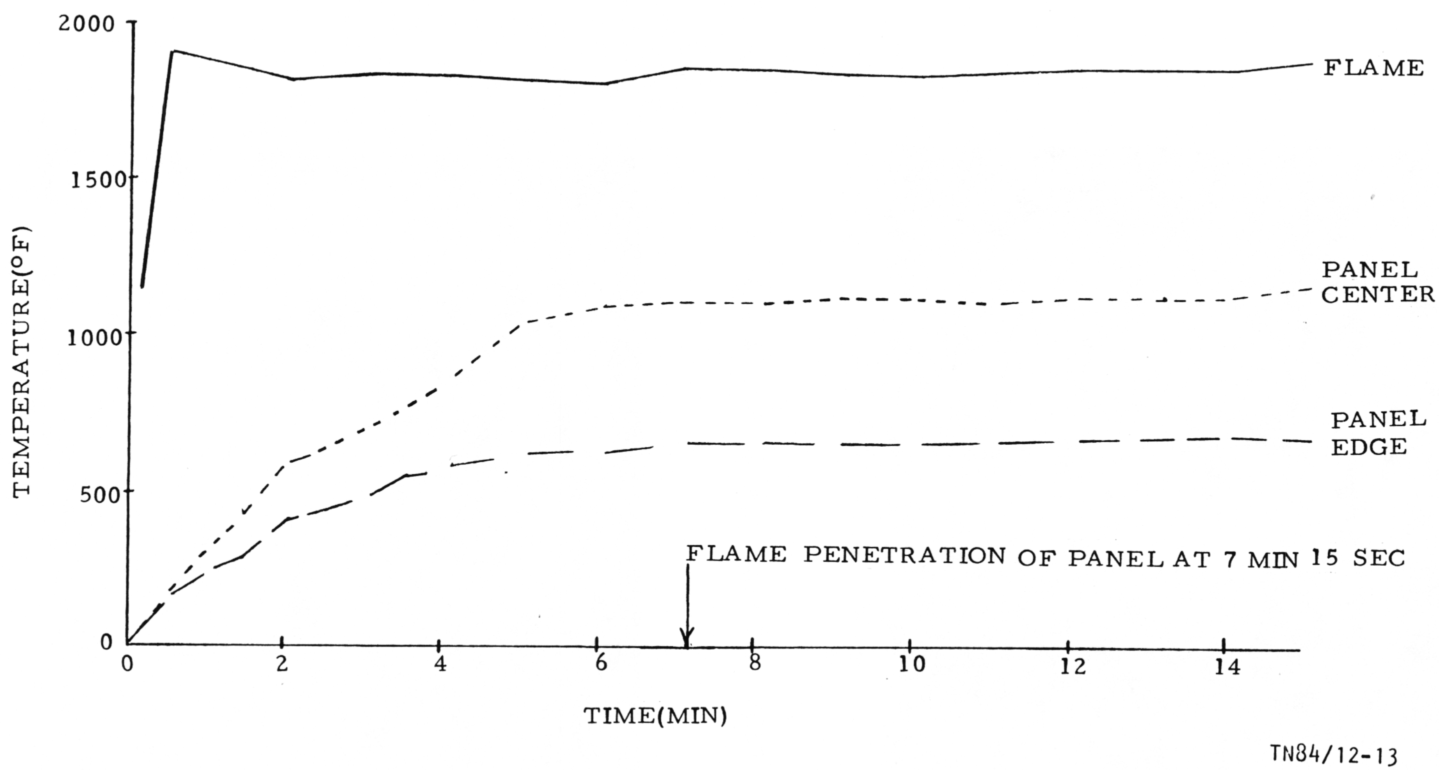

FIGURE 17. TIME-TEMPERATURE PLOT FOR SAMPLE NO. 3(EX-4133-5)

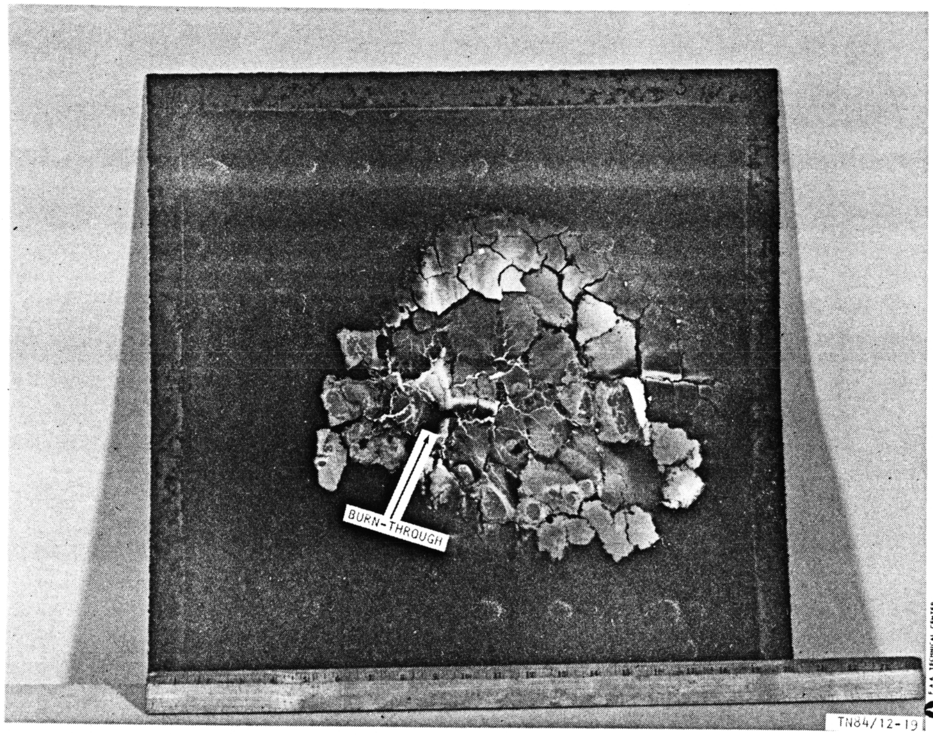

FIGURE 18. FRONT OF TEST SAMPLE NO. 3 (EX-4133-5) AFTER TEST

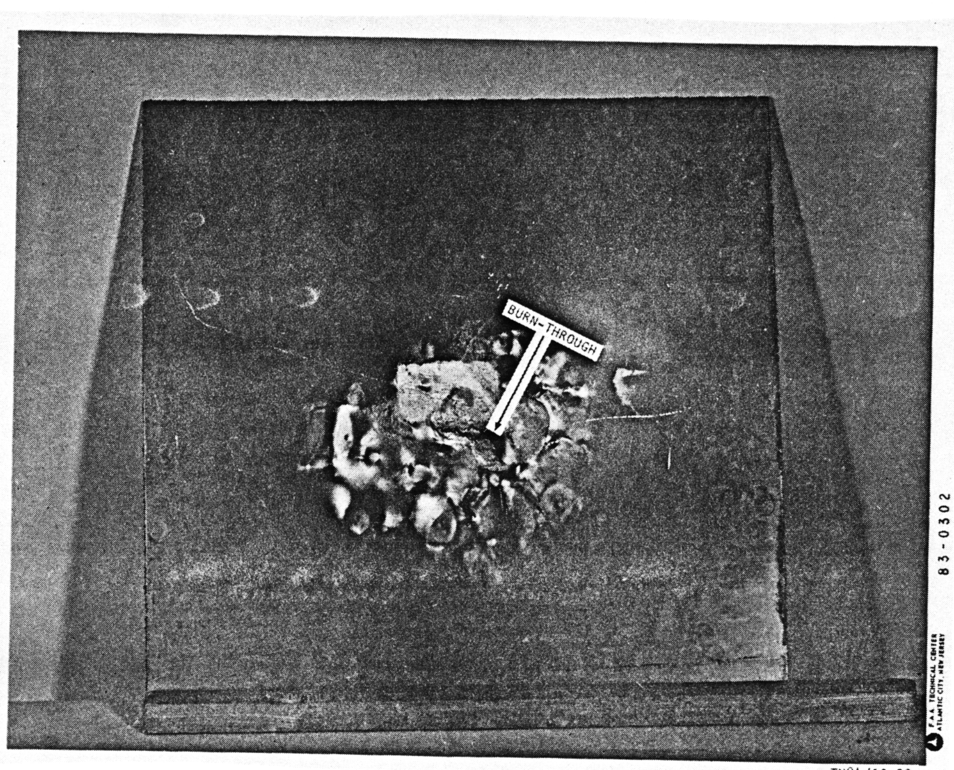

FIGURE 19. REAR OF TEST SAMPLE NO. 3 (EX-4133-5) AFTER TEST

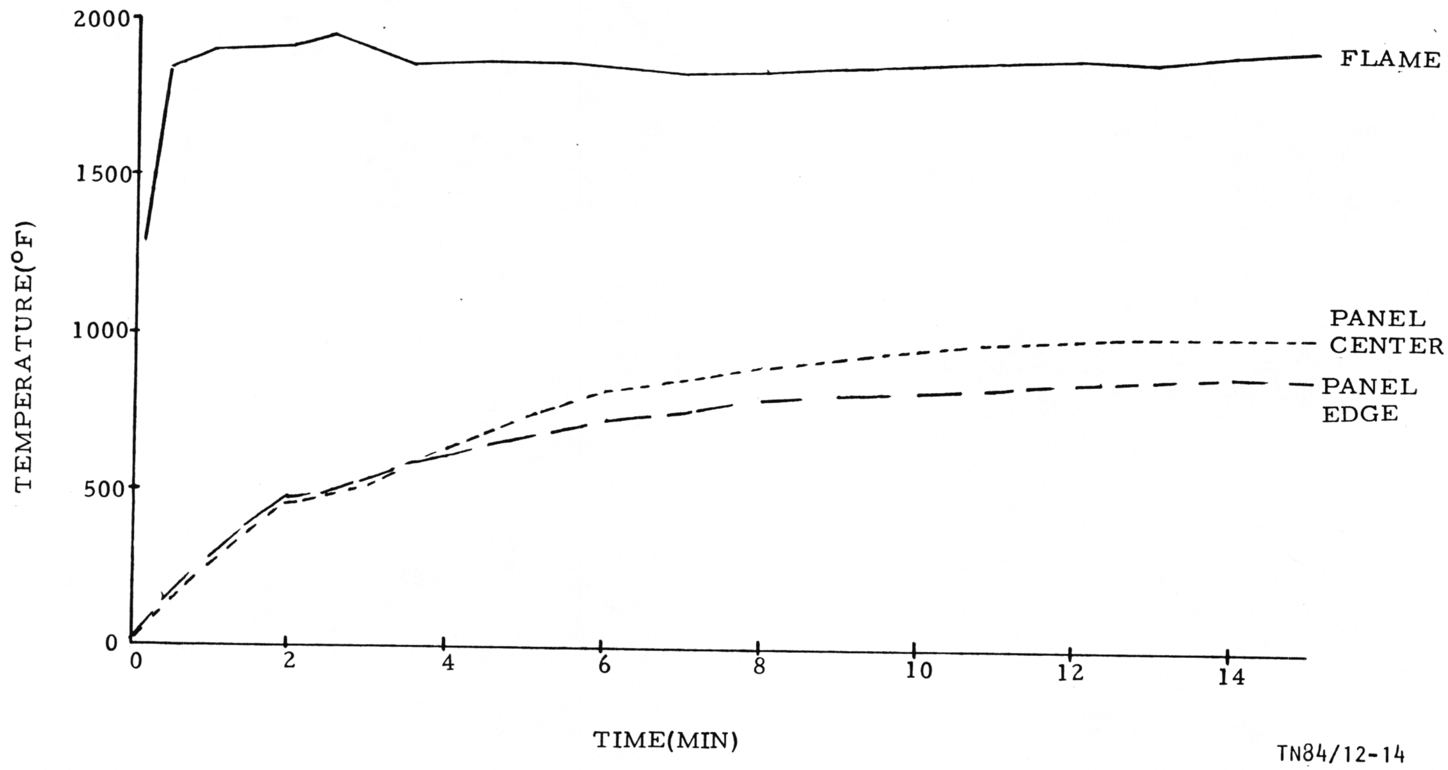

FIGURE 20. TIME-TEMPERATURE PLOT FOR SAMPLE NO. 4(EX-4133-5)

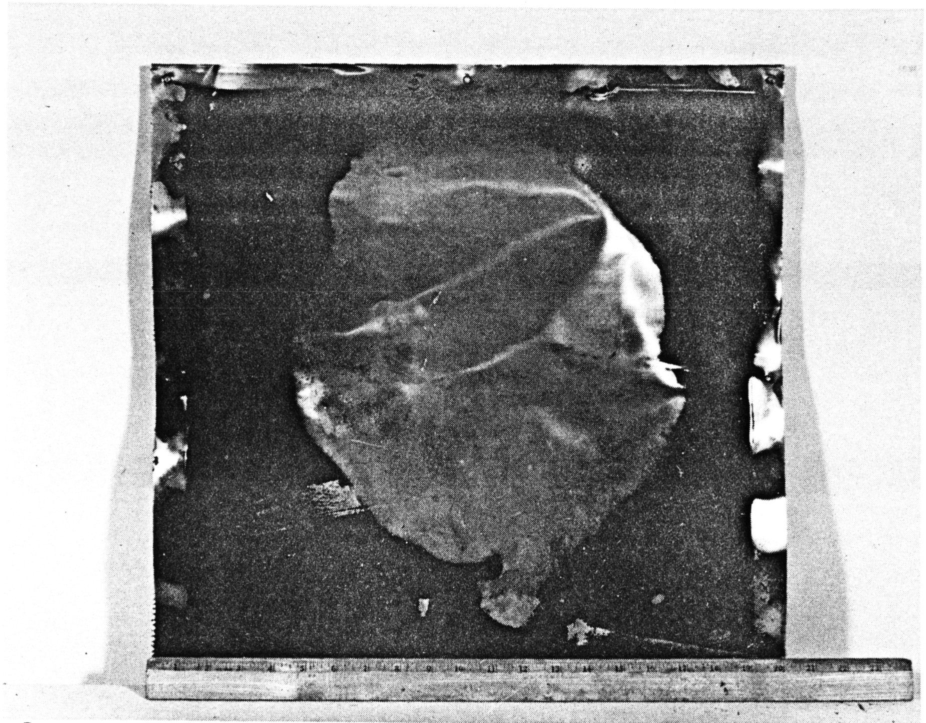

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FIGURE 21. FRONT OF TEST SAMPLE NO. 4 (EX-4133-4) AFTER TEST

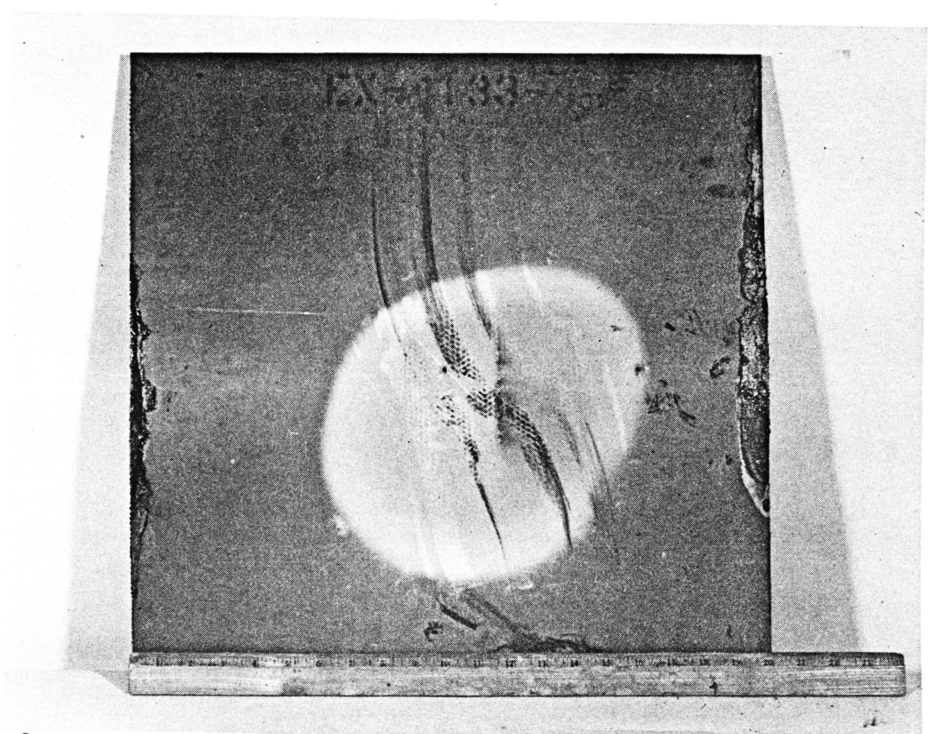

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FIGURE 22. REAR OF TEST SAMPLE NO. 4 (EX-4133-4) AFTER TEST

APPENDIX A

COMPARISON OF FLAME CHARACTERISTICS

OF THE STANDARD AND MODIFIED

STANDARD BURNER

The characteristics of the standard Federal Aviation Administration (FAA) fire test burner, as used in the testing of Boeing sample EX-4133-3, are documented in Report No. FAA-RD-76-213. The characteristics of the same burner after modification by the addition of a 4-inch by 8-inch extension horn, are documented in this appendix.

Figure A-1 is a graphical interpretation of the flame temperature through the center of the Carlin 200 CRD standard burner flame with the 6-inch by 11-inch extension horn. The data on which figure A-1 is based were taken from figure 14 of Report No. FAA-RD-76-213. The data in figure 14 display the flame temperatures as recorded two inches from the end of the extension horn. The vertical height of each column in figure A-1 is the average of the two temperatures taken on either side of the horizontal centerline of the standard burner shown in figure 14 of the FAA report. The 11 columns represent each inch of width of the 6 inch by 11 inch extension horn. The horizontal dashed line through figure A-1 represents the average flame temperature based on the data shown in this figure. That average is calculated to be 1857° F. The heat transfer rate to a 1/2 inch diameter water tube and total heat flux, also taken from the FAA report, are 4545 Btu/hr and 9.3-11.2 Btu/ft^2/sec, respectively.

Figure A-2 shows the temperature profiles through the horizontal centerline of the flame produced by the Carlin 200 CRD standard burner after it had been modified with the 4 inch by 8 inch extension horn. The profiles shown are for distances of 2 and 4 inches from the exit plane of the extension horn. The horizontal dashed line shown in figure A-2, represents the average flame temperature at the 2 inch distance. That value is calculated to be 1854° F. This compares to 1857° F for the same burner with the 6 inch by 11 inch extension horn.

Figure A-3 shows the heat flux values as recorded in the flame along the horizontal centerline of the 4 inch by 8 inch extension horn two inches from the exit plane. At this two inch distance the heat flux values ranged from a low of 7.6 to a high of 11.2 Btu/ft^2/sec. The horizontal dashed line through figure A-3, represents the average heat flux across the 8 inch width. This calculated to be 9.85 Btu/ft^2/sec. This compares to 9.3 to 11.2 Btu/ft^2/sec for the same burner with the 6 inch by 11 inch extension horn as documented in Report No. FAA-RD-76-213.

Using the heat transfer device, i.e., a 1/2 inch diameter copper tube through which water is flowing at a rate of 500 lb/hr, the heat transfer rate at a distance of two inches from the exit plane of the 4 inch by 8 inch extension horn was 4000 Btu/hr. This compares to 4545 Btu/hr as documented in Report No. FAA-RD-76-213 for the same burner with the 6 inch by 11 inch extension horn. The summary of these burner flame characteristics is shown in table A-1.

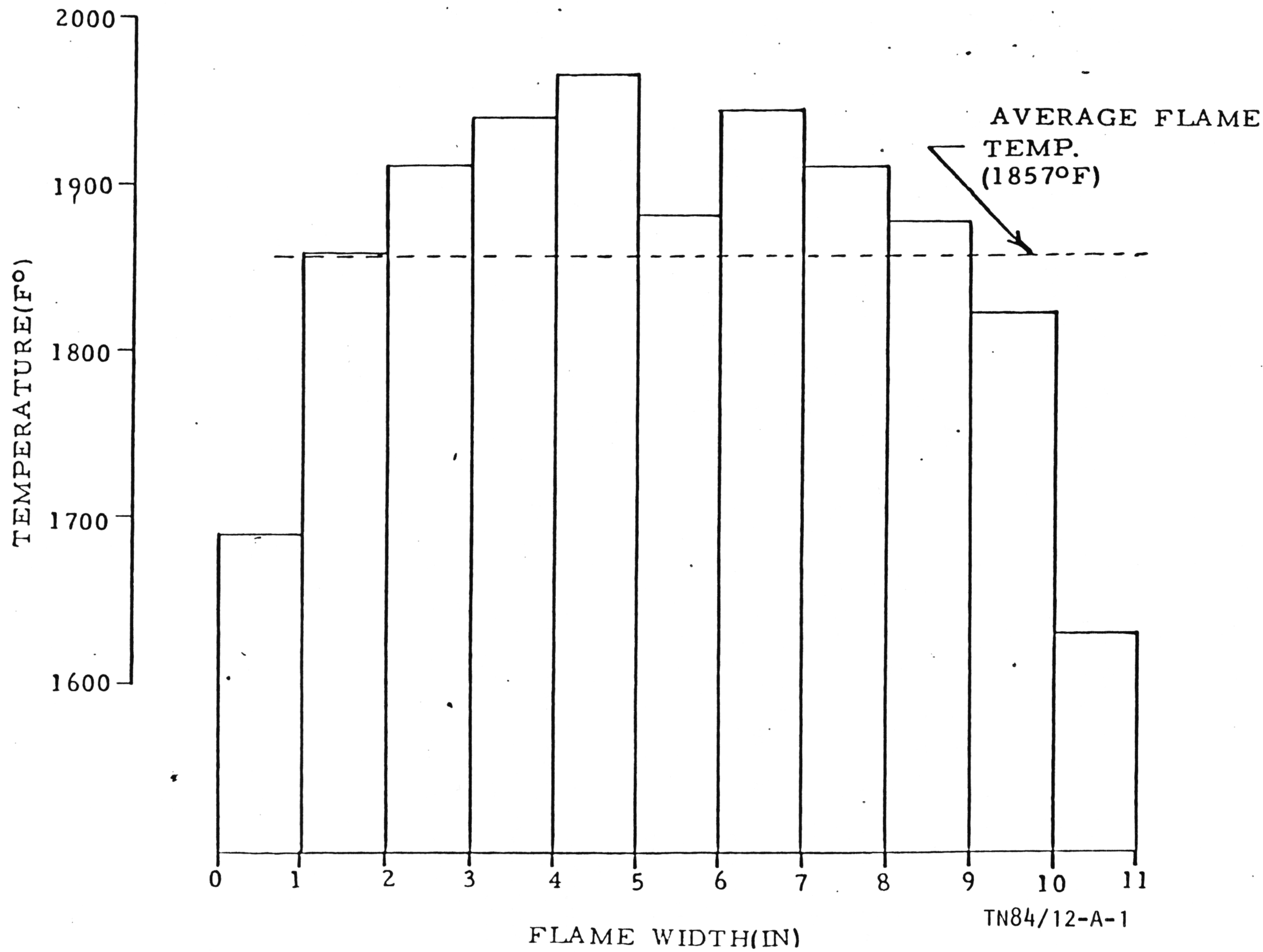

FIGURE A-1. FLAME TEMPERATURE PROFILE OF THE STANDARD BURNER

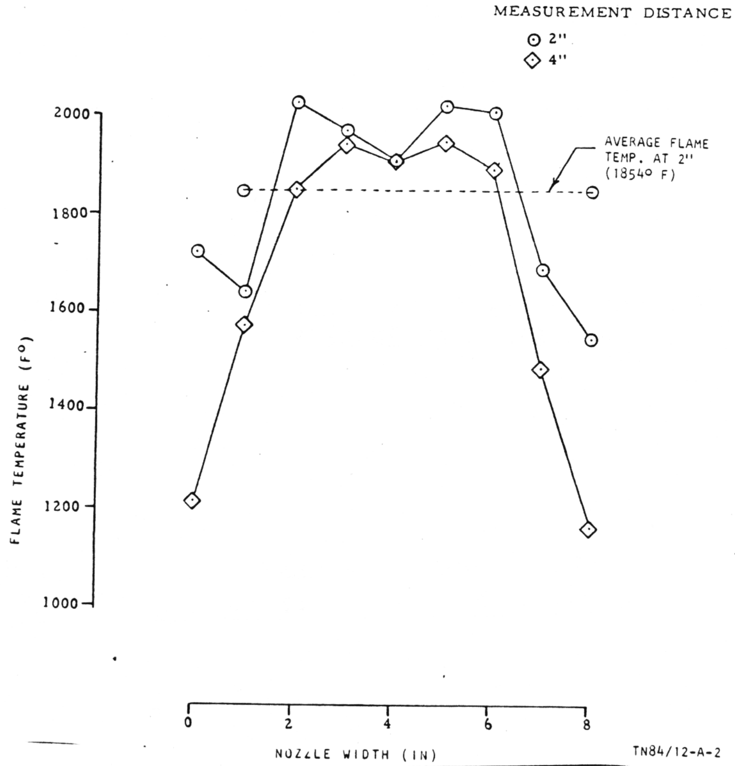

FIGURE A-2. MODIFIED STANDARD BURNER FLAME TEMPERATURE PROFILE

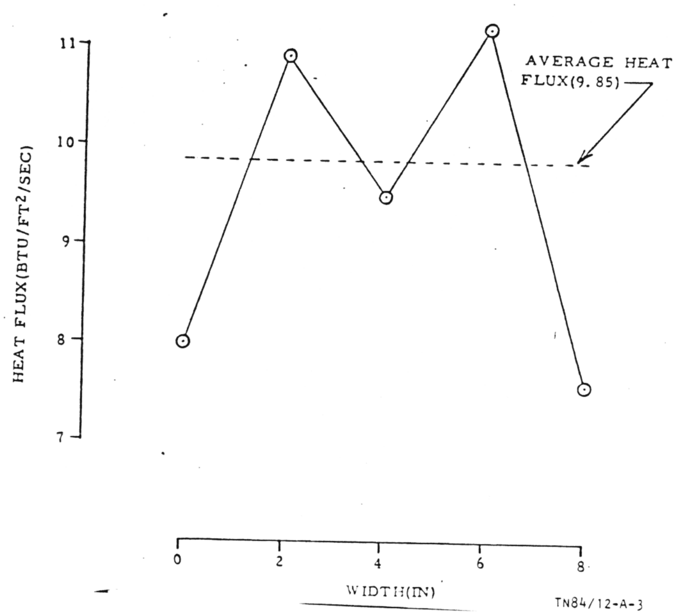

FIGURE A-3. MODIFIED STANDARD BURNER HEAT FLUX PROFILE RECORDED ALONG HORIZONTAL CENTERLINE TWO INCHES FROM NOZZLE EXTENSION

TABLE A-1. COMPARISON OF FLAME CHARACTERISTICS OF THE STANDARD AND MODIFIED STANDARD BURNERS

	AVG. FLAME TEMP (°F)	HEAT FLUX ($BTU/ft^2/sec$)	HEAT TRANSFER (BTU/hr)
STD. BURNER	1857	9.5/11.2	4545
MOD. STD. BURNER	1854	9.85	4000