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EVALUATION OF INSULATION FOR CRASH FIRE PROTECTION OF NEW FLIGHT RECORDERS

Thomas Rust, Jr
National Aviation Facilities Experimental Center
Atlantic City, New Jersey 08405

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FINAL REPORT

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16. Abstract

The work performed under this project involved the evaluation of flight recorder insulation arrangements relative to their ability to provide thermal protection for record tapes under conditions of crash fire. The evaluation encompassed fire testing four different types of insulation arrangements in accordance with three different time-temperature fire environments.

It was found that a combination of high-temperature insulation and a heat sink material employing water as the heat absorber provided the best protection for the record tapes when exposed to a realistic severe thermal environment.

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INTRODUCTION

Purpose

The purpose of this project was to evaluate new flight data and voice recorder insulation arrangements relative to their ability to provide adequate thermal protection for record tapes under conditions of crash fire.

Background

Federal Aviation Administration (FAA) regulations require one Cockpit Voice Recorder (CVR) and one Flight Data Recorder (FDR) on all turbine-powered commercial aircraft over 12,500 pounds which fly at altitudes over 25,000 feet. The requirements for the CVR's are specified in Technical Standard Order (TSO)-C84, while the FDR requirements are specified in TSO-C51. Both TSO's have the same fire protection requirement; i.e., the recorders, to be approved for aircraft use, must be subjected to flames of 1100°C (2012°F) over at least 50 percent of the outside area for an uninterrupted period of at least 30 minutes with a maximum allowable tape signal change of 2 dB.

Despite this rather stringent crash fire requirement, there have been significant crashes in which the record tapes have been destroyed by excessive internal heat without structural failure of the recorder housing. Reference 1 presents four examples of such incidents during the period 1959 through 1965. More recent examples of tape records being destroyed in aircraft crash fires are described in References 2, 3, and 4. References 2 and 3 concern crashes which involved Fairchild Hiller FH-227 aircraft. Both recorders, the CVR and the FDR, were located in the aft section of the fuselage which is deemed the least probable area to be exposed to a crash fire. However, Reference 2 states that "the CVR tape was melted to the extent that it was unreadable" after being "exposed to high heat after impact." The CVR onboard the FH-227 aircraft involved in the crash described in the Reference 3 report was "recovered from the wreckage approximately 20 hours after the accident" which produced a "postimpact ground fire." Although "there was no evidence of impact damage" to the CVR, "the reel of tape was found charred and fused. The portion of the tape lying across the recording head had been destroyed. There was no discernible magnetic recording remaining."

These two incidents illustrate the inability of two CVR's to protect the valuable record from severe crash fire conditions. Both of these CVR's employed a polyester magnetic recording tape whose exposure, according to Reference 1, "to temperatures above 300°F for durations of 15 minutes or more" will "preclude playback through a recorder." Thus, it may be deduced that the tapes in the CVR's noted in References 2 and 3 were exposed to internal compartment temperatures of at least 300°F for at least 15 minutes. It appears that the fire protection for CVR's could be improved to avoid complete thermal degradation of the record.

In addition to the above failures of CVR record tapes, there have been past failures of FDR tapes. References 3 and 4 cite examples of FDR tapes which failed to produce useful information. The tapes employed in the two FDR's involved in these two reported crashes were aluminum foil which Reference 1 specifies should not be exposed to temperatures above 1150°F to ensure the usefulness and survivability of the tape. Reference 4 states that "both the recorder and its recorder foil had been extensively damaged by the postimpact fire. Approximately the last 6 minutes of the tape record was destroyed by fire. This precluded the readout of any recorded information relative to the last landing and the rejected takeoff which resulted in the accident." Obviously the last 6 minutes of the tape was exposed to temperatures above 1150°F, resulting in the loss of an extremely important piece of information because this certified recorder did not perform its fire protection function adequately.

The incident reported in Reference 3 involved an FDR which was "recovered the morning after the accident from the burned out and still smouldering aft section of the aircraft. The (recorder) case was still warm to the touch approximately 24 hours after the accident." This statement leads to the deduction that since, as in the above example, recorders may be exposed to elevated temperatures for as long as 24 hours, the TSO fire protection requirement should specify a longer test period with gradual temperature decay.

Reference 3 also specifies that the foil tape recovered from the FDR had a number of holes and "the layers of foil on the takeup spool were stuck together." However, after careful preparation, all traces but one were readable. The report states that "the vertical acceleration trace was too nebulous to be readable." These facts indicate that the foil was exposed to temperatures of at least 1150°F, per results reported in Reference 1. This experience is quite interesting since this recorder was protected by three-eighths of an inch thick 2000°F insulating material, a material which was used in the test articles described in this report. However, this was the only protection against fire employed by the FDR involved in the accident.

Bearing in mind the above-cited examples of spoiled record tapes, it is interesting to theorize on the survivability of records in the case of a crash of a jumbo jet which carries considerably more fuel than any of those aircraft involved in the previously cited crashes. It can be seen that these large aircraft present considerably more danger to the survivability of present recorders due to the greater intensity and duration of a fire resulting from the greater onboard quantities of combustibles.

To compound this theoretical problem, the FAA regulations are now specifying that the recording capability of FDR's must be increased from the former 6 channels of data to 19 channels with the possibility of going to 26 channels in the near future. The requirement will negate the use of foil as a recording medium, and practically mandate the use of digitized data recording. This type of recorder has been designated a Digital Flight Data Recorder (DFDR), some of which are presently in production. The DFDR's must use a magnetic recording tape which normally would be a polyester tape requiring the recorder to be designed in such a way as to keep the tape compartment from experiencing temperatures above 300°F (per Reference 1). However, a metallic magnetic tape is available which can increase the maximum tape compartment temperature to possibly 1000°F. This tape is an iron, vanadium, and cobalt alloy which is dimensionally identical to commercial polyester tape. Such a tape, noted as "magnetic steel" tape, will be discussed later in this report. For the present, however, it must be assumed that both CVR's and DFDR's will have to protect the record medium from being exposed to temperatures above 300°F.

The failure of some record tapes to provide useful post-accident information is well documented. In 1968, a contract was awarded to determine the most efficient designs for a new line of recorders using new and more stringent thermal specifications proposed by the FAA. The results of this study are presented in Reference 5. Briefly, the study theoretically analyzed the effectiveness of various thermal protection arrangements when exposed to a number of different time-temperature profiles. The crash environment specified by the FAA is presented in Figure 1, and is noted as Profile 1 (as in Reference 5). However, the theoretical study also considered additional, less severe time-temperature histories. After many factors, such as the thermal properties of the materials, size of the enclosure, cost of the materials, and overall practicality were considered, recommendations were made suggesting a series of tests to be conducted. These tests were proposed to substantiate the theoretical results obtained from the study.

After some discussion with interested personnel, it was determined that a test program would be undertaken at the National Aviation Facilities Experimental Center (NAFEC) in response to the accident experience reported in the above paragraphs. The program was to provide the necessary experimental data to complete the overall effort aimed at increased thermal protection for record tapes in cases of severe crash fire conditions. This test program is described in detail in this report.

DISCUSSION

Test Articles and Pretest Instrumentation

The test program described herein encompassed flame and simulated fire testing of 10 experimental insulated boxes. Four different styles of boxes were tested, three of which were the direct result of the recommendations of Reference 5. They were designated Styles A, B, C, and D. All boxes were fabricated in accordance with Figure 2. Three boxes of each style, except Style D, were procured to allow for testing of each style box in accordance with three different time-temperature profiles as specified in Reference 5. Only one of the Style D type box was tested.

The outside box dimensions were within a one Air Transport Radio (ATR) standard size (19.5625 x 10.125 x 7.625 inches) as specified in Reference 6, while the insulation thicknesses were in accordance with the recommendations of Reference 5. All boxes were fabricated with a 1/8-inch-thick stainless steel shell, the interior of which was lined with a 1-inch 2000°F insulating material pad. Inside this pad, Style A box had 1 inch of a gelled water heat sink material, Style B had 1 inch of commercial paraffin, Style C had 1 inch of a low-cost stable insulating material, and Style D had 1-inch-thick solid material capable of evolving water when heated. The boxes were made in two halves with stepped mating surfaces, as shown in Figure 2, in order to avoid a direct heat path to the interior when the halves were mated. Fiberglass was formed over the insulating materials in order to keep the materials in place during handling and to form a better seal between the two halves when mated. One of the experimental boxes is shown with the halves mated in Figure 3. The flanges were provided on each half to permit a good seal when proper torquing of the bolts (used in the holes pictured) was accomplished. The flanges were an optional means of mating the two halves. A view of the separated two halves of the experimental boxes is provided in Figure 4. The stepping of the mating surfaces is evident in this figure, as is the fiberglass retainer on each half. A 1/4-inch hole, shown in Figures 3 and 4, through one of the halves was provided to allow access for instrumentation wires. This hole would be representative of that found in an actual recorder, since the shaft of the external drive motor would normally pass through the hole.

Prior to testing, the experimental boxes were weighed to the nearest one-hundreth of a pound and instrumented with thermocouples. At least two 18-gage metal-sheathed thermocouples were welded to the outer shell to measure the box skin temperature during testing. Two other thermocouples, 18-gage fiberglass-sheathed, were routed through the 1/4-inch hole provided, and mechanically held in place against an aluminum mass by aluminum screws. The aluminum mass with a weight of 2.72 pounds was located inside the boxes during testing to act as a heat sink with heat-absorbing properties similar to an actual recording cassette. This mass is shown in position in Figure 5. The attachment of one of the interior thermocouples is shown in Figure 6. The second thermocouple wire is also seen in this figure, and is similarly attached on the far side of the mass. The junction of the thermocouple is under the head of the aluminum screw. Installed in this manner, the thermocouples measured the temperature of the mass which, in effect, was the temperature to which a tape record would be exposed.

To get a correlation between the temperature of the mass and the actual effect on a tape record, specimens of three different types of prerecorded tapes were placed between the plates of the aluminum mass prior to testing. The specimens were coiled inside a piece of 1-inch-diameter aluminum tubing one-quarter inch long. One precorded specimen was 10 feet of 1/4-inch, 1-mil-thick commercial polyester magnetic recording tape. A second prerecorded specimen was 10 feet of 1/4-inch, 1-mil-thick lubricated polyester magnetic recording tape identical to the tape used in many of the current CVR's. A third prerecorded specimen was 10 feet of 1/4-inch, 1-mil-thick magnetic steel recording tape, which will be described more fully later in this report.

Test Program and Results

The project test program was broken down into three different series of tests, as noted in Table 1. Series 1 consisted of testing one box each of Styles A, B, and C in accordance with time-temperature Profile 2 (see Figure 1). Series 2 consisted of testing one box each of Styles A, B, and C in accordance with a modified Profile 1, which was designated Profile 6 and is defined in Figure 7. Series 3 consisted of testing one box each of Styles A, B, C, and D in accordance with a modified Profile 2 which was designated Profile 7 and is defined in Figure 7

Boxes Nos. 1, 2, and 3 were tested in Series 1 using kerosene-fueled flames exclusively. The following procedure was used during the testing of these three experimental boxes:

1. The instrumented test article was separated and the lower half containing the aluminum mass was placed under a heat lamp, as shown in Figure 8. The box, primarily its insulation, was shaded from the infrared rays of the heat lamp with only the aluminum mass being exposed. The two thermocouples attached to the mass were monitored. When, after approximately one-half hour, the temperature of the mass stablized at 120°F, the two halves of the box were assembled, and the assembly bolts were evenly torqued. The purpose for beginning the tests with the mass at this elevated temperature was to simulate actual recorder operation which, according to Reference 5, will internally generate up to 0.125 watt from frictional heat as the tape passes over the recorder heads.

2. Using three bolts on each of two opposite sides of the test article, the box was mounted in a fixture as shown in Figure 9. The box was canted at an angle of approximately 30° to the horizontal in order to allow maximum flame coverage. The two upper skin thermocouples are visible in this figure along with the asbestos-protected interior thermocouple leads and the nozzle of the NAFEC 12-gph kerosene burner in the test position. Along with the two upper thermocouples, there were two thermocouples on the lower side and two thermocouples on the front side of the box. The purpose for these thermocouples will be specified below.

3. The test commenced when the burner was lit, as can be seen in Figure 10. The box was kept in this environment for a period of 1 hour. Another view of the test article during testing is shown in Figure 11.

4. At the end of the first hour of the test, the burner was moved down and back from the test article to provide an environmental temperature in accordance with Profile 2. This temperature was obtained by averaging the two front thermocouples with the two lower thermocouples. The position of the burner which provided a temperature environment of approximately 1000°F is shown in Figure 12. As the time-temperature profile specified a lower temperature, the burner was backed away from the test article until at 2 hours into the test, when the profile temperature had reached 800°F, the 12-gph burner was replaced by the NAFEC 2-gph kerosene burner. This burner then maintained the required temperature in the same manner as specified above until at seven hours into the test the environmental temperature was

TABLE 1. EXPERIMENTAL BOX WEIGHT LOSS AND TAPE TEST RESULTS

	Box No.	Inner Material	Weight Before (lbs.)	Weight After (lbs.)	Weight Loss (lbs.)	Tape Condition: Commercial Polyester	Tape Condition: Lubricated Polyester	Tape Condition: Metallic	Remarks
Series #1, Profile #2	1	Gelled Water (Style A)	27.76	24.81	2.95	Readable	Readable	Readable	
	2	Paraffin (Style B)	27.30	26.60	0.70	Unplayable	Unplayable	Readable	
	3	Stable Insulator (Style C)	26.28	25.77	0.51	Unplayable	Unplayable	Readable	
Series #2, Profile #6	4	Gelled Water (Style A)	27.73	22.23	5.50	Unplayable	Unplayable	Readable	
	5	Paraffin (Style B)	27.64	23.12	4.52	Unplayable	Unplayable	No signal (blue)	Aluminum dummy partially melted
	6	Stable Insulator (Style C)	26.22	25.42	0.80	Unplayable	Unplayable	No signal (gray)	
Series #3 Profile #7	7	Gelled Water (Style A)	27.84	23.96	3.88	Readable	Readable	Readable	
	8	Paraffin (Style B)	28.14	23.80	4.34	Unplayable	Unplayable	Readable	
	9	Stable Insulator (Style C)	26.08	25.27	0.81	Unplayable	Unplayable	Readable	
	10	Water Evolving Material (Style D)	28.24	26.31	1.93	Readable	Readable	Readable	

stabilized at 400°F. This environment was maintained throughout the remainder of the test, which required a total of 24 hours of elevated temperature operation.

5. At the end of the test, the burner was shutdown and the test article allowed to cool to ambient temperature. The box was then opened and the tape specimens examined and played-back when possible. The condition of the tape specimens is noted in Table 1.

6. The boxes were then weighed and the weight loss calculated, both of which are shown in Table 1.

The time-temperature histories of the aluminum mass for Boxes 1, 2, and 3 are shown in Figures 13, 14, and 15, respectively. It can be seen that the gelled water of Box No. 1 maintained the aluminum mass at a temperature approximately equal to the boiling temperature of water throughout the test with the exception of the second hour, as shown in Figure 13. Even during this period, the interior temperature was low enough to allow survivability of the polyester tape specimens, as is noted in Table 1. However, Figure 14 shows that the Style B Box No. 2 with the paraffin heat sink material allowed the mass temperature to reach 400°F after 7 hours and was ineffective thereafter. This agrees with the results shown in Table 1 for the polyester tapes which were unplayable after this test. However, the interior temperature was kept low enough to allow the survivability of the steel tape. The Style C Box No. 3 with the stable insulator allowed the aluminum mass temperature to rise to almost 600°F in the first hour, as shown in Figure 15, after which the temperature decreased to about 300°F and then stablized at 400°F for the remainder of the test. The condition of the tape specimens shown in Table 1 indicates that the interior temperature did not allow the survival of the polyester tapes, but was sufficiently low to allow the steel tape to be readable.

The results of the Series 1 tests are also shown in Figures 16, 17, and 18 which are post-test views of Styles A, B, and C boxes, respectively. Some of the gelled water is visible in Figure 16, indicating that all of the water was not vaporized. This fact leads to the deduction that Box No. 1 could have protected the tape specimens against a more severe profile. Box No. 2 shown in Figure 17 appears to have some paraffin remaining, indicating that the Style B box could have protected the steel tape from a more severe test profile. Box No. 3 is shown after testing in Figure 18.

It should be noted as part of Series 1 that, during the transition from full flame coverage to partial flame coverage of Box No. 2 at the 1-hour mark, flames emitting from between the flanges of the two halves of the box were visible. This fact plus the time-temperature history indicates that the paraffin had vaporized within the box but due to lack of oxygen could not burn until the volatiles escaped to the ambient air. This point is quite important in the design of a Style B box since, if air is allowed to enter the interior of the box, burning will take place inside, thus raising the temperature of the interior considerably.

This fact is substantiated to a degree by the false start testing of another Style B box. The test was prematurely concluded at the 1-hour mark because the aluminum mass temperature had risen to approximately 1500°F. This test was stopped since it was felt that the interior was destroyed at this temperature. However, upon opening the box, the interior was in good condition, and the tape specimens were all satisfactory. Thus, it is theorized that the box was not sealed sufficiently to keep air from entering the interior cavity, thus allowing the paraffin to burn internally. The high temperature recorded by the thermocouple was apparently a local temperature in the area of the thermocouple but not the true temperature of the aluminum mass, since the mass showed no indications of melting. This box was refilled with paraffin and used in Series 3 as Box No. 8, and Box No. 2 was tested as reported.

After analyzing the results of the Series 1 testing, it was determined that Series 2 should be conducted using a more severe test profile. Since Reference 5 specifies that Profile 1 is too severe for these insulation arrangements and quantities of insulation, it was decided to employ a modified Profile 1. This profile is shown in Figure 7 and is designated Profile 6. It closely follows Profile 1 except that the test environment is limited to 1 hour at 2000°F instead of 2 hours at that temperature as specified by Profile 1. It was also decided that this series would be conducted using an electric furnace exclusively as the heat source. This decision was influenced by the Reference 5 recommendation that some tests be performed in an "oven."

Therefore, Boxes Nos. 4, 5, and 6, which were Styles A, B, and C, respectively, were tested in accordance with Profile 6, using an electric furnace to provide the environment. The severity of this environment was increased over that of Series 1 tests not only because of the higher temperatures, but also by the fact that during the entire test 100 percent of the box was exposed to the test environment, while in Series 1 only somewhat over 50 percent of the box was exposed to the flames. The difference in severity of a test using the percentage of coverage as the criterion is discussed in Reference 1.

The test procedure for Series 2 tests was the same as described for Series 1 tests except that the environment was controlled by the furnace thermostat and the raising and lowering of the furnace door instead of the location of flames. The test was begun by placing the test article, supported in a fixture which allowed maximum heat coverage, in the furnace which had been thermally stabilized at 2050°F. As the box was placed in the furnace, the furnace temperature, which was measured by a thermocouple located within 2 inches of the box, dropped to about 1900°F. In approximately 5 minutes the temperature had stabilized at 2000°F where it remained for the balance of the first hour of the test. The furnace thermostat was then reduced to 1000°F, and the furnace was allowed to coast as the temperature dropped in accordance with Profile 6. When the fourth hour of the test was reached, the furnace temperature was not falling quickly enough to maintain the test profile. To correct the situation, the furnace door was gradually raised or lowered to maintain the proper temperature until the seventh hour of the test when both the test profile and the furnace temperature stabilized at 500°F. This environment was maintained until the end of the test, at which time the box was removed from the furnace, and allowed to cool before it was opened.

The results of the time-temperature histories of the interior aluminum mass in Boxes Nos. 4, 5, and 6 are presented in Figures 20, and 21, respectively. It can be seen from Figure 19 that the gelle er was performing satisfactorily through the eighth hour of the test, icn time the water was consumed and the temperature of the mass steadily rose until at the sixteenth hour it coincided with the furnace temperature. These data agree with the results of the tape specimens listed for Box No. 4 in Table 1. With the maximum temperature of the interior being 500°F, it is seen that the polyester tapes were unplayable, but the steel tape was still readable.

It is seen from Figure 20 that the paraffin in Box No. 5 did not give the desired protection since the interior temperature rose steadily to 1300°F at the second hour of the test. As would be expected with internal temperatures of that magnitude, none of the tape specimens was readable (see Table 1) and, in fact, the aluminum mass was partially deformed indicating that it had partially melted during the test. The melting temperature of aluminum is approximately 1200°F.

It is seen from Figure 21 that the stable insulator in Box No. 6 also failed to provide adequate protection. The internal temperature rose to 1050°F at the fourth hour of the test, after which its effective insulating properties were of no value. The results for Box No. 6 shown in Table 1 indicate that none of the tape specimens was readable after the test.

After analyzing the results of Series 2, an overall picture of the potential of the boxes was obtained. It was determined that Series 3 would have to employ a test profile less severe than Profile 6, more severe than Profile 2, but also consistent with what is to be expected in a present-day crash fire environment. Thus, it was decided that Series 3 would use the time-temperature Profile 7 as defined in Figure 7. The first hour of this profile entailed exposure of the test article to 2000°F flames corresponding to a 1-hour kerosene-fueled crash fire environment after which the box was transferred to an electric furnace which provided the remainder of the test environment. This profile was deemed quite practical and within the possible capabilities of the test articles.

The test procedure for Series 3 tests was the same as described for Series 1 tests except that the furnace environment was controlled in the same manner as in Series 2 tests. The transfer of the test article from the flame test fixture to the furnace was accomplished expeditiously with the maximum time for transfer being 2 minutes.

The results of the time-temperature histories of the interior aluminum mass in Boxes Nos. 7, 8, 9, and 10 are presented in Figures 22, 23, 24, and 25, respectively. It is seen from Figure 22 that the gelled water protected the interior quite well, with the aluminum mass temperature never exceeding the boiling temperature of water. These data agree with the results of the tape specimens listed for Box No. 7 in Table 1.

It is seen from Figure 23 that the paraffin in Box No. 8 failed to provide adequate protection with the internal temperature reaching 1550°F at the first hour. However, this temperature dropped rapidly until at the fourth hour it coincided with the profile temperature. These data again indicate internal burning of the paraffin. The results listed for Box No. 8 in Table 1 indicate unplayable polyester tape specimens, as expected, and a readable steel tape.

It is seen from Figure 24 that the stable insulator provided limited protection with the peak internal temperature being 800°F at the end of the first hour, and an average internal temperature of 500°F between the first and sixth hours, after which the profile and internal temperatures were identical. As expected, the results listed for Box 9 in Table 1 indicate unplayable polyester tape specimens and a readable steel tape.

It is seen from Figure 25 that the water-evolving material performed satisfactorily as it maintained the internal temperature at 240°F or below throughout the entire test. The results listed for Box No. 10 in Table 1 indicate that all tape specimens were readable, as expected.

An overall review of the weight losses of the same style boxes is quite revealing. The weight lost by Style A boxes was 2.95 pounds, 3.88 pounds, and 5.50 pounds when tested in accordance with Profiles 2, 7, and 6, respectively. The order of increasing weight loss is consistent with the severity of the test indicating that more gelled water was required to cool the interior of the boxes as the severity of the test increased. This also lends credence to the theorized relative severity of the three profiles used. This factor also may be seen in the Style B tests. The losses for these boxes were 0.70 pounds, 4.34 pounds, and 4.52 pounds when they were tested in accordance with profiles of increasing severity; i.e., Profiles 2, 7, and 6, respectively. Since Style C boxes involved a stable insulator, a comparison of the weight losses of these boxes would not be relevant.

Use of Magnetic Steel Recording Tape

Although it is not the intent of this report to present the attributes and faults of magnetic steel recording tape, the tape was used extensively in the tests described herein, and therefore merits some discussion. As previously stated, the steel tape is manufactured of an alloy consisting of iron, cobalt, and vanadium. This alloy exhibits good permanent magnetic properties and is inexpensive relative to similar alloys.

Comparing the steel tape with polyester tape, it is noted that the steel tape is stronger (for like thicknesses), has a lower percent elongation under the same load, and has a higher operating temperature. One manufacturer specifies that this tape may be exposed to operating temperatures of up to 600°F without the magnetic properties of the tape being altered.

While working with the steel tape during the previously described tests, the following items were noted:

1. It was found that the tape used in the tests, which was 1-mil-thick by 1/4-inch-wide, was recordable, but the level of the recorded information was not steady. It was impossible to record a constant level 1000 Hertz signal on the tape even when professional recording equipment was employed. However, another user had no trouble at all making such a recording using tape he purchased. It may be surmised that the tape used in these tests was not within required manufacturing tolerances. Thus, the steel tape specimens used in the tests described herein were prerecorded with a voice signal which was readable when played back but not always at the same sound level.

2. A number of specimens of steel tape were exposed to temperatures between 600°F and 1000°F for at least a 6-hour duration with the result that no signal loss was apparent.

3. When prerecorded tape was stored on a reel for an extended period of time, approximately 2 months, a noticeable signal loss was apparent. Other users have also noted this factor. Apparently the magnetic flux data will bleed off gradually due to the metallic characteristics of the tape and the proximity of the layers of tape.

4. Another user noted that the steel tape will not survive for 24 hours in salt water without severe corrosion and loss of data. A quick test was run with the NAFEC tape and it was found that very little corrosion appeared on the tape after the 24-hour salt water test. The specimen was playable and readable.

5. It was found that the tape must be handled carefully to avoid creating wrinkles and creases, since this will disturb the playback of the tape data and lead to possible fracturing of the tape. However, it is not difficult to handle the tape in such a way as to prevent the wrinkles.

SUMMARY OF RESULTS

The results obtained from the tests conducted were as follows:

1. The polyester tapes in the Style A boxes were readable after exposure to time-temperature Profiles 2 and 7, but the polyester tapes exposed to time-temperature Profile 6 were not.

2. The polyester tapes in the Style D box were readable after exposure to time-temperature Profile 7.

3. The polyester tapes in the Styles B and C boxes were not readable after exposure to time-temperature Profiles 2, 6, and 7.

4. The steel tapes in the Styles A, B, and C boxes were readable after exposure to time-temperature Profiles 2 and 7, as was the steel tape in the Style D box when exposed to Profile 7.

5. The steel tapes in the Style A box were readable after exposure to time-temperature Profile 6, while the steel tapes in Styles B and C boxes were not readable after exposure to Profile 6.

6. The weight of the water lost from the Style A boxes and the weight of the paraffin lost from the Style B boxes were dependent on the severity of the profiles to which the boxes were exposed.

CONCLUSIONS

Based the results obtained from the tests conducted, it is concluded that:

1. A flight data recorder employing the insulation arrangement specified as Style A herein will provide adequate thermal protection for either a polyester or a steel tape record when exposed to the crash fire conditions specified by Profiles 2 and 7 herein, but will not provide this protection against the crash fire conditions specified by Profile 6 herein unless steel tape is employed.

2. A flight data recorder employing the insulation arrangement specified as Style D herein will provide adequate thermal protection for either a polyester or a steel tape record when exposed to the crash fire conditions specified by Profile 7.

3. A flight data recorder employing the insulation arrangements specified as Styles B and C herein will not provide adequate thermal protection for a polyester tape record when exposed to the crash fire conditions specified by Profiles 2, 6, or 7 nor for steel tapes when exposed to conditions specified by Profile 6, but will provide adequate thermal protection for a steel tape record when exposed to the crash fire conditions specified by Profiles 2 and 7.

4. It is possible for a flight data recorder which is within a 1 ATR standard size to provide adequate thermal protection for record tapes when exposed to crash fire conditions as specified herein.

5. The time-temperature profile specified as Profile 7 is a practical and adequate test of moderate severity which closely parallels the theoretical temperatures which may be expected during a crash fire.

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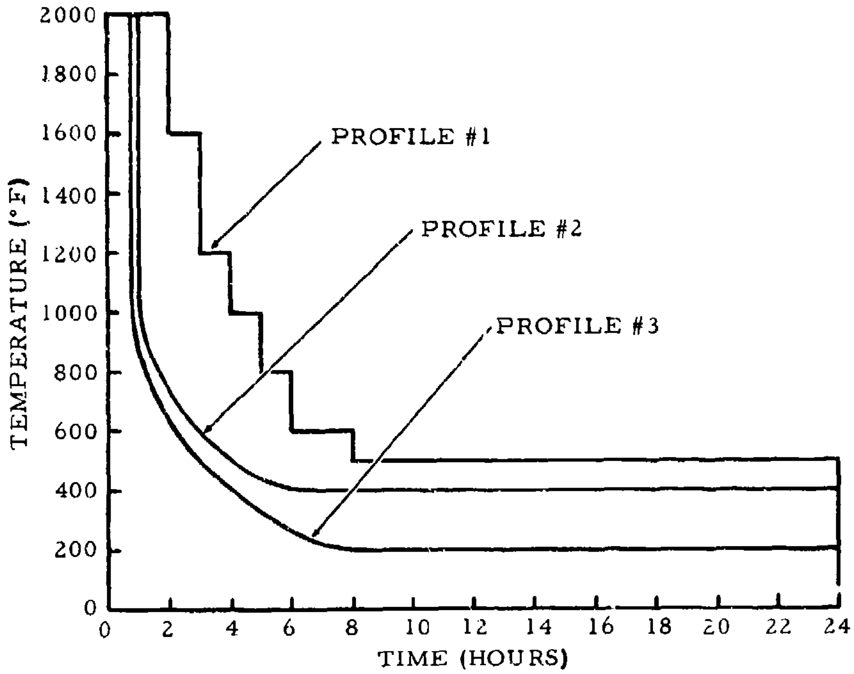


FIGURE 1. RECOMMENDED TIME-TEMPERATURE TEST PROFILES FOR FLIGHT RECORDERS

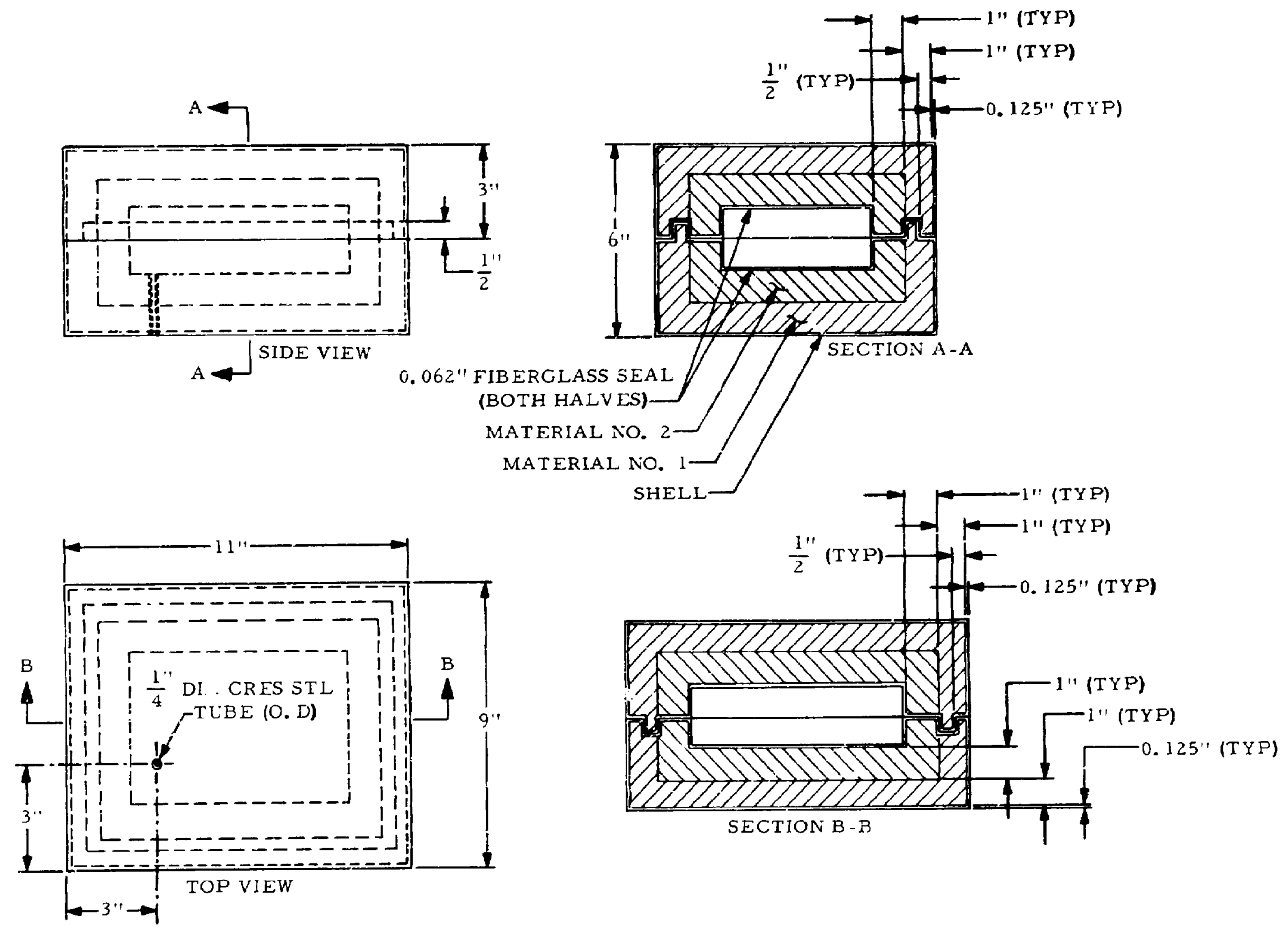


FIGURE 2. DRAWING OF EXPERIMENTAL BOX INSULATION ARRANGEMENT

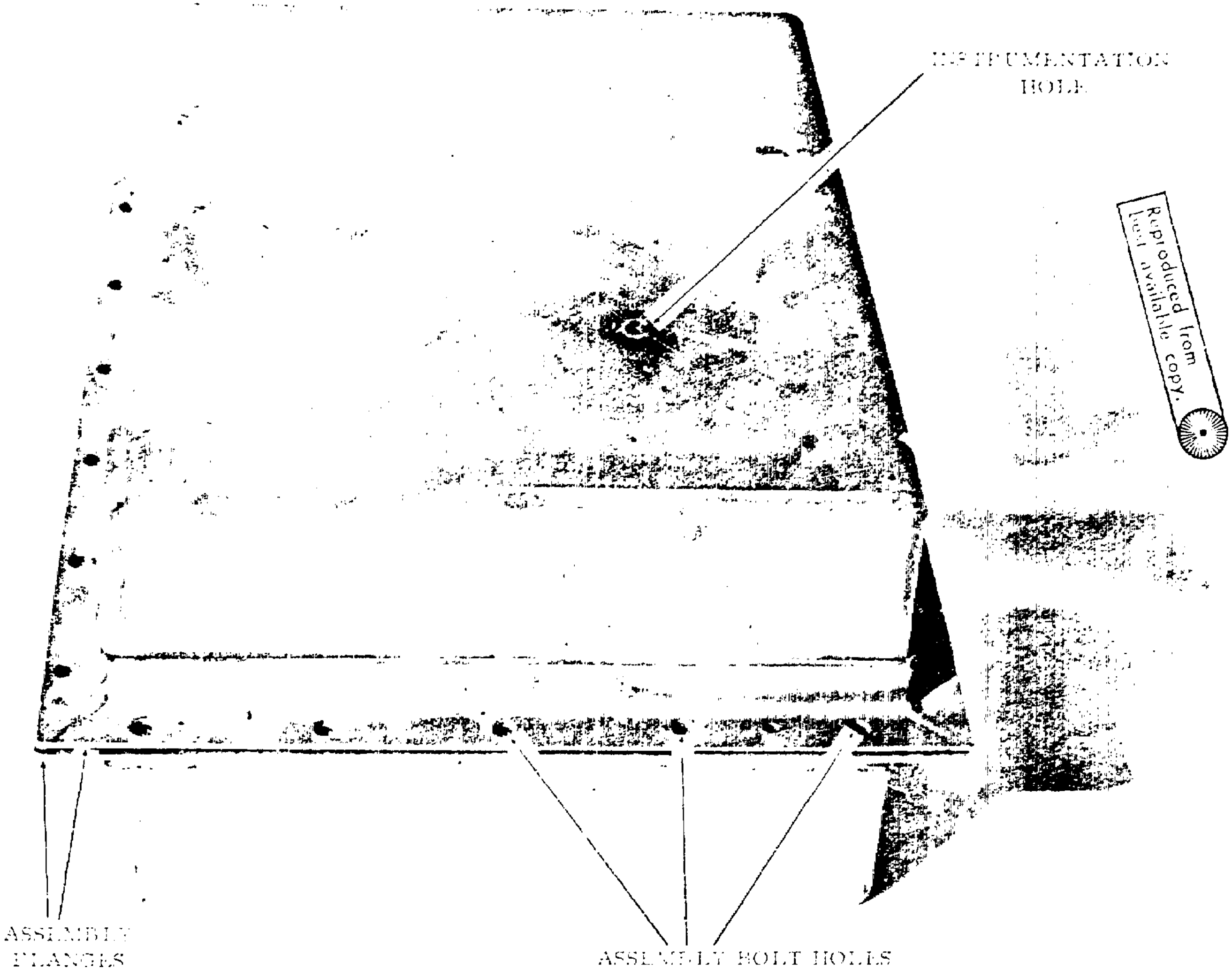


FIGURE 3. OVERALL VIEW OF EXPERIMENTAL BOX

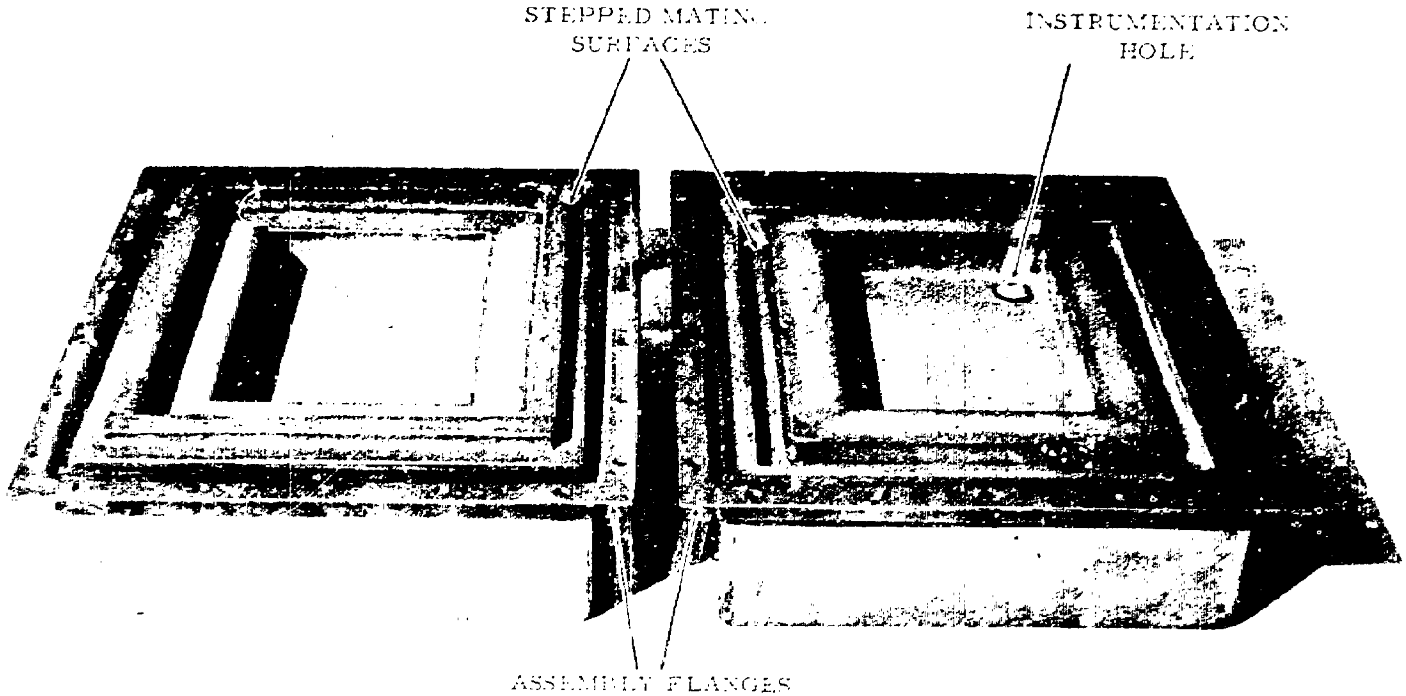


FIGURE 4. VIEW OF THE INTERIOR OF A TYPICAL EXPERIMENTAL BOX

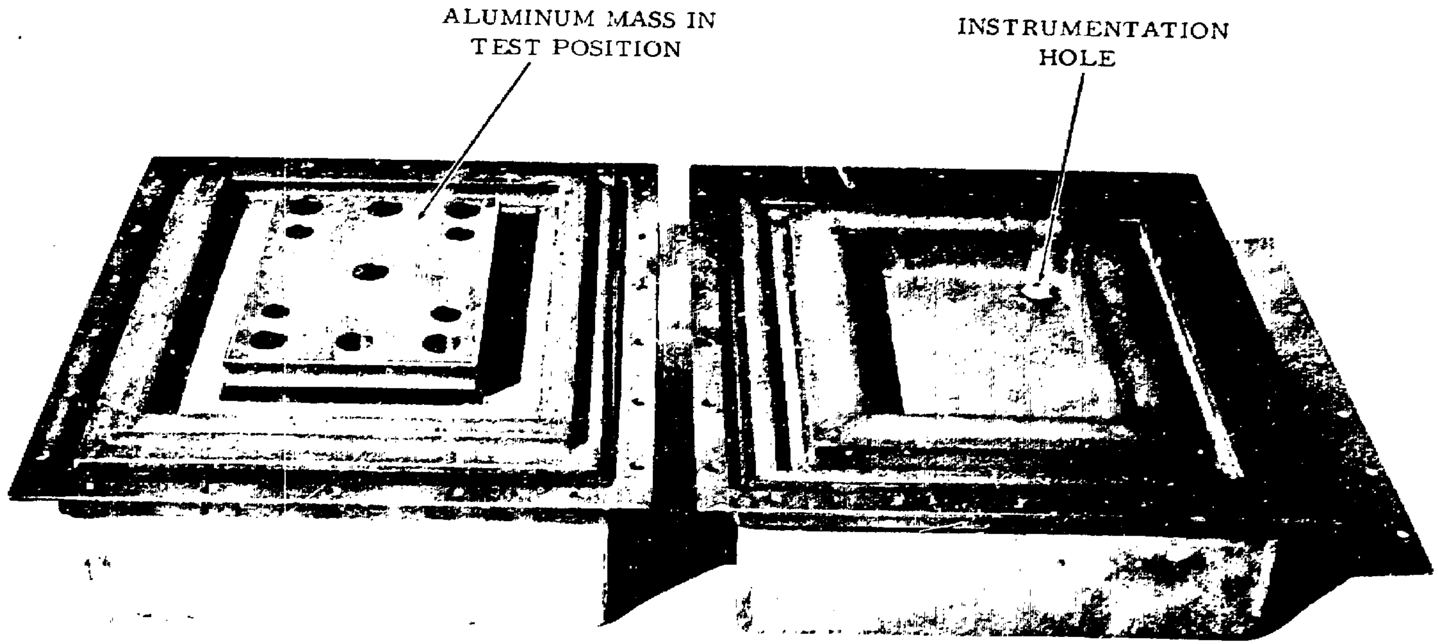


FIGURE 5. VIEW OF A TYPICAL EXPERIMENTAL BOX WITH THE ALUMINUM MASS IN POSITION

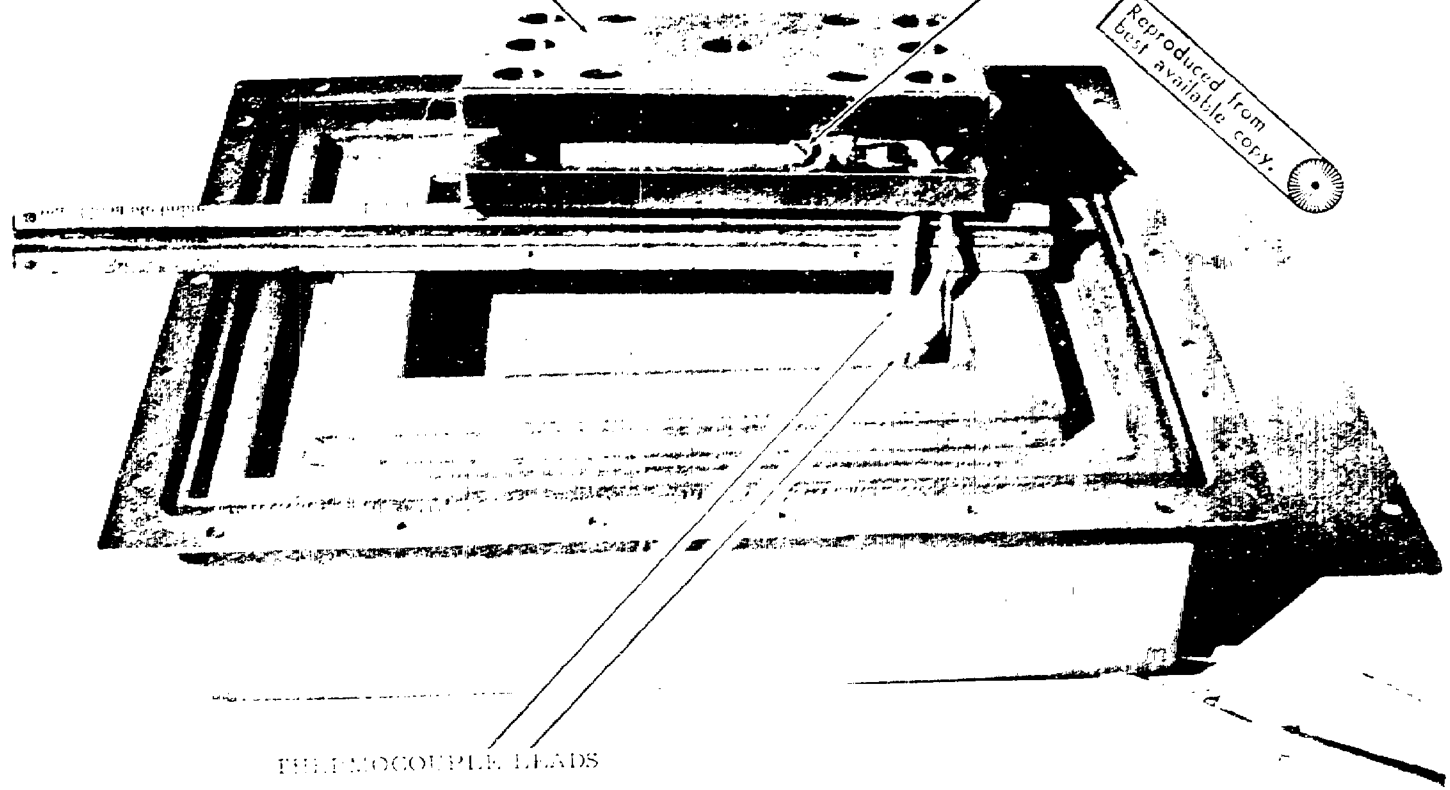


FIGURE 6. VIEW OF THE ATTACHMENT OF THE INSIDE THERMOCOUPLE TO THE ALUMINUM MASS

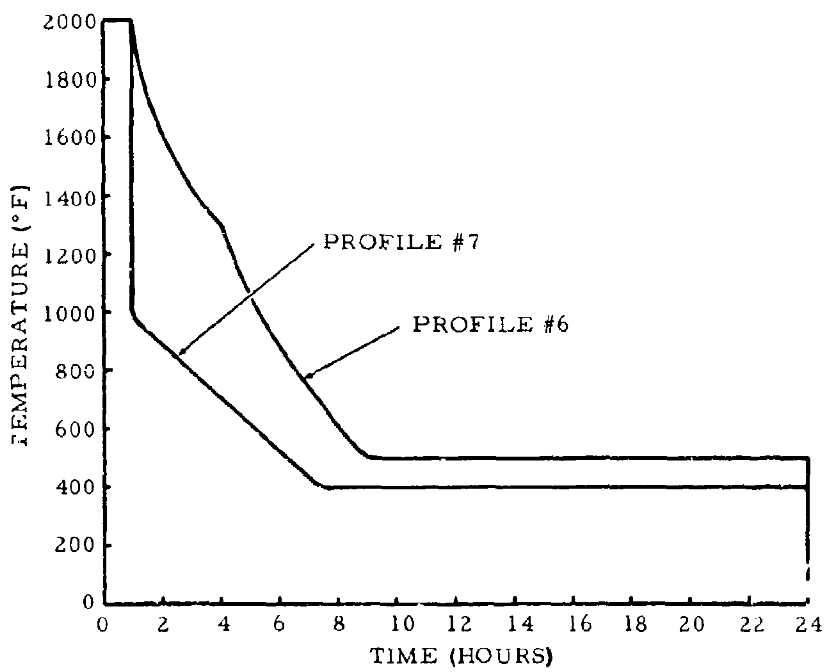
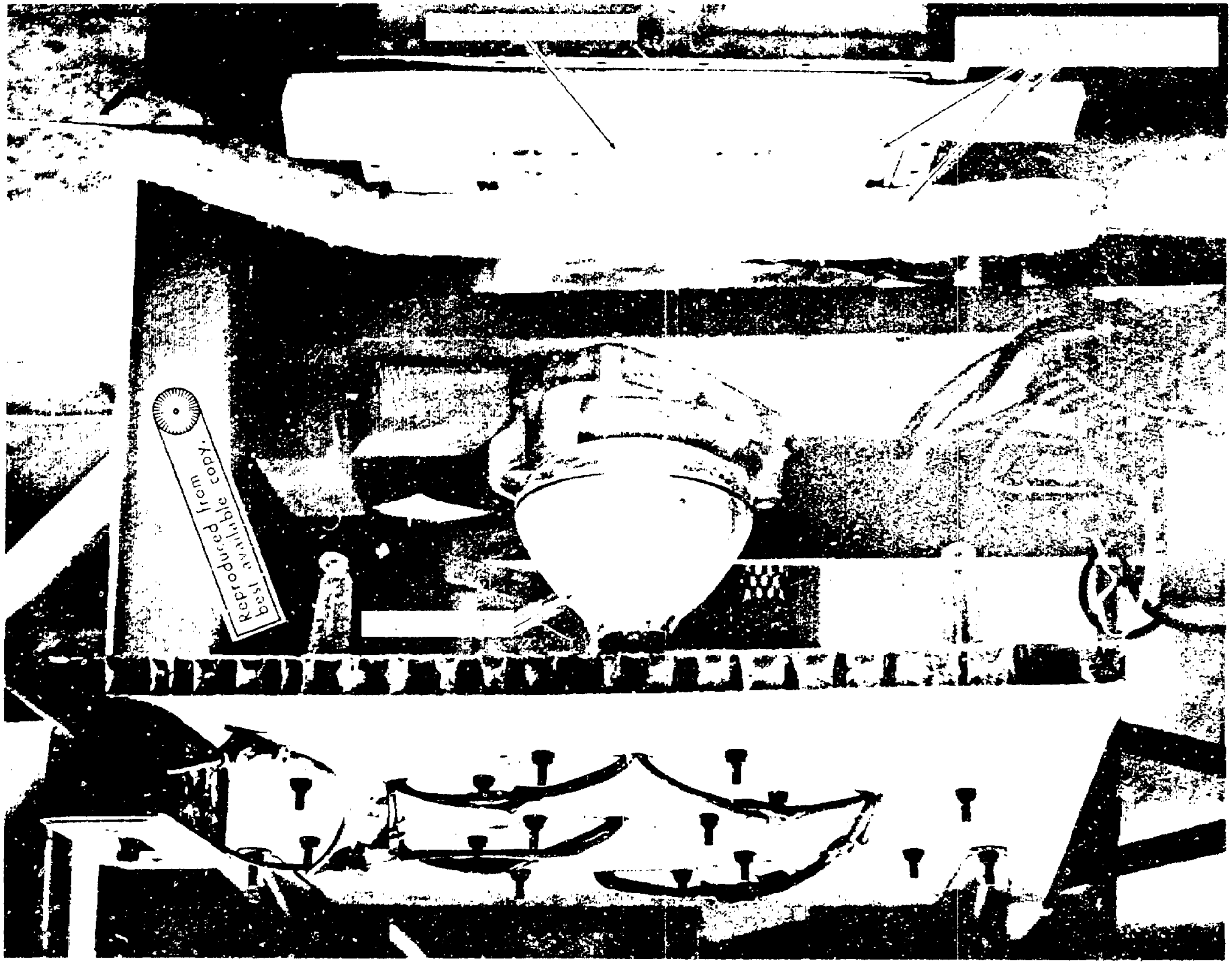


FIGURE 7. MODIFIED TIME-TEMPERATURE TEST PROFILES FOR FLIGHT RECORDERS



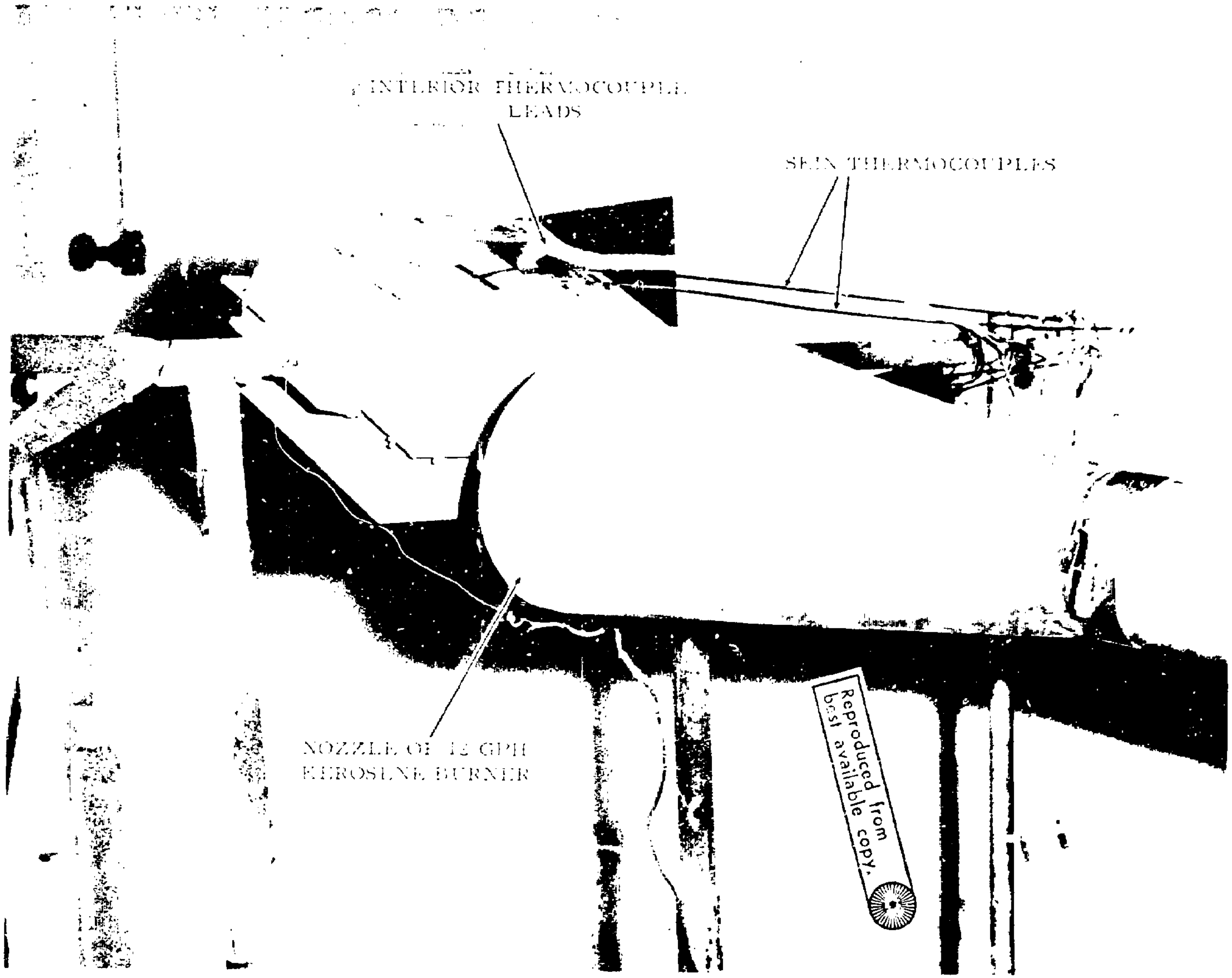


FIGURE 9. EXPERIMENTAL BOX IN TEST POSITION

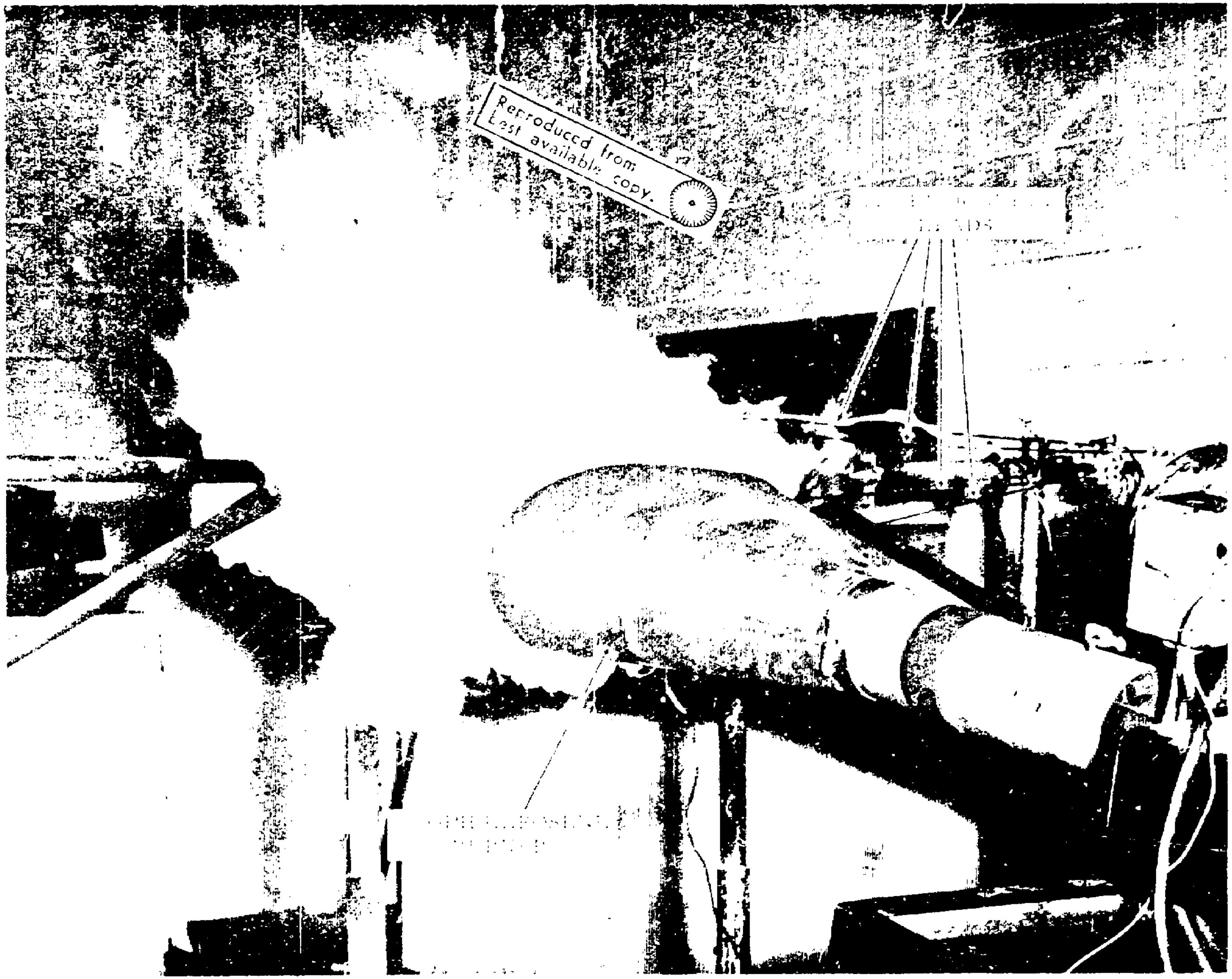


FIGURE [illegible]. FRONT VIEW OF EXPERIMENTAL TOY BEING EXPOSED TO 2000 F FLAMES

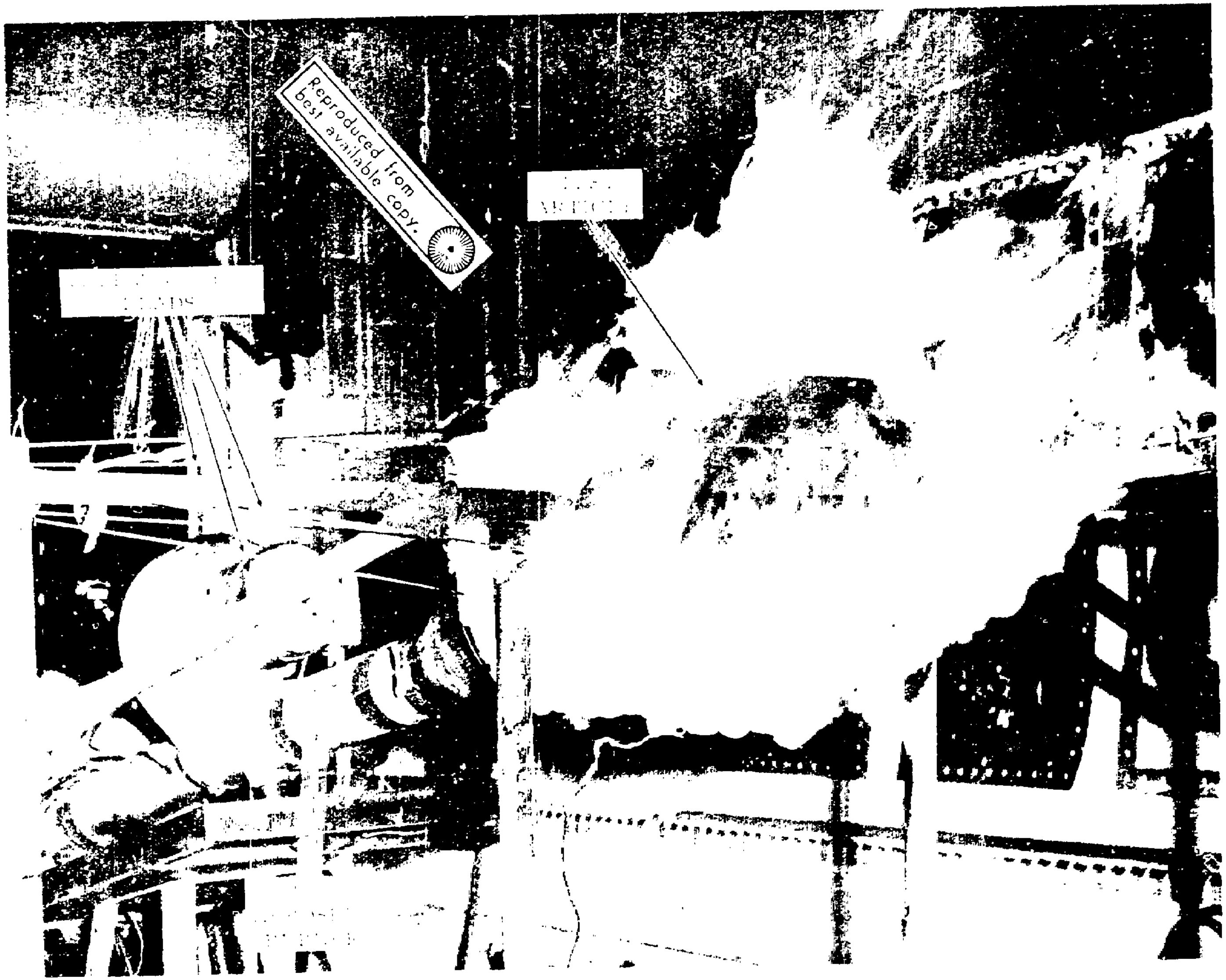
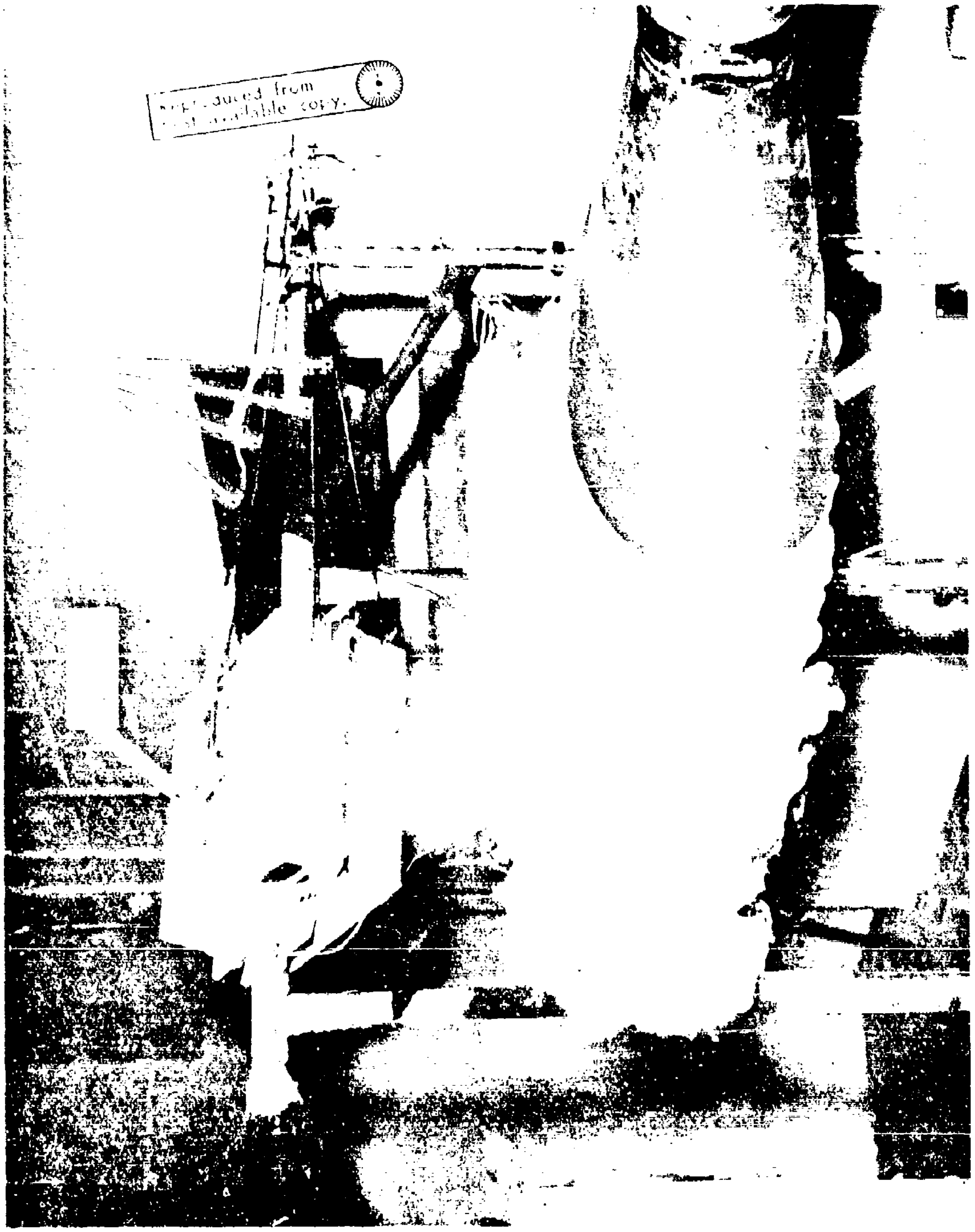


FIGURE 11. REAR VIEW OF EXPERIMENTAL BOX BEING EXPOSED TO 2000 F FLAMES



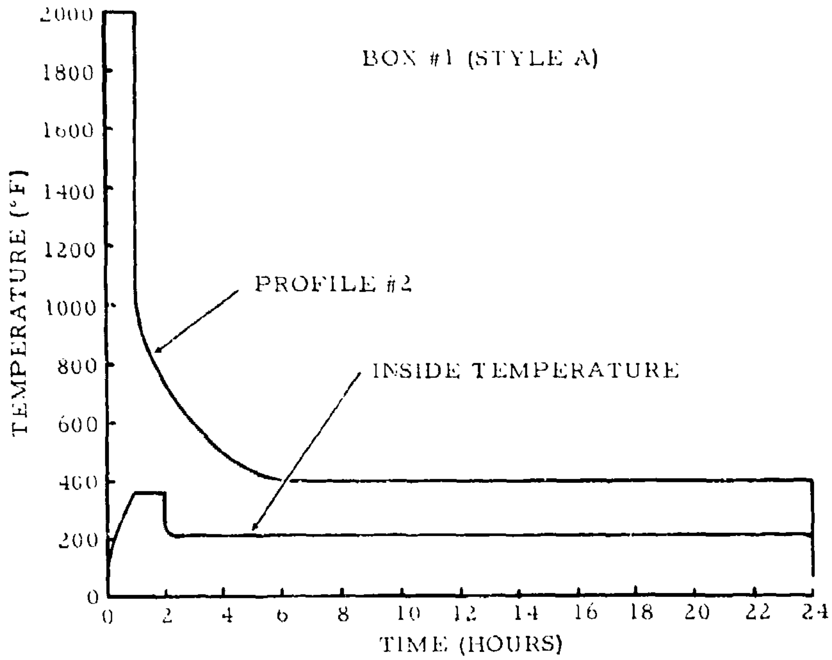


FIGURE 13. TIME-TEMPERATURE HISTORY OF THE ALUMINUM MASS INSIDE BOX NO. 1

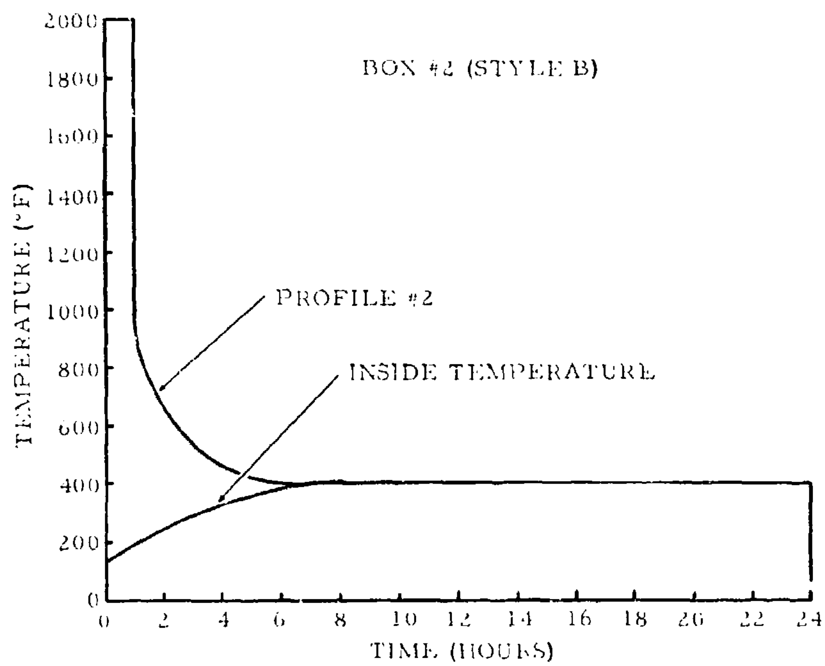


FIGURE 14. TIME-TEMPERATURE HISTORY OF THE ALUMINUM MASS INSIDE BOX NO. 2

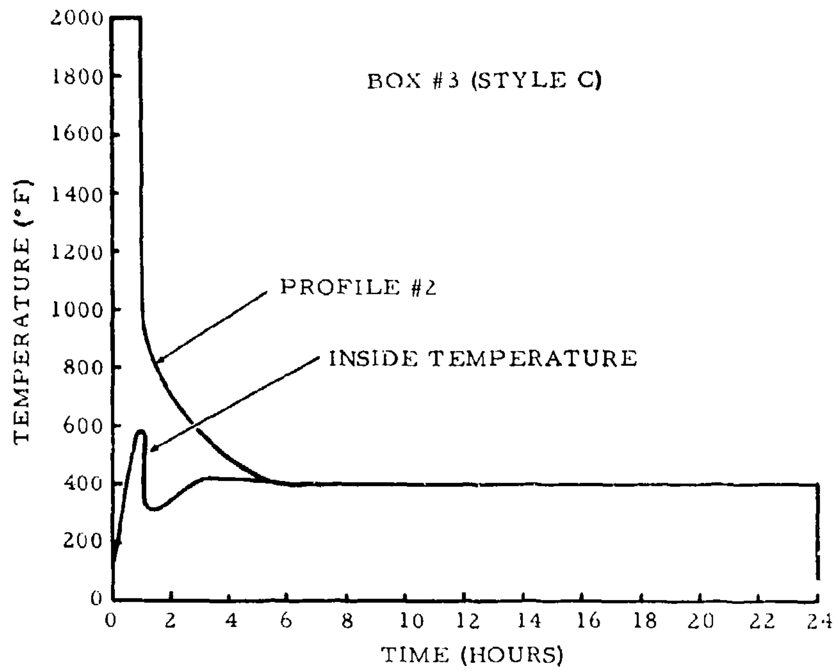


FIGURE 15. TIME-TEMPERATURE HISTORY OF THE ALUMINUM MASS INSIDE BOX NO. 3

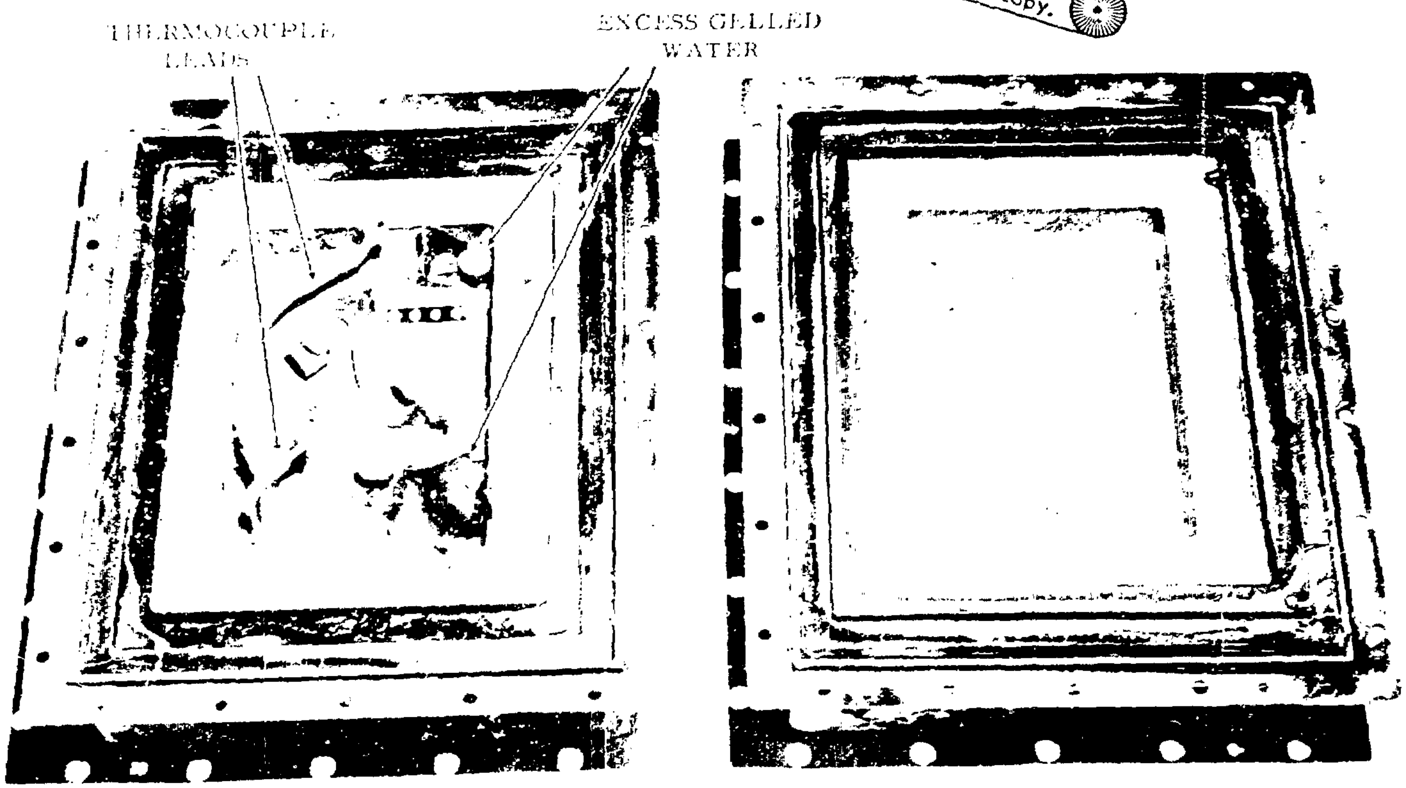


FIGURE 16. POST-TEST VIEW OF BOX NO. 1

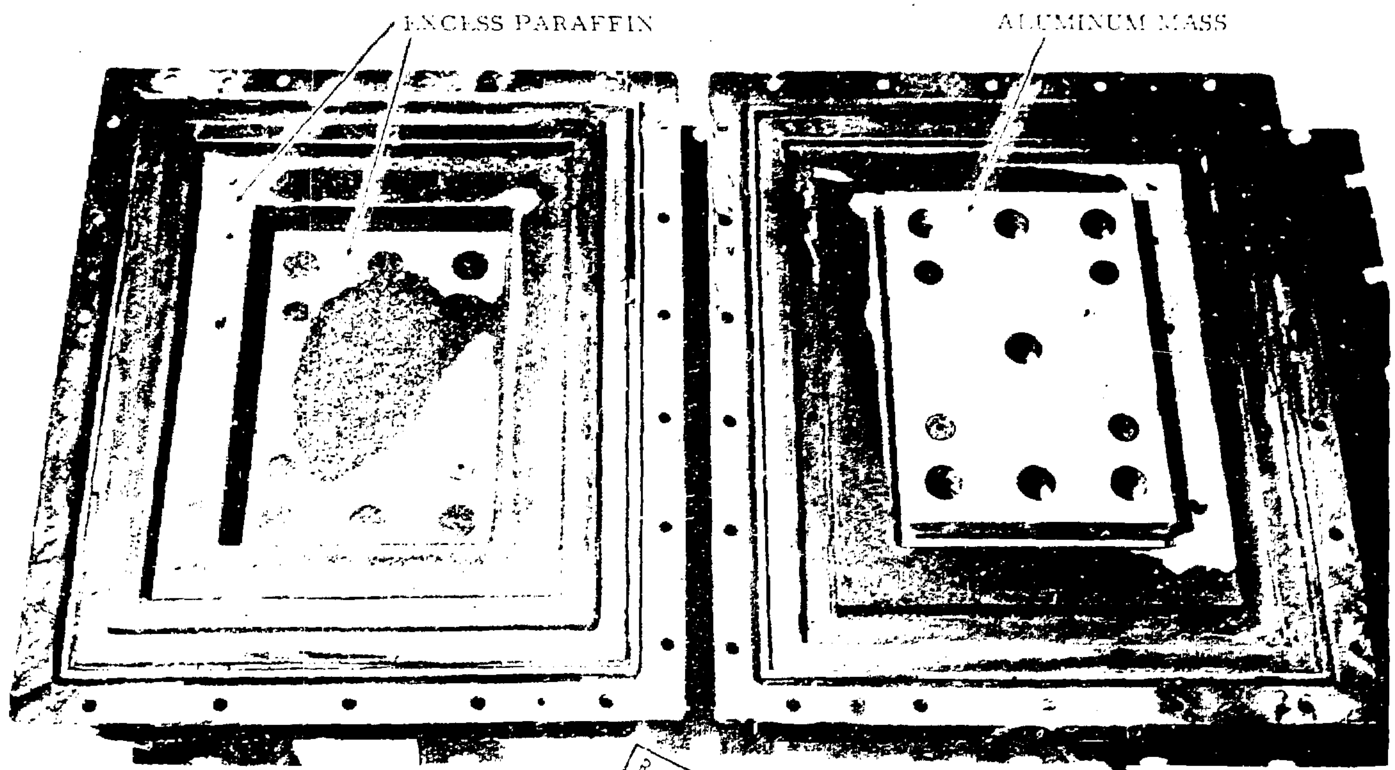


FIGURE 17. POST-TEST VIEW OF BOX NO. 2

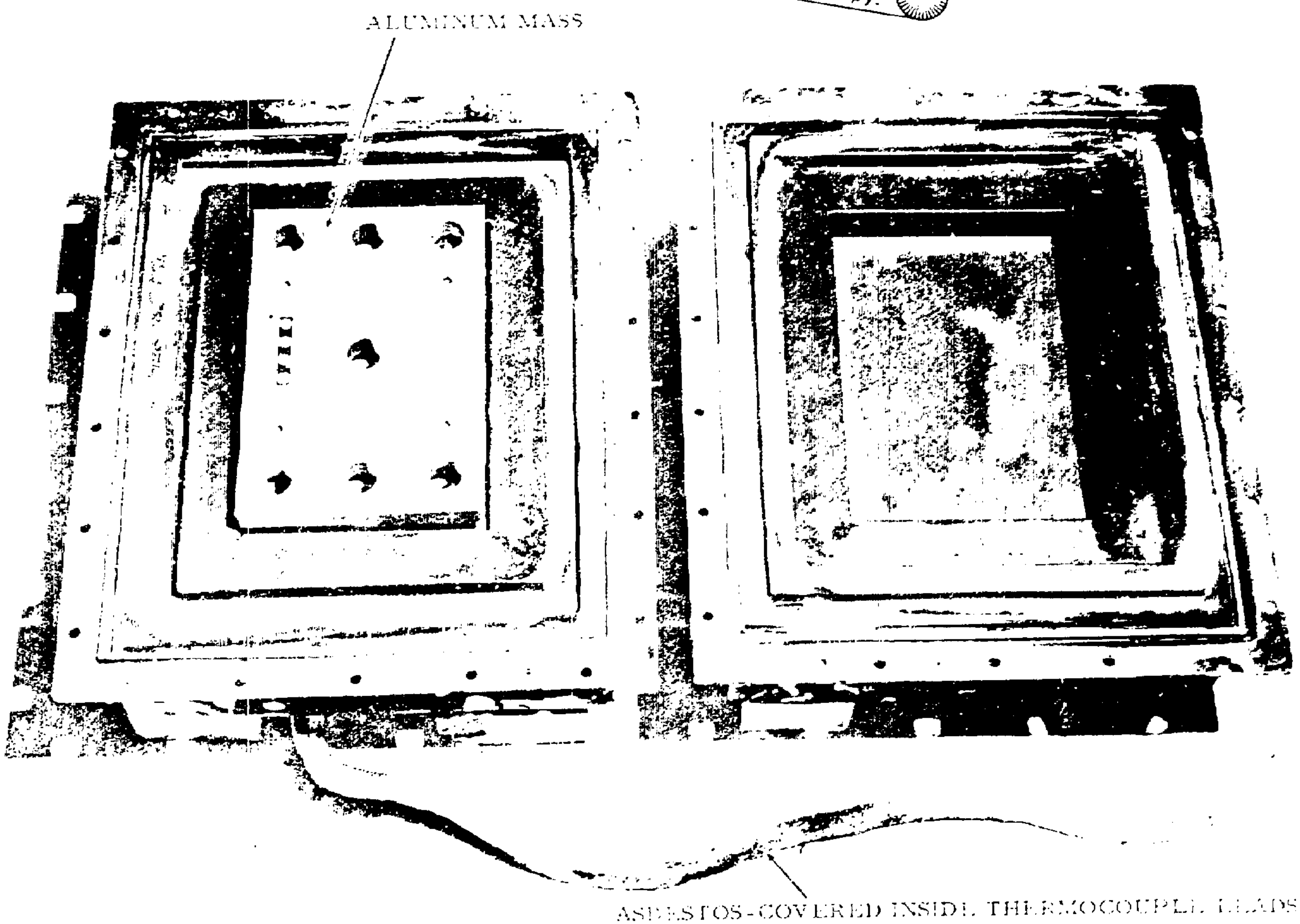


FIGURE 18. POST-TEST VIEW OF BOX NO. 3

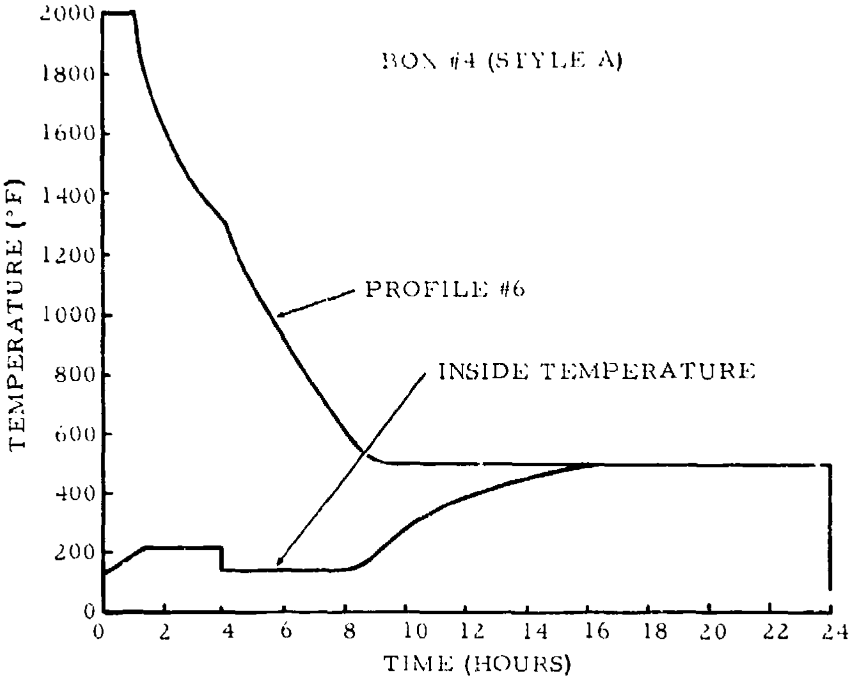


FIGURE 19. TIME-TEMPERATURE HISTORY OF THE ALUMINUM MASS INSIDE BOX NO. 4

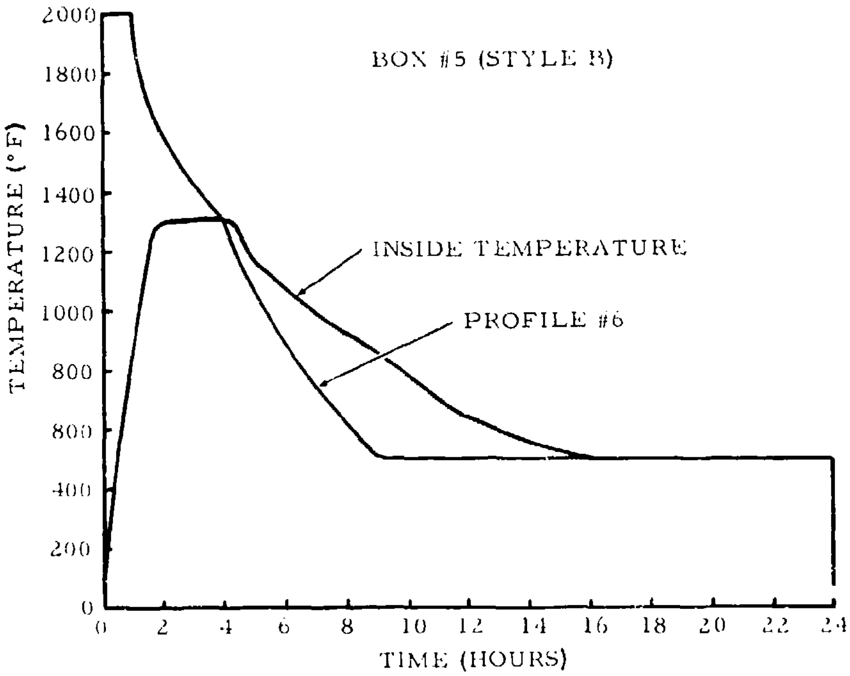


FIGURE 20. TIME-TEMPERATURE HISTORY OF THE ALUMINUM MASS INSIDE BOX NO. 5

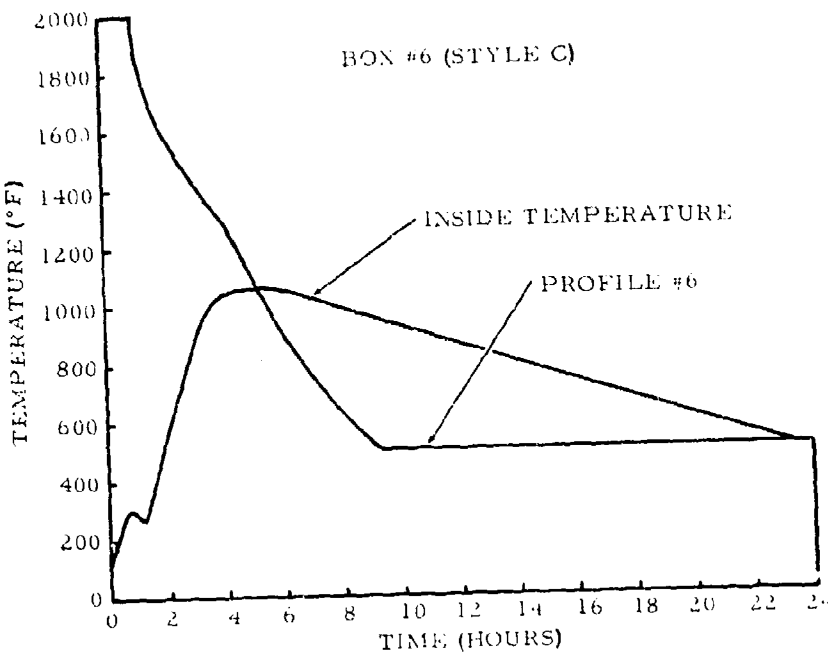


FIGURE 21. TIME-TEMPERATURE HISTORY OF THE ALUMINUM MASS INSIDE BOX NO. 6

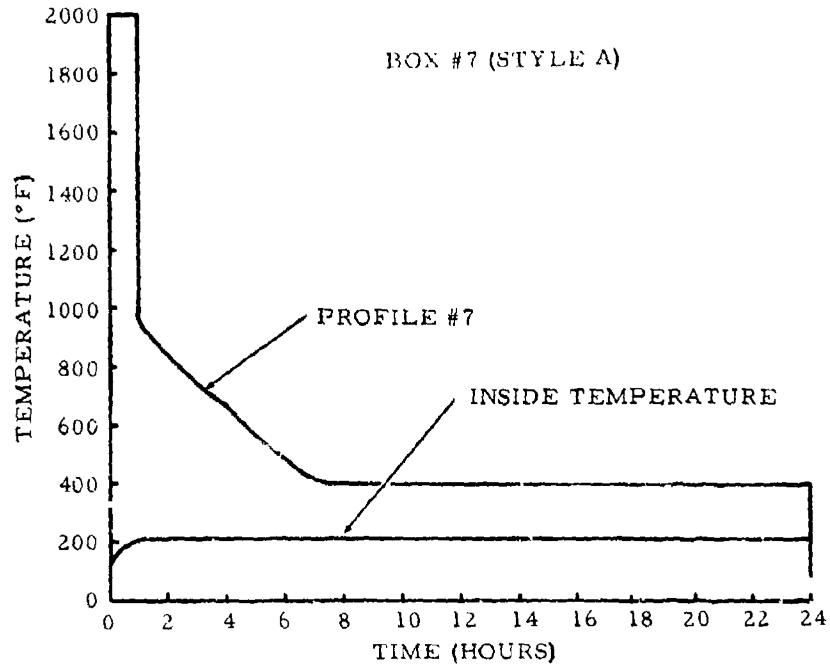


FIGURE 22. TIME-TEMPERATURE HISTORY OF THE ALUMINUM MASS INSIDE BOX NO. 7

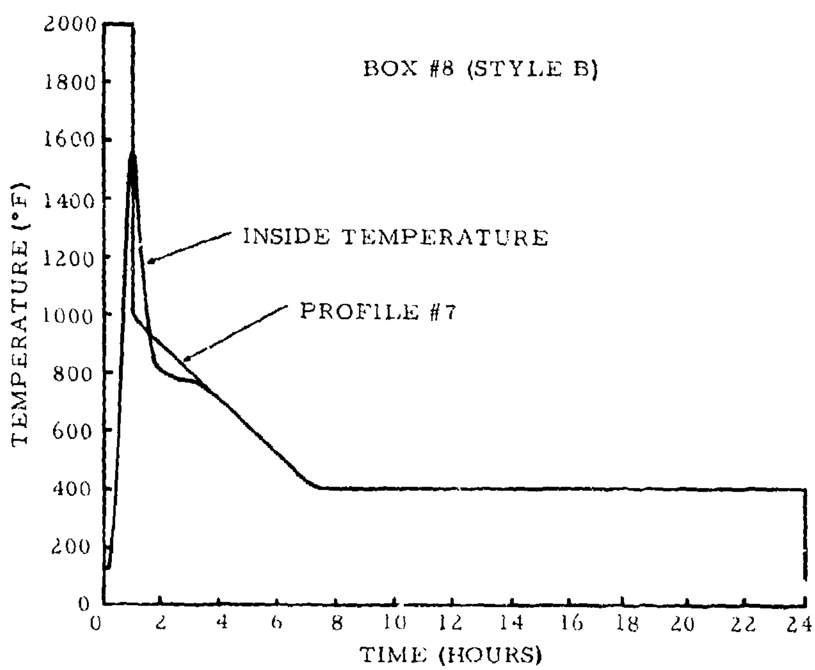


FIGURE 23. TIME-TEMPERATURE HISTORY OF THE ALUMINUM MASS INSIDE BOX NO. 8

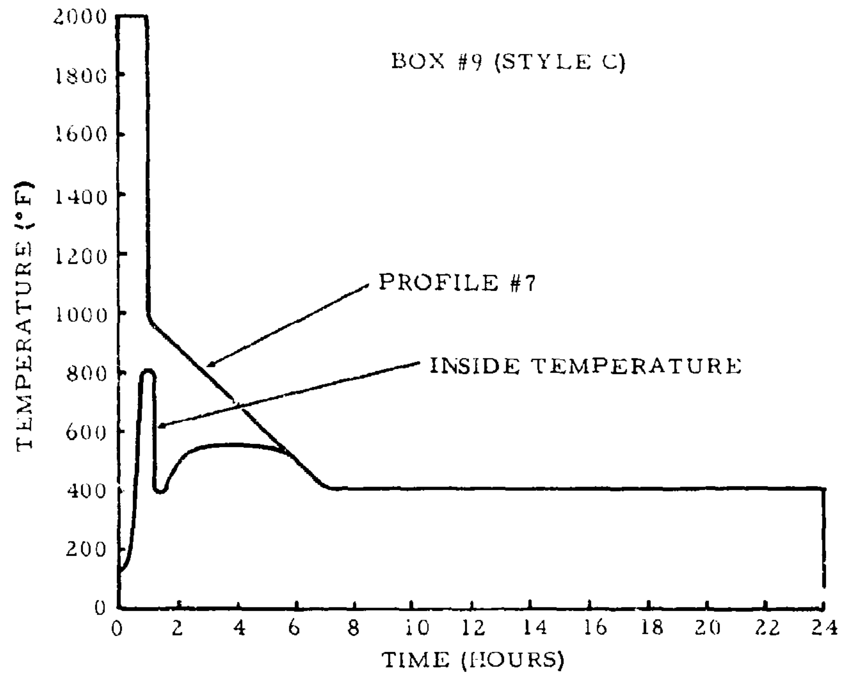


FIGURE 24. TIME-TEMPERATURE HISTORY OF THE ALUMINUM MASS INSIDE BOX NO. 9

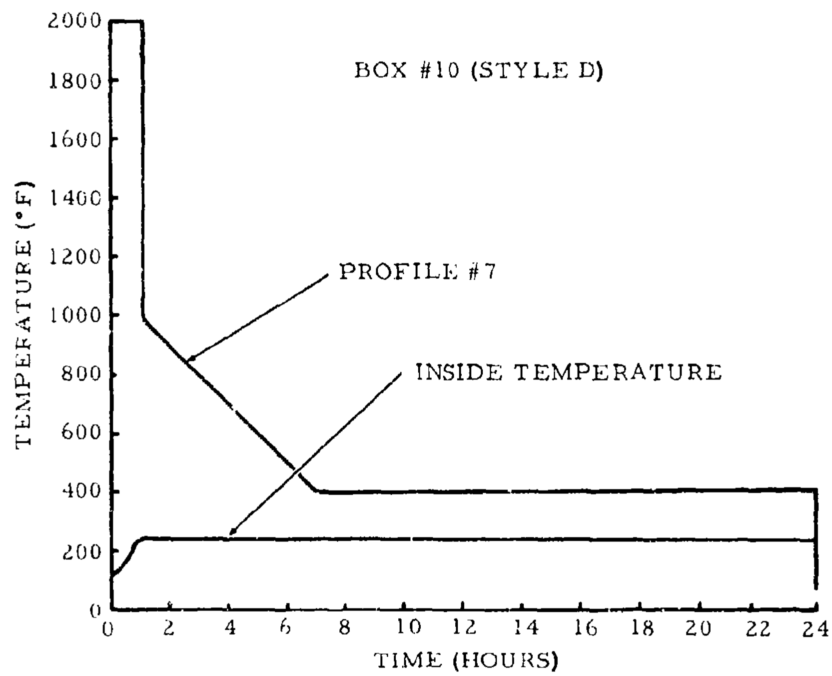


FIGURE 25. TIME-TEMPERATURE HISTORY OF THE ALUMINUM MASS INSIDE BOX NO. 10