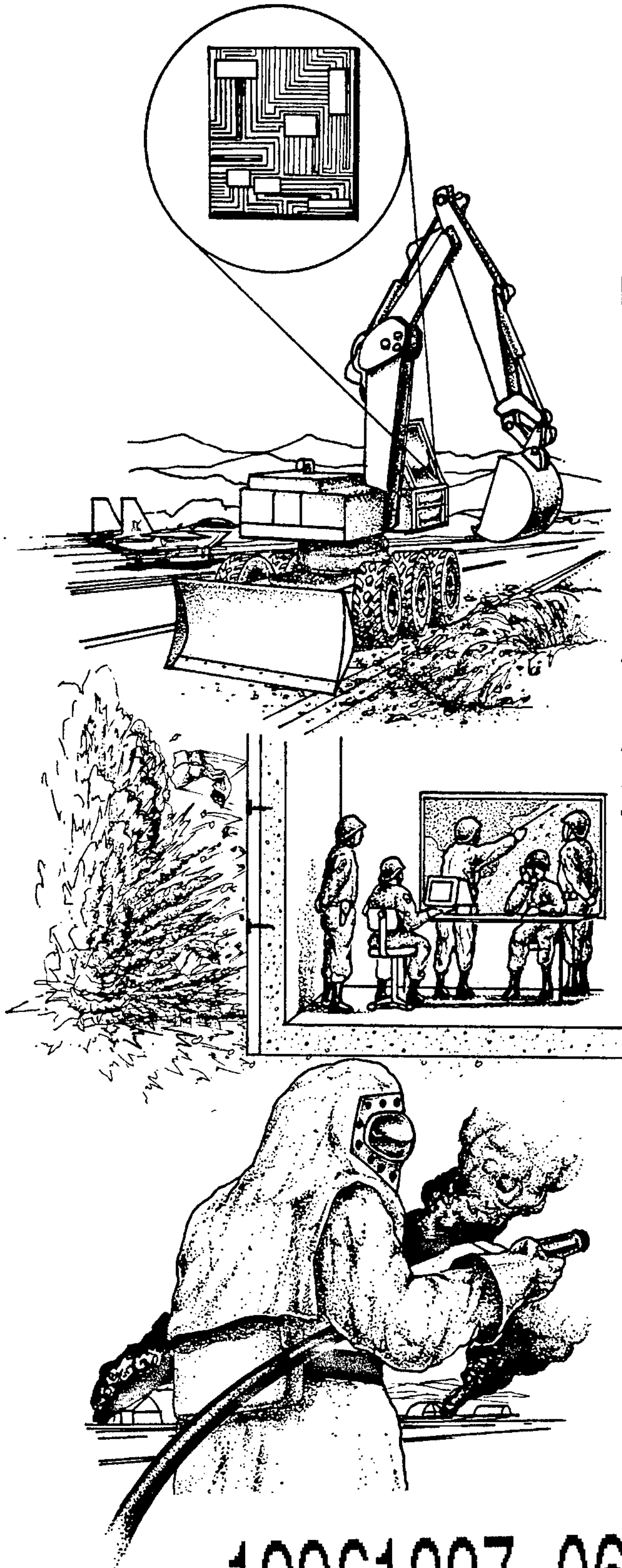

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LABORATORY TESTING OF HIGH DENSITY FOAM

DOUGLAS F. NELSON
RICHARD W. HUNTER

AIR FORCE CIVIL ENGINEERING LABORATORY
AIR FORCE CIVIL ENGINEERING SUPPORT AGENCY
TYNDALL AFB FL 32403-6001

DECEMBER 1996

FINAL REPORT

FEBRUARY 1992 - MARCH 1992

ENGINEERING RESEARCH DIVISION
Air Force Civil Engineering Support Agency
Civil Engineering Laboratory
Tyndall Air Force Base, Florida 32403

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A high density styrofoam made by Dow Chemical Company is being used in a special Air Force structural application without any surface covering. Recently, a fire inspection team expressed concern with the fire safety of using styrofoam insulation in this manner. A solution to the problem is being sought by AFCESA.

The objective of this effort was to find, through laboratory testing, the best fire protective covering for the high density styrofoam. The best covering materials found in laboratory testing will be tested in a larger scale test.

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EXECUTIVE SUMMARY

A. OBJECTIVE

The objective of this effort was to find, through laboratory testing, the best fire protective covering for the high density styrofoam being used in a special Air Force application. The best covering materials found in laboratory testing will be tested in a larger scale test.

B. BACKGROUND

A high density styrofoam made by Dow Chemical Company is being used in a special Air Force structural application without any surface covering. Recently, a fire inspection team expressed concern with the fire safety of using styrofoam insulation in this manner. A solution to the problem is being sought by AFCESA.

C. METHODOLOGY

The fire challenge was provided by a standard laboratory bunsen burner mounted to impinge a one inch long flame onto a vertically mounted test specimen. A high temperature probe attached to a strip chart recorder was used to record the changes of temperature with time. The temperature versus time plot was a valuable record of the results of the test burn. In addition, most burns were video taped and some were photographed with a 35mm still camera.

D. RESULTS

Both 1/2 and 5/8 inch sheetrock were tested. Little difference was found in the performance between these two thicknesses. The temperature on the back side of the gypsum sheetrock was measured with the high temperature probe. The temperature of the sheetrock rose to a constant temperature because at that temperature the heat from the bunsen burner was being dissipated into the air at the same rate as it was being provided by the burner. For this size of sample, the constant temperature turned out to be around 140 degrees Fahrenheit on the backside of the sheetrock, almost enough to melt the styrofoam. The backside of a very large piece of sheetrock (like the ones that would be used for this Air Force application) would stay cooler than this, unless it was exposed to a very large room engulfing fire.

Sheetrock never burned through. The test could have been continued indefinitely. The sheet rock provided a good thermal barrier because the back side of the sample stayed at a constant 140 F while a fire of 1500 F was on the front side.

E. CONCLUSION

Sheetrock has the advantages of being nonflammable (except for the paper on the surface) and a good thermal barrier (i.e. it does not transmit heat through to the styrofoam very quickly). The disadvantage of sheetrock is that it has poor physical strength; it can be easily damaged from

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bumps. Finally, hanging sheet rock is not an easy job, but it could be done at an Air Force installation in a "self help" mode.

D. RECOMMENDATION

Sheetrock is recommended as the best overall material for covering high density styrofoam in the Air Force application being studied. It is nonflammable, a good thermal barrier, and not too difficult to install. It will certainly prevent the self sustained burning of styrofoam in a corner. And it will not allow the melting or ignition of styrofoam behind it from all realistic heat sources, e.g. burning diffuser plastic or diesel fuel.

PREFACE

This report was prepared by the Air Force Civil Engineering Laboratory, Air Force Civil Engineering Support Agency, Tyndall Air Force Base, Florida 32403.

Mr. Douglas F. Nelson, AFCESA/RACF was the Project Officer. This test program was completed in support of the USAF Chief of Fire Protection, AFCESA/DF and Mr. Fred Walker, as the using organization Project Officer. This report presents the results of the Laboratory Testing of High-Density Styrofoam Program conducted at the Fire Research Laboratory from 7 February to 6 March 1992 at Tyndall AFB, Florida.

This report has been reviewed by the Public Affairs Officer (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nationals.

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TABLE OF CONTENTS

Section	Title	Page
I	INTRODUCTION	1
	A. OBJECTIVE	1
	B. BACKGROUND	1
II	EXPERIMENTAL PROCEDURES	2
	A. INSTRUMENT AND TEST APPARATUS	2
	B. METHOD USED FOR TEST	2
III	RESULTS AND DISCUSSION	4
IV	CONCLUSIONS AND RECOMMENDATION	15
	REFERENCES	17

LIST OF FIGURES

Figure	Title	Page
1	Bunsen Burner with Test Material	3
2	Laboratory Test Setup	3
3	Sheet Rock	5
4	Strip Chart Trace from Sheet Rock Test	5
5	Burned Masonite	7
6	Temperature vs. Time for Masonite	7
7	Formica	8
8	Containers of Different Stucco Material	8
9	Sure-Fix Concrete	9
10	Bonsal Surewall Elastocoat	9
11	Marblecrete	12
12	Unburned and Burned Wall Liner	12
13	Stucco Box Burning	13
14	Bottom View of Stucco Box	13
15	Burning Diffuser Plastic on Stucco	14
16	Backside of Diffuser Plastic on Stucco	14

LIST OF TABLES

Table	Title	Page
1	List of Materials Tested and Results ....6...	14

SECTION I
INTRODUCTION

A. OBJECTIVE

The objective of this effort was to find, through laboratory testing, the best fire protective covering for the high density styrofoam being used in a special Air Force application. The best covering materials found in laboratory testing will be tested in a larger-scale test.

B. BACKGROUND

A high-density styrofoam made by Dow Chemical Company is being used in a special Air Force structural application without any surface covering. Recently, a fire inspection team expressed concern with the fire safety of using styrofoam insulation in this manner. A solution to the problem is being sought by AFCESA.

The Underwriter Laboratory (UL) found a significant danger with uncovered foam on the interior of buildings exists. They discovered that when there is a mechanism for thermal feedback, like in the corner of a room, very high rates of flame spread can be experienced (Reference 1).

Small-scale laboratory tests (e.g., vertical and horizontal Bunsen burner flammability tests) show that fire-retardant chemicals, like those used in the high-density styrofoam, can make a significant difference in the flammability of styrofoam (expanded polystyrene). Nevertheless, there are reported incidences where even foams made with fire-retardant chemicals had very high flame surface spread rate under large-scale real-world conditions.

Laboratory testing was undertaken to better understand the issues involved so that a better test plan can be written for the larger-scale testing to follow. UL recommends the use of a large-scale corner test to most accurately test the fire hazards of structural foams with different types of covering material.

SECTION II
EXPERIMENTAL PROCEDURES

A. INSTRUMENT AND TEST APPARATUS

The following is a list of the laboratory equipment used in this effort:

1. Bunsen burner
2. Electric heater
3. High temperature probe (up to 2000 Degree Fahrenheit)
4. Strip chart recorder
5. Hot plate
6. Video camera
7. 35mm camera

B. METHODS USED FOR TEST

The fire challenge, as is shown in Figure 1, was provided by a standard laboratory Bunsen burner mounted to impinge a one inch long flame onto a vertically mounted test specimen. A high temperature probe attached to a strip chart recorder was used to record the change of temperature with time (Figure 2). In many experiments, the temperature versus time plot was a valuable record of the results of the test burn. A typical temperature plot is shown in Figure 4. In addition, most burns were video taped and some were photographed with a 35mm still camera, providing the color prints shown in this report.

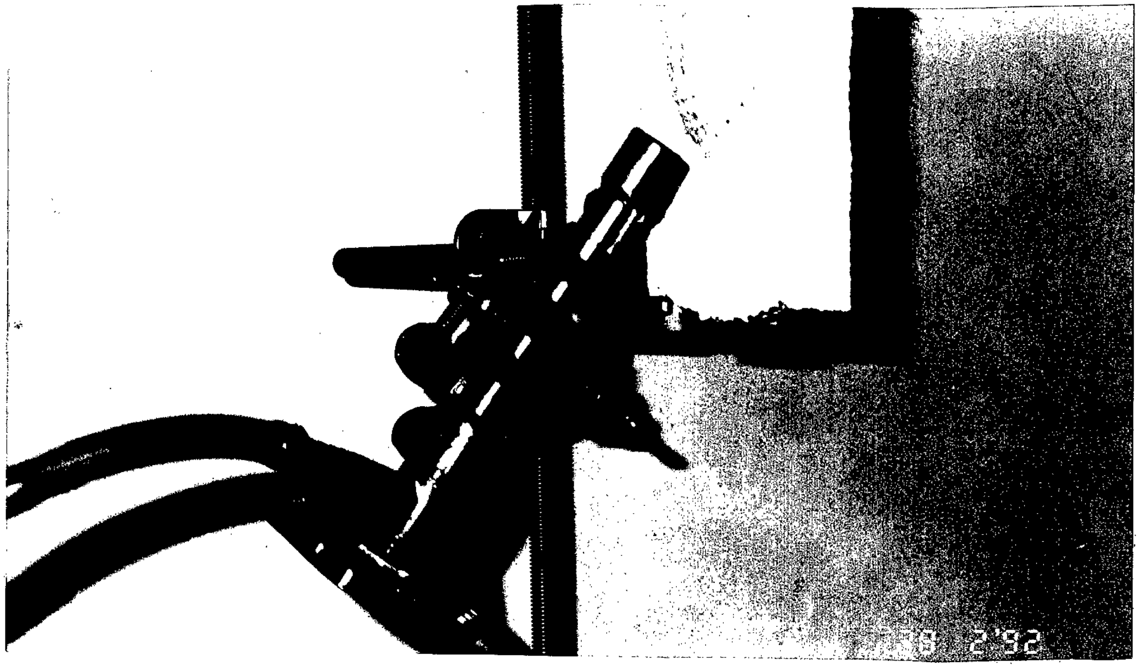

Figure 1. Bunsen Burner with Test Material

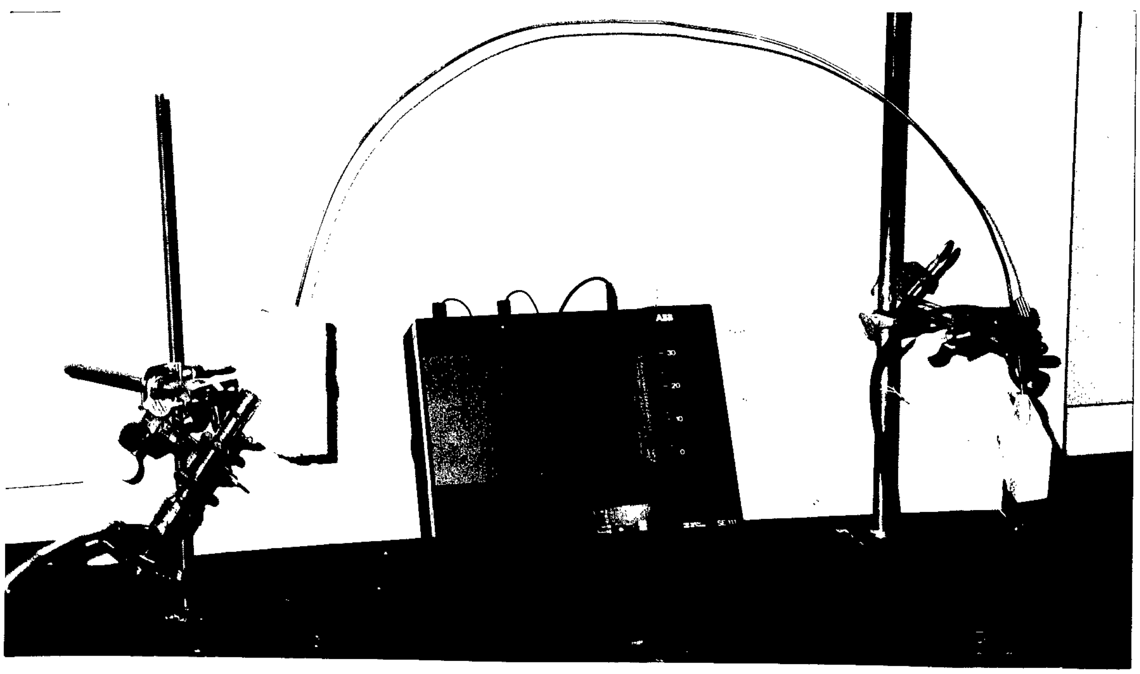

Figure 2. Laboratory Test Setup

SECTION III
RESULTS AND DISCUSSION

A. HIGH-DENSITY STYROFOAM ALONE

The special high-density styrofoam being tested is manufactured by Dow Chemical. It has less air in it than the styrofoam normally used for insulating private homes. The left upper quadrant of Figure 11 shows a sample of the high-density styrofoam without any covering but only the plastic screen.

The high-density styrofoam melts at around 150°F by getting soft and tacky. Around 200°F, it shrinks away from the heat source and shrivels up. This is characteristic of foamed thermal plastics which tend to pull away from a heat source rather than burn. This property explains many of the results observed in this test. For example, in the test of the high density styrofoam covered with stucco, the styrofoam hollowed out behind the stucco. It did not burn. It simply melted, once the temperature got above 200°F.

In a test using an electric space heater, the high density styrofoam ignited at around 700°F. With radiant heat applied, it continued to burn. Furthermore, the melted styrofoam (liquid polystyrene) pooled, gave off vapors, and burned with a great deal of heat.

B. SHEETROCK

A photograph of a sheetrock sample is shown in Figure 3. Both 1/2- and 5/8-inch sheetrock were tested. Little difference was found in the performance between these two thicknesses.

The temperature on the back side of the gypsum sheetrock was measured with the high-temperature probe. The temperature of the sheetrock rose to a constant temperature because at that temperature the heat from the Bunsen burner was being dissipated into the air at the same rate as it was being provided by the burner. For this size of sample, the constant temperature turned out to be around 140°F on the backside of the sheetrock, almost enough to melt the styrofoam. Figure 4 is a strip chart trace for a test on sheetrock. The back side of a very large piece of sheetrock (like the ones that would be used for this Air Force application) would stay cooler than this, unless it was exposed to a very large room-engulfing fire.

However, the sheetrock never burned through. The test could have been continued indefinitely. The sheet rock provided a good thermal barrier because the back side of the sample stayed at a constant 140°F while a fire of 1500°F was on the front side.

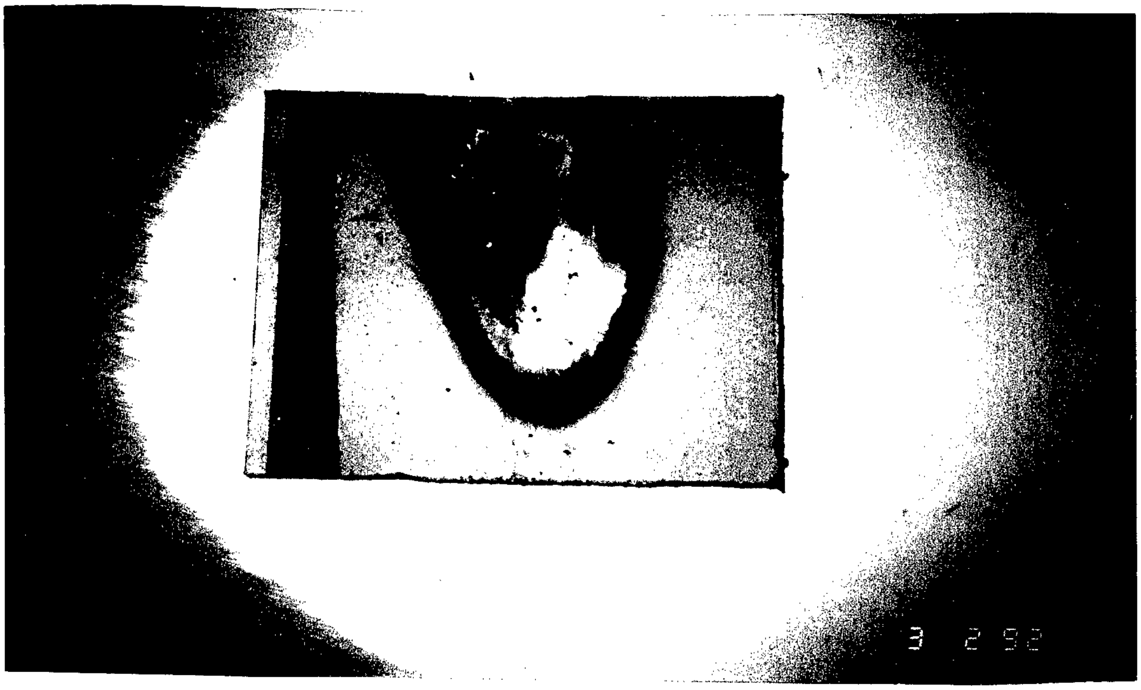

Figure 3. Sheet Rock

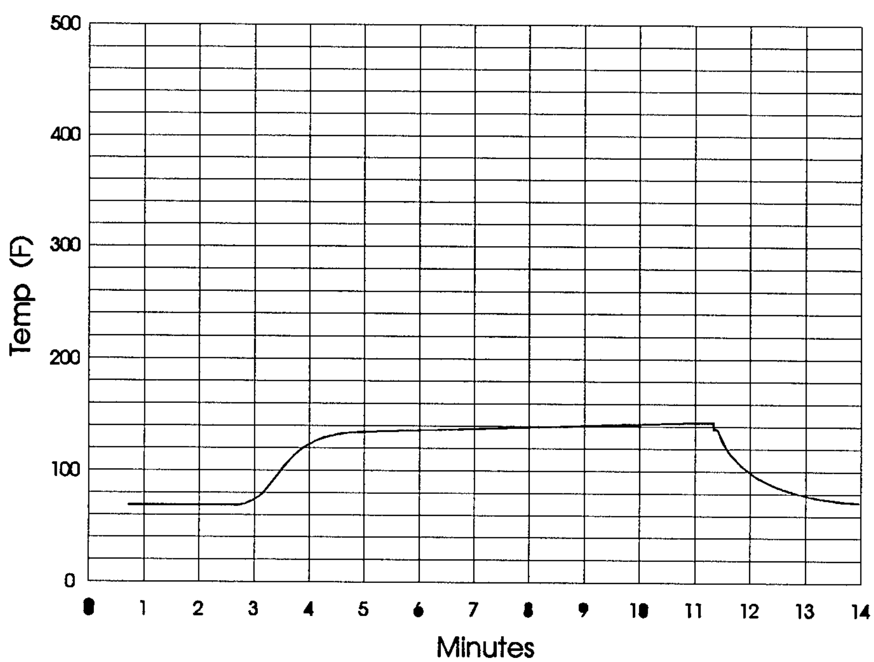

Figure 4. Strip chart Trace From Sheet Rock Test

C. MASONITE

The masonite sample is shown in Figure 5. The masonite was a good thermal barrier. As shown in Figure 6, the temperature behind the masonite sample did not rise significantly until burn-through occurred almost 9 minutes after fire impingement was started. Once fire penetration occurred, the masonite self-sustained in burning and the temperature at the probe increased rapidly.

D. FORMICA

The formica sample, shown in Figure 7, was tested in the test apparatus. The formica, popped and crackled as it delaminated in less than 1 minute after being exposed to the flame of the Bunsen burner. Formica does not appear to be a suitable covering material for high-density styrofoam.

E. SURE-FIX CONCRETE

Figure 8 shows the containers from which the next three different kinds of covering material were taken. They all can be considered variation of stucco, but only the last one is true stucco material. The Sure-Fix concrete is the container on the left.

Figure 9 is a picture of the high-density styrofoam covered with Sure-Fix. It did not burn, but it was poor thermal barrier because the flame heat was conducted rapidly through the Sure-Fix®. This caused the styrofoam to melt on the back side of the concrete, resulting in the hollowing out of the test specimen, even though the fire did not penetrate through.

F. BONSAL SUREWALL ELASTOCOAT

The Bonsal Surewall Elastocoat sample is shown in Figure 10. Surewall is a synthetic stucco material. It is a flexible polymeric material, like acrylic paint, which explains why it began to burn in less than a minute after being exposed to the flame. Nevertheless, the fire did not penetrate through because the filler in the product is sand making it mostly nonflammable. But like concrete, the heat was conducted through the surface rapidly resulting in the melting away of the styrofoam behind the Surewall. It comes premixed and is easy to apply.

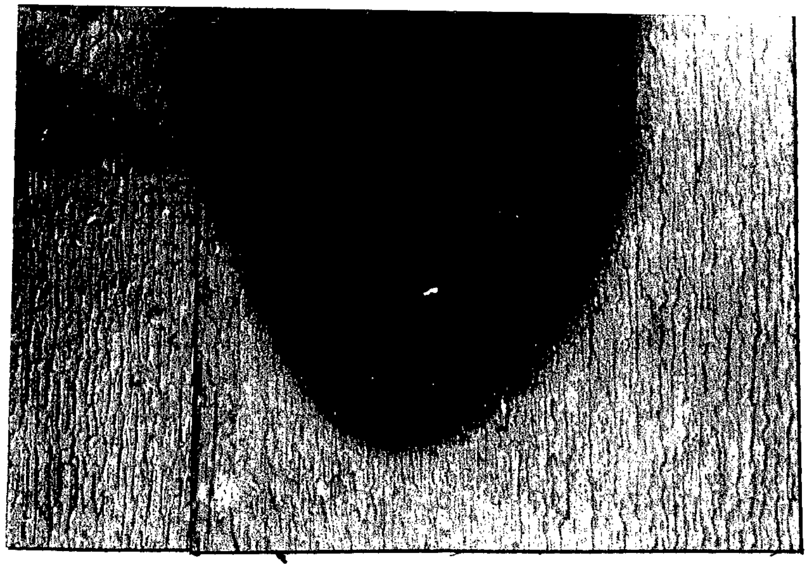

Figure 5. Burned Masonite

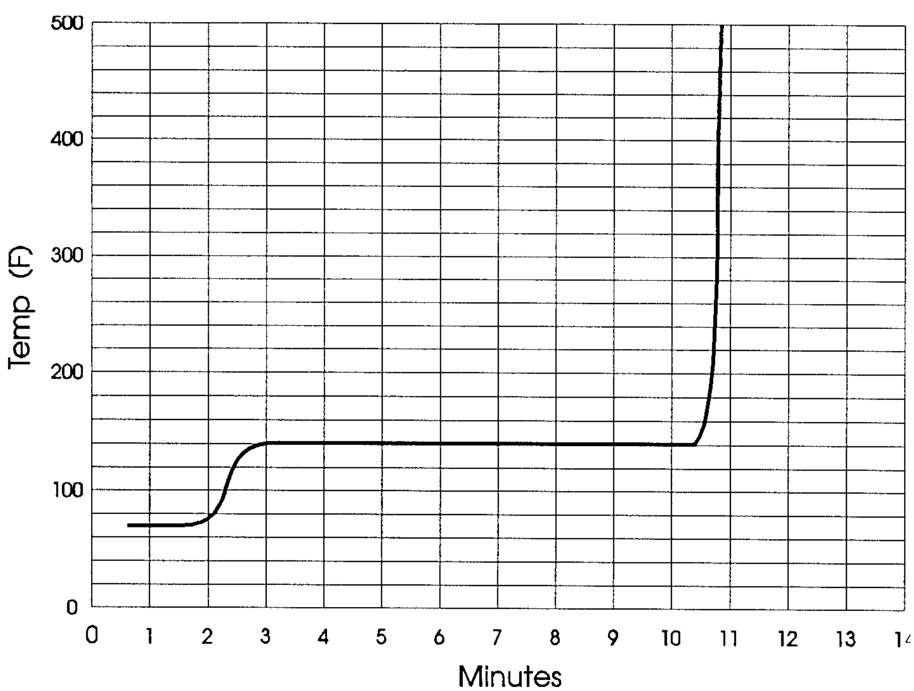

Figure 6. Temperature vs Time for Masonite

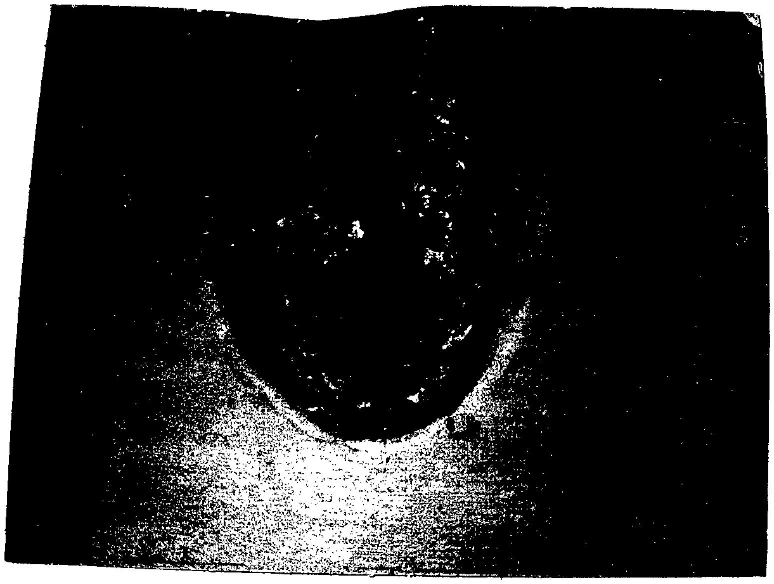

Figure 7. Formica Sample

Figure 8. Containers of Different Stucco Materials

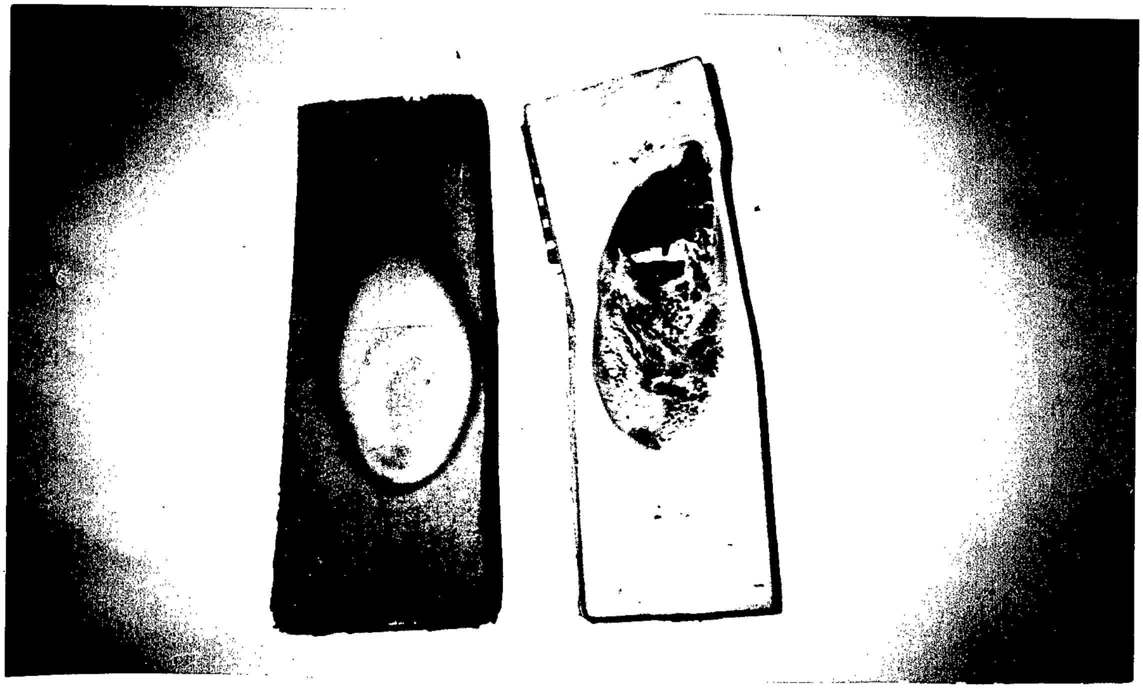

Figure 9. Sure-Fix® Concrete

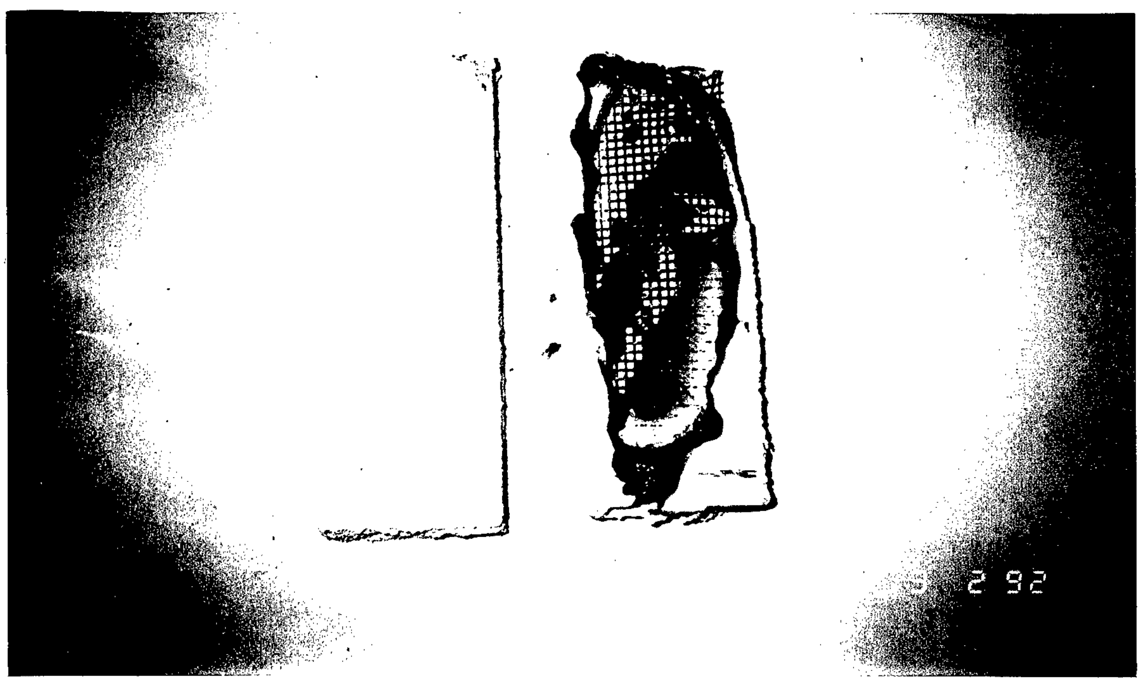

Figure 10. Bonsal Surewall Elastocoat

G. MARBLECRETE STUCCO

Shown in Figure 11 is a standard stucco material. It contains both marble and concrete. Like concrete, it does not burn, but it rapidly conducts heat to the styrofoam behind it. This again causes the styrofoam to melt and hollow out the inside of the test sample without any polystyrene burning. The test samples were covered on the sides to prevent any flames from going around the stucco and burning the styrofoam.

H. WALL LINER

The wall liner, shown in Figure 12, burned through in only a few seconds. It compared unfavorably with all the other covering material, and thus is not recommended as a high-density styrofoam covering material.

I. STUCCO BOX

A cube of styrofoam was covered with two layers of stucco to more accurately simulate the actual application of the high density styrofoam. The resulting box, 4 inches on a side and filled solid with medium density styrofoam, was burned in a 7-inch diameter petri dish (Figure 13). The temperature probe was put through the top of the box so that the tip of the probe was right behind the stucco covering on the side of the box, thus measuring the temperature that the styrofoam would see directly behind the stucco.

Within minutes, the styrofoam melted out through the open bottom of the box (Figure 14) which increased the intensity of the fire as liquid polystyrene mixed with the JP-4. Once again, the stucco proved to be a poor thermal barrier by conducting heat from the fire rapidly to the styrofoam behind. The probe showed a temperature rise to 150°F, which was sufficient to melt the styrofoam.

J. SHEETROCK BOX

A 0.5-inch thick sheetrock box, 3.5-inches on a side, was made and filled with medium density styrofoam. The temperature probe was inserted through the top of the box. It was burned in a 7-inch diameter petri dish.

After 4 minutes, the temperature on the inside wall of the sheet rock was up to 138°F. The styrofoam melted halfway up the sheetrock box before the test was stopped. The flame temperature outside the box was well over 700°F. This means that the temperature difference across the sheetrock sides was well over 500°F. Again this demonstrated that sheetrock is a good thermal barrier. The styrofoam eventually melted because the whole box was heated up above the melting point of styrofoam.

H. DIFFUSER AND MARBLECRETE

Burning plastic from a fluorescent light diffuser lens was dripped onto a test sample of 2 layers of marblecrete stucco plastered over high density styrofoam (Figure 15). The burning plastic did not burn the stucco, instead it left behind a crystalline residue. Still, enough heat was transmitted through the stucco to hollow out the styrofoam behind the stucco (See Figure 16).

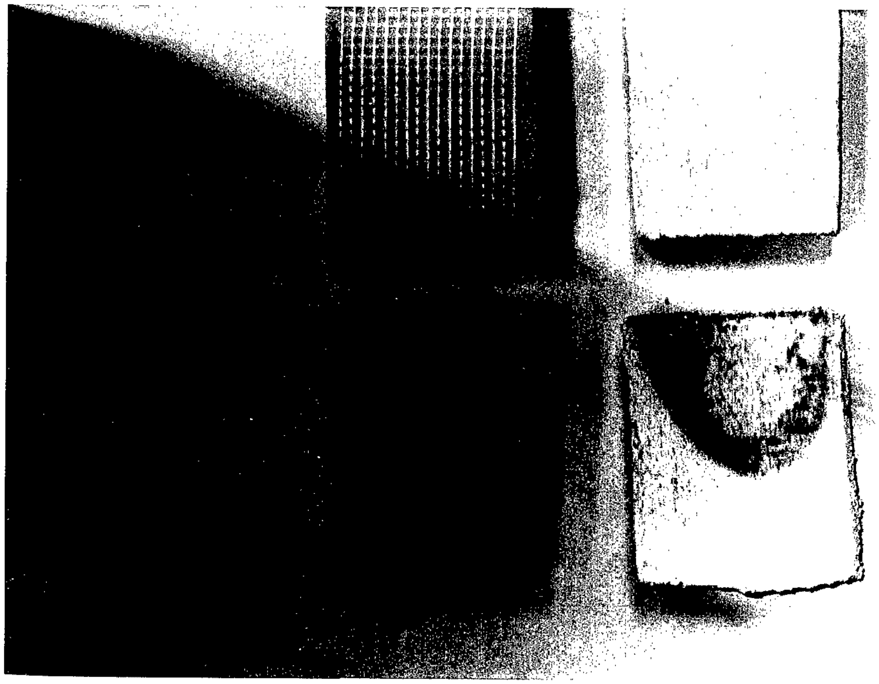

Figure 11. Styrofoam with Screen, Unburned Marblecrete
Back of Burned Marblecrete, Front of Burned Marblecrete

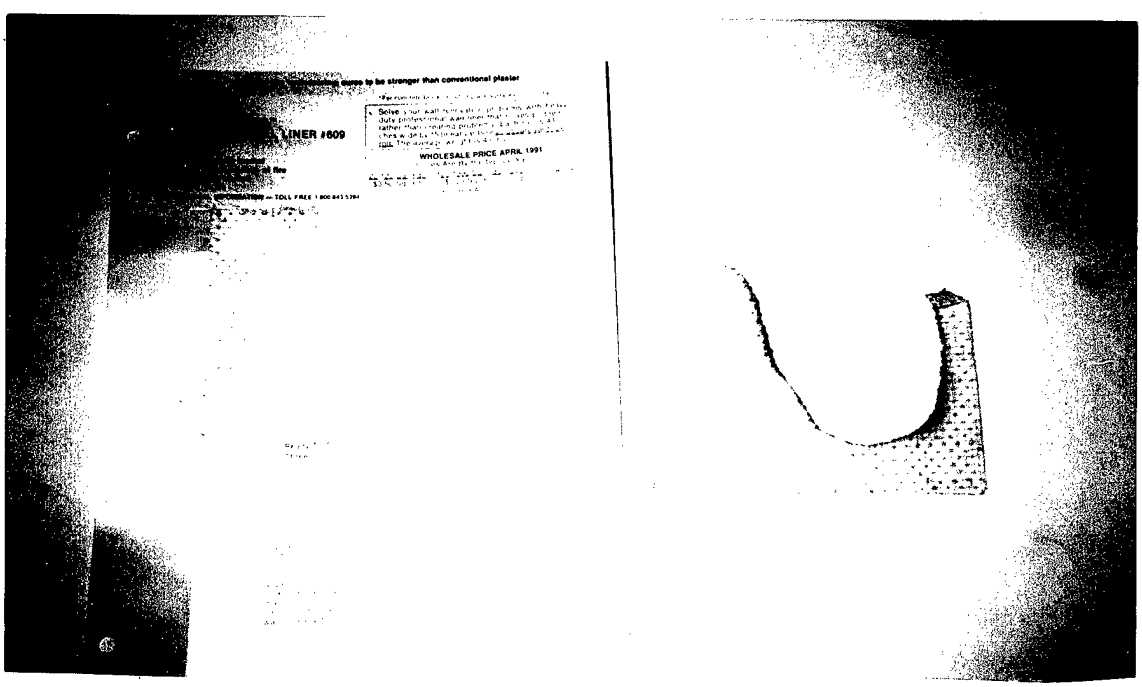

Figure 12. Unburned and Burned Wall Liner

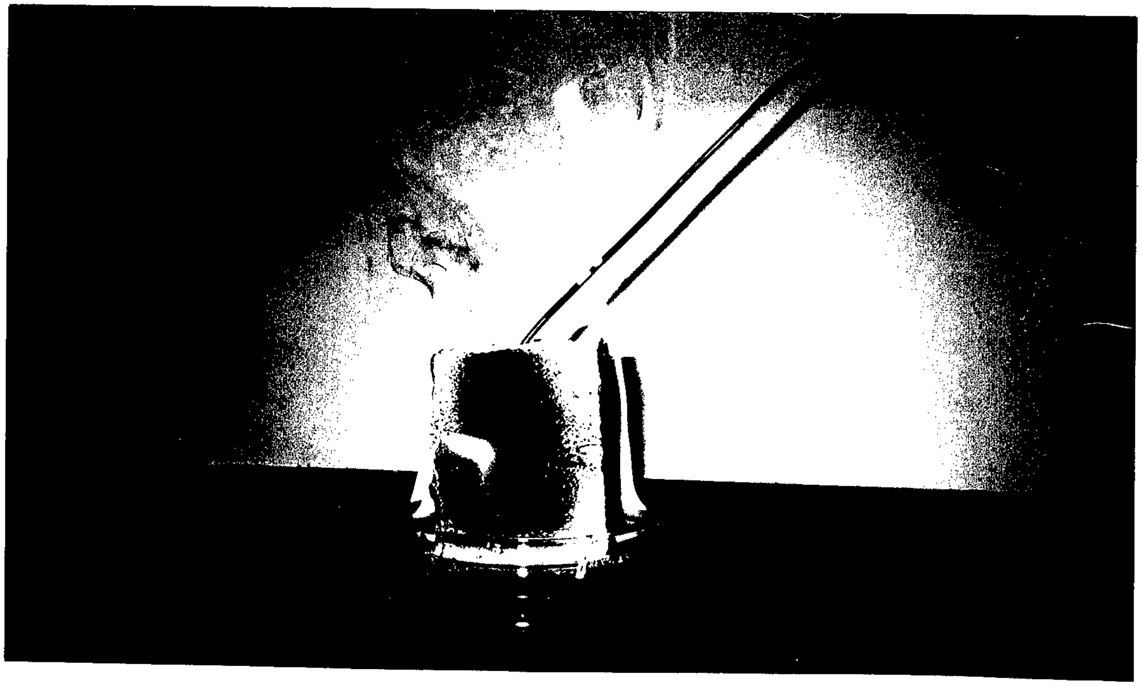

Figure 13. Stucco Box Burning

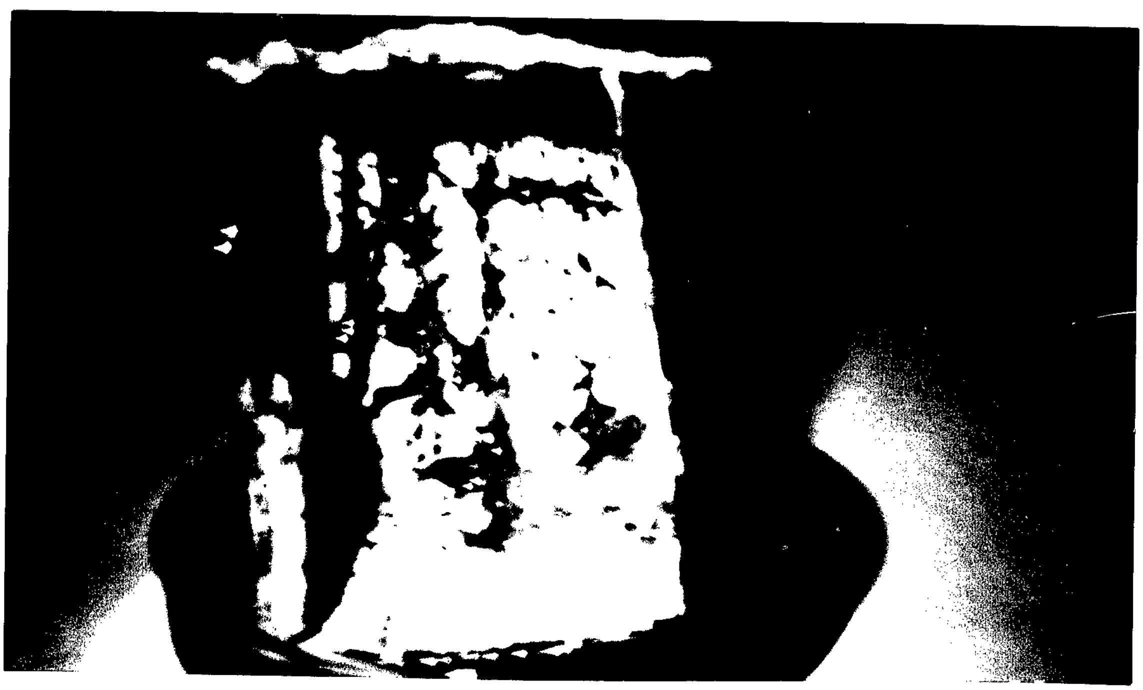

Figure 14. Bottom View of Stucco Box

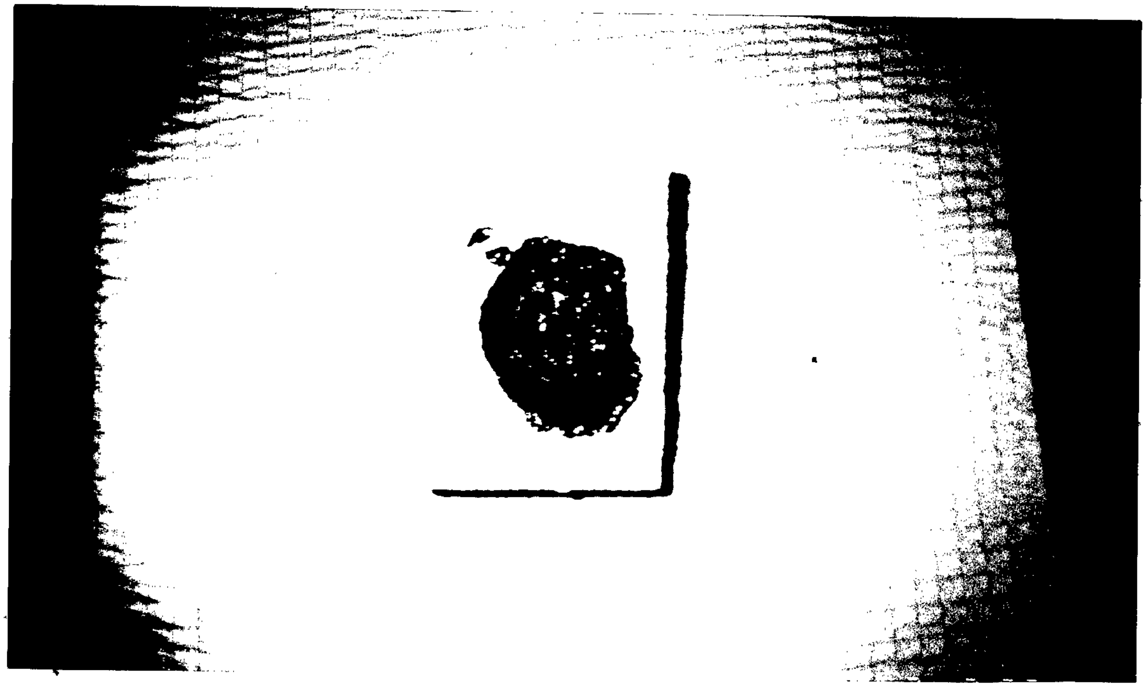

Figure 15. Burning Diffuser Plastic on Stucco

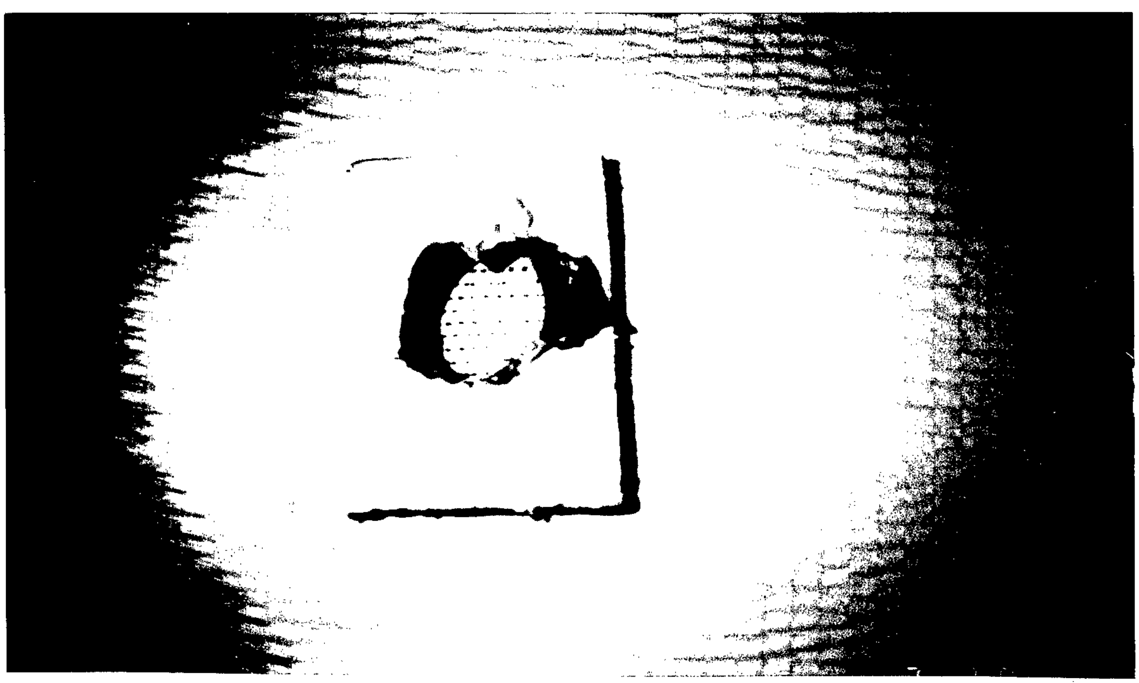

Figure 16. Backside of Diffuse Plastic on Stucco

SECTION IV
CONCLUSIONS AND RECOMMENDATION

Table 1 summarizes the results of the Section III, Results and Discussion.

TABLE 1. HIGH DENSITY STYROFOAM COVERINGS

Material	Time	Comments
1/2 in. Sheet Rock	more 20 min	Indefinitely
Formica	approx 1 min	Explodes
Masonite	9 min	Good Thermal Barrier Eventually burns thru
1/4 in. Concrete	2 min	To separation
Wall Liner	15 sec	To burn through
Surewall Elastocoat	15 sec 1 1/2 min	To catch on fire To melt through
Stucco (Marblecrete)	1 1/2 min	To melt through
Stucco Box		Styrofoam melted
Sheet Rock Box		Styro partially melted
Diffuser on Stucco		Styro hollowed out

The Formica, the Wall Liner, and the Surewall were found to be unsatisfactory for a styrofoam covering material. While the Bonsal Surewall Elastocoat is a nice user-friendly product that comes premixed and is easy to apply, it does burn and should not be considered a viable candidate.

The Sure-Fix concrete performed adequately, but the regular stucco material tested (Marblecrete), works just as well, since it also is mostly concrete. In addition, the Marblecrete is more attractive in appearance and therefore preferable to a straight concrete product like Sure-Fix.

Looking at Table 1, this leaves three products for consideration as styrofoam-covering materials: sheetrock, masonite, and regular stucco. The following is a discussion of the advantages and disadvantages of these alternatives with the recommended best material for a styrofoam covering material. Another final choice could be made, given other facts not being considered here.

A. SHEETROCK

Sheetrock has the advantage of being nonflammable (except for the paper on the surface) and a good thermal barrier (i.e. it does not transmit heat through to the styrofoam very quickly). The disadvantage of sheetrock is that it has poor physical strength; it can be easily damaged from bumps. Finally, hanging sheet rock is not easy, but could be done at an Air Force installation in a "self-help" mode.

B. MASONITE

The masonite provided a good thermal barrier for up to 9 minutes in our laboratory testing, and an attractive durable covering material that could be installed by Air Force personnel with normal carpentry tools and procedures. After 9 minutes of exposure to an open flame, it did burn through and begin to burn on its own. Masonite is flammable, although it can be quite fire-resistant with proper treatment.

C. STUCCO

The major advantage of stucco is that it is nonflammable. Neither the Bunsen burner flame nor the burning diffuser plastic had any effect on the stucco surface. It also is fairly easy to apply over the plastic screen. It's major drawback is that it is a good conductor of heat, thus a poor thermal barrier. The heat from the flame was rapidly conducted through the stucco, causing the styrofoam behind it to melt. The resulting liquid polystyrene ran down and out where it burned.

D. RECOMMENDATION

The Sheetrock is recommended as the best overall material for covering high-density styrofoam in the Air Force application being studied. It is nonflammable, a good thermal barrier, and not too difficult to install. It will certainly prevent the self-sustained burning of styrofoam in a corner. And it will not allow the melting or ignition of styrofoam behind it from all realistic heat sources, e.g., burning diffuser plastic or diesel fuel.

REFERENCES

1. "Plastic," Fire Protection Handbook, Fifteenth Edition, National Fire Protection Association, pp. 4-77 to 4-81.

2. Schultz, Neil, Fire and Flammability, Van Nostrand Reinhold Company

3. "Standard Guide for Room Fire Experiments," 1991 Annual Book of ASTM Standards

4. "Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter," 1991 Annual Book of ASTM Standards