AD-A140 153 UNDERWRITERS LABORATORIES FIRE TESTS OF SPRAYED POLYURETHANE FOAM APPLIED.. (U) NAVAL CIVIL ENGINEERING LAB PORT HUENEME CA R L ALUMBAUGH ET AL. DEC 83 1/2

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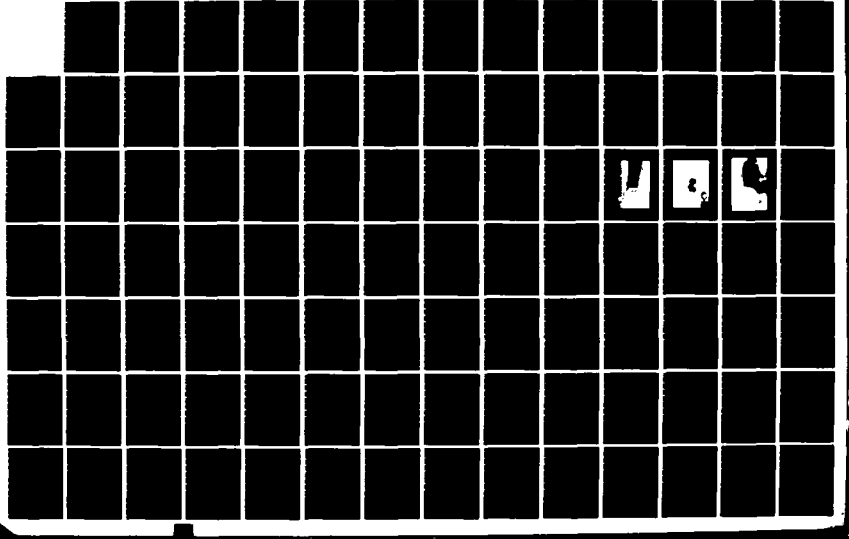

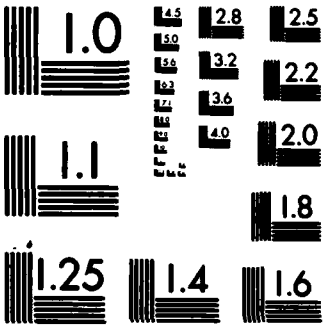

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TITLE: UNDERWRITERS LABORATORIES FIRE TESTS OF SPRAYED POLYURETHANE FOAM APPLIED DIRECTLY TO METAL ROOF DECKS

AUTHOR: R. L. Alumbaugh and S. R. Conklin

DATE: December 1983

SPONSOR: Chief of Naval Material and
Naval Facilities Engineering Command

PROGRAM NO: ZO371-01-112B

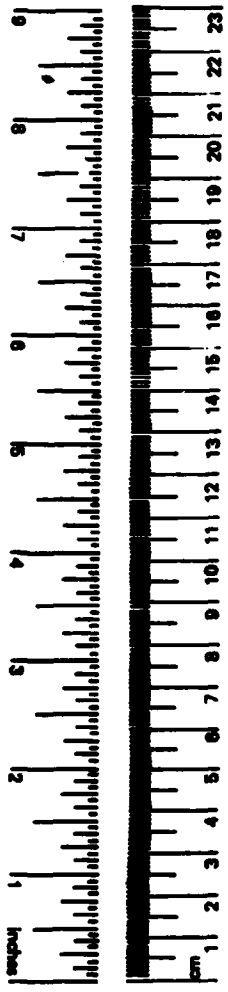
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

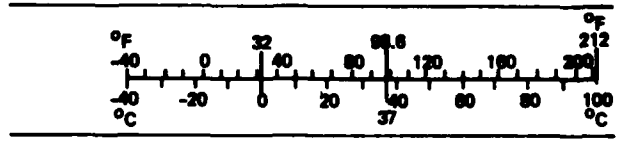
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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The Naval Civil Engineering Laboratory has conducted extensive fire testing of sprayed polyurethane foam (PUF) roof systems applied directly to metal roof decks. Testing was conducted at Underwriters Laboratories (UL) and the work was sponsored by the Naval Material Command and the Naval Facilities Engineering Command. The work was conducted in three phases with the first phase being directed toward PUF systems applied principally to standing

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Continued

seam metal decks, the second phase toward PUF on corrugated metal decks, and the third phase toward PUF applied to fluted metal decks.

The fire test program was most successful. Results showed that the PUF roof systems performed as well as, if not better than, the standard built-up roof system. This report provides details of the test program, the roof deck construction classifications that resulted from the tests and a listing of over 100 PUF roof systems that are now classified under the three Roof Deck Constructions. These classified systems meet the fire safety criteria (specifically DOD and Navy criteria) and can be used on appropriate metal roof decks at Naval Shore Activities.

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The Naval Civil Engineering Laboratory has conducted extensive fire testing of sprayed polyurethane foam (PUF) roof systems applied directly to metal roof decks. Testing was conducted at Underwriters Laboratories (UL) and the work was sponsored by the Naval Material Command and the Naval Facilities Engineering Command. The work was conducted in three phases with the first phase being directed toward PUF systems applied principally to standing seam metal decks, the second phase toward PUF on corrugated metal decks, and the third phase toward PUF applied to fluted metal decks.

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CONTENTS

INTRODUCTION

Over the past several years, the Naval Civil Engineering Laboratory (NCEL) has conducted research investigations on a variety of roofing systems. The original objective of these efforts was to provide a significant reduction in maintenance costs for roofing systems at Naval Shore Bases around the world by defining existing problems and identifying new materials and methods to eliminate these problems. The original efforts included an extensive survey of Naval Shore Bases in different climatic areas to delineate their most recent roofing problems (Ref 1). Early in the program, investigations were initiated on sprayed polyurethane foam (PUF) roofing systems. In addition to their potential for solving some of the Navy's roof maintenance problems, the PUF systems appeared to warrant consideration because of their excellent insulating characteristics and their potential energy conservation. Since that time, NCEL has conducted extensive experimental field investigations at various sites in the Northeast (Ref 2 and 3), the West coast, and the Caribbean areas as well as numerous laboratory studies (Ref 4,5,6).

Although fire tests of the roofing materials were not included in the original effort, it became apparent that sprayed urethane foam roof systems applied directly to metal roof decks might constitute a serious hazard in the case of fire originating inside a building. A possibility that had to be considered was that a PUF roofing system applied directly to metal roof decks might contribute fuel or smoke to the fire inside the building, propagating the fire. This type of roof deck assembly had not been evaluated by either Underwriters Laboratories, Inc. (UL) or by Factory Mutual (FM), and therefore did not meet construction criteria specified by either the Department of Defense (Ref 7) or the fire safety criteria specified by the Naval Facilities Engineering Command (Ref 8).

The Naval Facilities Engineering Command (NAVFAC) tasked NCEL to conduct fire tests of sprayed polyurethane foam systems applied directly to metal roof decks at the Underwriters Laboratories. Discussions with UL resulted in an agreement on the tests that would be required to obtain classification of the PUF systems applied directly to metal decks.

FIRE SAFETY CRITERIA

Many adverse comments have been made about the flammability and fire safety of polyurethane foam roofing systems, and many horror stories have been disseminated about potential fire problems with these materials. In actual fact, very few problems have occurred with fire on PUF roof systems particularly where proper fire-classified systems have been employed. NCEL has always maintained that polyurethane foam roofing

systems should meet the same fire safety requirements as any other roofing system. That is, the PUF roof systems should be required to meet UL or FM requirements.

Criteria in this area is provided by two sources. The first is the Department of Defense Construction Criteria Manual, DOD 4270.1M (Ref 7), while the second is NAVFAC Design Manual DM-8 (Ref 8). For combustible and metal roof decks, DOD 4270.1M requires that "the entire roof construction assembly, including the insulation, be either Underwriters Laboratories (UL) Fire [Classified], or Factory Mutual approved for Class I roof deck construction." That is, either a classification in accordance with UL790 for exterior fire exposure and UL Subject 1256 for internal fire exposure or a Factory Mutual Class I classification is required. The UL Subject 1256 or FM Class I is not required if the insulation is installed above poured concrete or poured gypsum roof decks, nominal 2-inch-thick tongue-and-groove wood plank roof decks, or over precast roof deck panels or planks which are FM approved as noncombustible roof deck construction. In such cases, only a UL790 classification for exterior fire exposure is required.

NAVFAC DM-8 is more specific with requirements for both roof coverings and roof deck assemblies. Section 7 gives the following requirements:

> 1. Roof Coverings. All roof coverings shall be [classified] by Underwriters Laboratories, Inc. UL, Building Materials Directory lists three classes (A, B, and C) of acceptable roof coverings based upon Test Methods for Fire Resistance of Roof Covering Materials, UL790 [for exterior fire exposure]. Class C roof coverings shall be restricted to housing and small, insignificant buildings with light exposure.
>
> 2. Roof Deck Assemblies. Roof deck assemblies are composed of decking with materials (adhesive, vapor barrier insulation, and roof surfacing) added in layers to the deck. They may contribute significantly to the spread of fire beneath the roof deck when exposed to an interior fire. Assemblies acceptable from an interior fire exposure standpoint [shall meet the requirements for] Class I in the Factory Mutual Approval Guide [or] a Fire [classification for roof deck assemblies] in Underwriters' Laboratories, Building Materials Directory. Roof deck assemblies shall be of acceptable type when used in buildings that are not fully sprinklered [i.e., acceptable roof deck assemblies shall have either a Factory Mutual Class I listing or an Underwriters Laboratories [Inc.] Roof Deck Construction Classification].

In addition, Section 2.1d of Reference 8 includes the following:

> d. Roof Exposure. When a combustible exposed building roof is below the top of the exposing building, the exposed roof may receive sufficient radiant heat to be set on fire. A burning brand, large enough to cause pilot ignition, may also fall on the (lower level) roof (from the upper level roof).

For such a case, the exposed building roof covering shall [meet the requirements for] either Factory Mutual approved or [classification by] Underwriters Laboratories [Inc.] as a Class A [Built-up or Prepared Roof Covering Material.]."

Neither these nor other DOD or Navy criteria require a particular flamespread rating for roofs. However, most civilian Building Codes require use of a Class II foam (a flamespread of 75 or less per UL723, ASTM E84). NCEL believes this to be a reasonable requirement.

When this work was initiated, about 40 PUF roof systems (foam and protective coating systems) were classified by UL under UL790 for exterior fire exposure. Well over 130 foam and coating combination systems classified under UL790 currently exist. Thus, a variety of PUF roof systems are readily available that are classified for resistance to exterior fire exposure under the same criteria used for conventional roofing. However, until this work was initiated, neither UL nor FM had classified any PUF roof system assemblies directly applied to metal decking for exposure to interior fire. At that time neither of these laboratories felt that they had sufficient data available to assign proper classifications for these newer roofing materials without a thermal protection material between the metal decking and the PUF.

UNDERWRITERS LABORATORIES TEST PROGRAM

Scope of Tests

NCEL has conducted an extensive program of fire testing of polyurethane foam roofing systems sprayed directly on metal roof decks at UL. The work was carried out in phases with the majority of work in each phase concentrated on a given type of metal decking. The phases are described below.

Phase I - Standing seam* galvanized steel metal decks with a minor effort on corrugated galvanized steel metal decks

Phase II - Corrugated galvanized steel metal decks

Phase III - Fluted metal decks

*Standing seam galvanized steel metal decks include Butler "Hi-Rib" panel which was the decking included in the Phase I test. This older Butler "Hi-Rib" panel is very prevalent in Butler Buildings at Naval Shore Activities.

Phase I was the largest effort and involved fire testing candidate PUF roof systems in accordance with the following test methods:

1. UL790 - Tests for Fire Resistance of Roof Covering Materials (exterior fire exposure).

2. UL Subject 1256 - "Outline of the Investigation for Roof Deck Construction," (25-foot Tunnel - underdeck fire exposure required for Roof Deck Construction Classification).

3. UL Small-Scale Furnace - (underdeck fire exposure).

4. 100-foot Tunnel or White House Test (underdeck fire exposure for full-scale building).

Results from Phase I were very satisfactory. As a result of the large scale datum test and the correlative smaller scale tests, it was only necessary to test similar candidate PUF roof systems according to UL Subject 1256 (25-foot tunnel) in Phases II and III.

Two different foam materials and two different coating systems were utilized in all three phases, while a third foam and coating combination was included only in Phase III. These materials were designated as follows:

FOAMS

PUF1 - a nominal 2-1/2-lb/ft^3 density foam with a flamespread of 75 or less (Class II)

PUF2 - a nominal 3-lb/ft^3 density foam with a flamespread of 75 or less (Class II)

PUF3 - a nominal 3-lb/ft^3 density foam with a flamespread of 25 or less (Class I)

COATINGS

C1 - a single component silicone elastomer coating

C2 - a waterbased acrylic elastomer coating

C3 - a catalyzed urethane elastomer coating consisting of aromatic base coats and aliphatic topcoats

The various foams and coatings were combined into the following systems:

System 1 - PUF1 + C1
System 2 - PUF2 + C1
System 3 - PUF1 + C2
System 4 - PUF2 + C2
System 5 - PUF3 + C3

A more complete description of these systems including foam and coating thickness is given in Table 1.

UL Test Methods and Criteria

A description of the four test methods conducted at UL and the UL criteria for passing these tests are described below.

UL790 - Tests for Fire Resistance of Roof Covering Materials. This test is for exterior fire exposure and was used only in Phase I of the UL tests. The roof system for the spread-of-flame test is applied to a plywood panel 40 inches wide by 13 feet long. The roof systems are normally applied to plywood panels for expediency regardless of the type of roof deck to which the system may be applied in actual practice with the condition that the plywood does not become a contributing factor in the test. The apparatus in which the prepared panels are tested consists of a fire and air supply duct and an adjacent dolly for holding and providing slope to the test panel. The slope of the test panel can be adjusted from dead level to 5 inches per horizontal foot. The test apparatus is shown in Illustration 1 of Appendix A. A system meeting their criteria at a slope of 5 inches per horizontal foot is classified by UL as acceptable when applied to any slope up to a vertical surface. Prepared panels were cured 27 days under ambient conditions prior to testing.

At the conclusion of the spread-of-flame tests, the requirements are that flaming shall not have spread beyond 6 feet for Class A, 8 feet for Class B, and 13 feet (the length of the deck) for Class C. In addition, "at no time during or after the intermittent-flame, spread-of-flame, or burning-brand tests shall:

a. Any portion of the roof covering material be blown or fall off the test deck in the form of flaming or glowing brands, or

b. The roof deck be exposed by breaking, sliding, or cracking or warping of the roof covering, or

c. Portions of the roof deck fall away in the form of glowing particles."

The intensity of the flame varies with the classification.

Duplicate spread-of-flame tests were conducted for each system with a Class A gas flame applied continuously for 10 minutes per test. The test decks were positioned at an incline of 3-1/2 inches per horizontal foot.

Additional information on the UL790 test is presented in Appendix A and in Reference 9.

UL Subject 1256 - Outline of the Proposed Investigation for Roof Deck Construction. This test is for underdeck fire spread due to interior fire exposure and was the test utilized in all three phases of the UL testing. The foam roof systems were applied to nominal 2- by 8-foot sections of 26-gauge galvanized standing seam metal panel, a nominal 2- by 24-foot panel of 26-gauge galvanized corrugated metal sample (one 8-foot section and one 16-foot section fabricated into a single panel) and nominal 2- by 8-foot sections of 22-gauge fluted metal deck samples.

The metal was primed prior to application of the foam. In addition, foam was applied to the fluted metal panels using the following four treatments:

No. 1 - Foam sprayed directly onto primed fluted metal panels

No. 2 - Flutes were filled with cementitious fill 7 days prior to foaming

No. 3 - Flutes sealed with 4-inch polyester tape placed longitudinally along the flutes prior to foaming

No. 4 - Cut PUF boardstock was friction-fit into flutes prior to foaming

Tunnel test specimens are shown in Illustration 2, Appendix A for standing seam panels; Illustration 1, Appendix B for corrugated metal; and Illustrations 1 and 1A, Appendix C for fluted metal panels.

The test apparatus is a 25-foot enclosed tunnel with glass viewing ports located along the sides to visually determine the extent of underdeck flame propagation. For the standing seam, three 8-foot sections of the test decks were placed end-to-end on a ledge near the top of the tunnel with the panel metal ends overlapping 1-1/2 inches. The corrugated panels were continuous for their full length, while the three sections of the fluted metal panels were butted end-to-end. Side and end views of the 25-foot tunnel are shown in Illustrations 3 and 4, respectively, Appendix A. The burner assembly is ignited and a forced air draft blows the flames along the length of the panel for a short distance. Any combustible gases forced into the tunnel through the centerline seam can cause propagation of the fire on the underside of the deck. Test duration is 30 minutes or when underdeck flaming has progressed beyond the UL acceptable criteria, after which the fire is extinguished.

Duplicate samples were run on each of the PUF system/metal deck assemblies included in the tests. Deck assemblies were allowed to cure a minimum of 7 days under ambient conditions after foaming and coating before conducting the tests. UL criteria for "Fire Classified" assemblies are:

"1. Flame propagation on the underside of each assembly shall not exceed 10 feet in 10 minutes and 14 feet in 30 minutes.

2. Examination of fire-tested assemblies shall show:

a. Thermal degradation (damage in the form of charring, loss of integrity, etc.) shall not extend to the downstream extremity of the test deck.

b. Damage shall diminish at increasing distance from the immediate fire exposure area to the extent that material located beyond the area of degradation could be judged acceptable for further use."

Additional details on this test are presented in Appendixes A, B, and C and in Reference 9.

UL Small Scale Furnace Test. This test is for underdeck fire exposure and provides the same fire exposure conditions and time-temperature curves as those of UL263, "Fire Tests of Building Construction and Materials," but on smaller samples. It was used only in Phase I of the UL tests. Additional exposure conditions were simulated by altering the firing rate of the gas flame to produce time-temperature curves with 850 and 500°F as the upper temperature limits. A natural gas diffusion flame was used for these tests.

The roof systems were applied to nominal 3- by 3-foot sections of 26-gauge standing seam and corrugated galvanized metal decks with a longitudinal centerline seam. Details of the panel construction are shown in Illustration 5 of Appendix A. The primed, foamed, and coated PUF roofing panels cured for a minimum of 7 days before fire testing in the Small Scale Furnace. The furnace is shown in Illustration 6 of Appendix A.

Twelve fire tests were conducted on assemblies using both ribbed and corrugated steel decks. Each of the roof covering systems applied to ribbed decks were subjected to three different temperature configurations:

1. The standard time-temperature curve contained under UL263, Illustration 16, Appendix A (Systems 1 through 4)

2. The time-temperature curve with an upper limit of 850°F after 30 minutes, Illustration 7, Appendix A (Systems 1 through 4)

3. The time-temperature curve with an upper limit of 500°F after 30 minutes, Illustration 7, Appendix A (Systems 2 and 3).

Tests were also conducted on Systems 1 and 2 applied to corrugated steel deck and subjected to the standard time-temperature curve. Observations were made during the tests of flammability of the assemblies and the assemblies were examined following the tests. There was no established UL criteria for this series; the tests were performed to determine the effect of the different time-temperature configurations on the foam and on the centerline seam. Additional details on the test are given in Appendix A.

White House Test. This was a single, full scale test for interior fire exposure where the building's roof was 20 feet wide, 100 feet long and 10 feet high (floor to steel decking) and is shown in detail in Illustration 8 of Appendix A. Illustration 21 of Appendix A shows the building before the test. The walls were constructed from 8-inch concrete block and the first 40 feet were protected on the interior by a nominal 1-inch thickness of spray-applied cementitious mixture. A number of open ports were located along the length of the building to permit viewing of the progress of the underdeck flaming. The flue end of the structure was closed with a sheet metal breeching which diverted the exhaust gases from horizontal to vertical. The metal roof deck panels were standing seam galvanized steel 24-1/4 inches wide (24-inch cover width) and were formed from No. 26 gauge galvanized steel. Each panel contained a nominal 1-inch-high rib along its longitudinal centerline and ribbed side edges. The panels were installed perpendicular to and

attached to purlins with self-drilling, self-tapping steel fasteners. Each row of panels contained one end lap joint that was overlapped 6 inches.

Prior to application of the foam, the metal roof deck panels were primed. The foam roof system used for the White House Test, System 1, was selected on the basis of the screening tests of Systems 1 through 4. A nominal 3 inches of the 2-1/2-pound Class II foam was applied over the entire roof assembly. The spray application of the foam was completed 36 days prior to the fire test. The moisture-curing silicone elastomeric roof coating was spray applied over the foam. The total foam roof system is described in Table 1.

The fire exposure was provided by heptane fuel pumped through two atomizing nozzles. A continuous pilot ignition was provided. The firing rate of heptane was selected so that temperatures in the first 20 feet of the building approximated the standard time-temperature curve of UL263. The heptane flow rate varied from an initial value of 1.0 gpm to a maximum of 2.7 gpm after 17 minutes. The maximum flow of 2.7 gpm was continued until test termination, which occurred after 30 minutes.

The Standard Roof Assembly consists of a metal roof deck with 1-inch plain vegetable fiberboard attached by mechanical fasteners and with a built-up (tar or asphalt) roof covering and gravel surface. When subjected to the same test in the past, this standard assembly produced underdeck flamespread to approximately 60 feet with occasional flashes of flame extending to approximately 72 feet. Beyond 60 feet, damage to the fiberboard diminished and only a light char of the fiberboard occurred at the far end of the structure. This performance, judged on the basis of underdeck flamespread and damage, has served as the basis for judging other roof assemblies and was the criteria used by UL for judging the performance of the foam roofing system. Additional details on the test structure and test procedures are contained in Appendix A.

RESULTS

Results of each phase of the UL Fire Test Program are discussed briefly below.

Phase I - Principally Standing Seam Galvanized Steel Metal Deck

UL790. Results of the exterior fire exposure tests, UL790, are presented in Table 2. Systems 1 through 4 were all tested by this method. No flying or flaming brands of roof covering material nor exposure of the roof deck occurred during any of the tests. Systems 1, 3, and 4 met UL requirements for a Class A built-up roof covering system as applied to noncombustible decks at inclines not exceeding 3-1/2 inches to the horizontal foot. System 2, the silicone coating over the 3-lb/ft^3 density foam, exhibited more flamespread than the other three but still met UL requirements for a Class C system. However, System 2 was retested later by the coating manufacturer and received a Class A listing. Systems 1, 3, and 4 were selected for further screening as candidates for the full scale "White House" test.

Subject 1256 - 25-Foot Tunnel. Results of the tunnel tests of the four foam roof systems applied directly to standing seam galvanized steel metal decks are presented in Table 3. The spread of underdeck flaming of the four systems compared favorably with the UL's current requirements. Only one test (System 1) resulted in an underdeck flamespread exceeding the guideline limit of 10 feet in the first 10 minutes, and this was not considered serious. All test results were within the criteria limit of 14 feet after 30 minutes.

For all tests using the standing seam galvanized steel deck, the extent of damage to the foamed plastic was judged to comply with the intent of the statements related to damage contained in UL's Subject 1256; that is, no char was observed, only discoloration.

Results of tunnel tests of the four foam systems applied directly to corrugated metal decks were very erratic. Of the eight tests conducted, five exceeded the flamespread criteria and three did not comply with the damage criteria (see Appendix A). Part of the problem was attributed to the fact that in a number of cases, the foam had disbonded from the corrugated metal prior to fire testing, giving a foam-air interface. Additional testing over corrugated metal decks was conducted in Phase II.

Small Scale Furnace Test. Results of these tests showed increasing flaming and damage with increasing intensity of exposure conditions. The increased propensity for System 2 to support exterior flaming (top surface) as compared to Systems 1, 3, and 4 was evident in the difficulty of controlling exterior flaming that occurred at the periphery of the samples.

The silicone coating system (C1) demonstrated that it is more resistant to thermal degradation and flaming breakthrough than the acrylic coating system (C2). Additional details on the results of individual tests of each system in the Small Scale Furnace are contained in Appendix A.

White House Test. On the basis of the results from the three screening tests described above, System 1 was selected for testing over a standing seam galvanized steel metal deck on the White House. Results of the test are presented in Table 4; the following comments supplement the data in that table.

Three minutes after heptane ignition, light smoke was emitted from the exterior roof edges along the perimeter of the fire end. Figure 1 shows the exterior of the roof during the test burn. After 4 minutes, smoke began issuing from the joints in the underside of the roof, becoming very dense after 8 minutes. This obscured vision of the burners from the flue end; however, smoke had cleared within the structure after 11-1/2 minutes. The density of the smoke fluctuated but did not again obscure vision within the structure. Figure 2 shows the burners from the flue end 5 minutes after initiation of the test, while Figure 3 gives the same view about 20 minutes after test initiation. Note the lack of smoke inside the White House. It is understood that when testing a conventional or standard built-up roof (BUR) assembly, dense smoke fills the interior of the White House after 4 to 7 minutes, and the density remains constant thereafter until the end of the 30-minute test period; i.e., the very dense smoke does not clear as it did with the foam roof.

Underdeck flaming commenced after 4 minutes in the fire area and reached a maximum of 40 feet after 11 minutes. Thereafter, underdeck flaming receded and ceased after 17 minutes. Flaming on top of the roof deck occurred about 6 minutes after test initiation. Flaming moved along the rooftop and the flame front reached a maximum of 53 feet at the conclusion of the test (30 minutes). It was felt that the limited flaming on the top of the roof deck was an excellent validation of the UL790 test because a 26-mph wind was blowing diagonally across the roof from the fire toward the flue end of the White House. Had the system being tested not been a UL790 Class A rated system, it is believed that the top of the roofdeck flaming would have occurred clear to the 100-foot end of the tunnel.

The maximum spread of underdeck flaming in the White House Test was 40 feet (see Table 4). This compares very favorably with a maximum spread of underdeck flaming of approximately 60 feet with flashes of flame extending to 72 feet as recorded in the test of the Standard Roof Assembly. In most cases, the PUF roof systems performed in a manner not just equivalent to but superior to the conventional BUR system.

Phase II - Corrugated Metal Deck

Subject 1256 - 25-Foot Tunnel. Results of these tunnel tests are presented in Table 5. Only Systems 1 and 4 were fire-tested in this phase. In all cases, the foam was well-bonded to the corrugated metal panels. The underdeck flamespread was well within the UL-prescribed criteria of 10 feet in 10 minutes and 14 feet in 30 minutes. One test assembly of each system performed extremely well, exhibiting underdeck flamespreads of only 2 feet for System 1 and 0 feet for System 4. Neither of the systems exhibited any evidence of char at the 23-1/2-foot level of the test assembly. The foam only showed varying degrees of discoloration. The successful results on Systems 1 and 4 permitted classification of Systems 1, 2, 3, and 4.

Phase III - Fluted Metal Deck

Subject 1256 - 25-Foot Tunnel. Results of the tunnel tests of Systems 1, 4, and 5 applied over fluted metal decks are presented in Table 6. System 1 was applied over all four flute treatments (see footnote a, Table 6) while Systems 4 and 5 were applied directly onto the primed fluted metal decks.

All four flute treatments coated with System 1 and the single treatment of System 5 were within the prescribed UL criteria of underdeck flaming; i.e. no more than 10 feet in 10 minutes and 14 feet in 30 minutes. Also, there was no char at the end of the panels, only varying degrees of discoloration. The two surface treatments of System 1 that had cementitious fill and cut PUF boardstock wedged into the flutes--treatments No. 2 and 4, respectively--were well within the UL criteria, ranging from 4.0 to 5.5 feet of underdeck flaming.

Both System 4 tests were terminated early because they had exceeded the allowable underdeck flaming within the first 10 minutes. However, results were not considered representative because the foam did not rise properly during application resulting in an excessively high density of 4.3 lb/ft^3.

DISCUSSION

Results from all three phases of the fire tests emphasize the fact that properly formulated PUF roof systems can be applied directly to the three types of metal roof decks included in these tests and readily meet existing Navy/DOD criteria for fire safety. All of the five systems included in these tests have been classified by Underwriters Laboratories under Roof Deck Construction (RDC) No. 136 for standing seam or UL Classified Butlerib II galvanized steel metal decks, RDC No. 181 for corrugated galvanized steel metal decks, and RDC No. 206 for fluted steel metal decks.

Although it was necessary for NCEL to have UL conduct the four tests described in this report to provide a mechanism for classifying PUF systems applied directly to metal decks, it is only necessary for foam and coating manufacturers to meet the UL criteria for a UL790, Class A or B, and the UL Subject 1256 in order to obtain classification for their systems under the three roof deck constructions mentioned. Such classifications can also be obtained over other types of proprietary metal decking by conducting this type of UL testing. Quite a number of foam and coating manufacturers have obtained these classifications; over 90 different foam/coating combinations have now been classified by UL under RDC No. 136, 8 under RDC No. 181, and 7 under RDC No. 206 (see Ref 13). Details of RDC No. 136, 181, and 206 are shown in Figures 4, 5, and 6, respectively. It is anticipated that as other manufacturers become aware of RDC No. 181 and 206, the number of systems classified will increase as has been the case with RDC No. 136. One company has obtained Roof Deck Construction Classifications for their products over a different type of fluted metal decking (Type B-2). Details of these constructions, RDC No. 74 and 82, are shown in Figures 7 and 8, respectively.

In order to assist those considering or specifying PUF roofs for use over metal decks, tables have been prepared that describe those systems currently classified by Underwriters Laboratories as of January 1983 (Ref 13). The number of systems and specific systems classified will change with time. There will be additions as well as some deletions. However, these tables list those systems currently classified by UL in Reference 13. Systems classified by UL for use directly on standing seam metal decks (RDC No. 136) are listed in Table 7; those classified for application directly over corrugated galvanized steel metal decks (RDC No. 181) are listed in Table 8; and those classified for use over fluted metal decking are listed in Table 9. Systems classified under Roof Deck Constructions No. 74 and 82 are listed in Tables 10 and 11, respectively. It should be noted that all of these classifications are for roof systems and are thus limited to PUF systems applied to the exterior surfaces of the metal buildings. These classifications do not cover foam applied to interior metal building surfaces.

NCEL strongly believes that results of these series of fire tests at UL should lay to rest the false horror stories and misinformation about potential fire problems when PUF is applied directly to specified steel metal decks. One of the most persistent of these tales is that in a fire situation, the urethane foam melts, runs, and drips through the cracks in the metal deck dripping burning urethane on whatever is underneath. This series of tests proved that this phenomena does not occur. The urethane is consumed by the fire, venting most of the degradation

products produced to the outside air. These tests have shown that foam roof systems are no more hazardous, and often less hazardous, than many conventional BUR systems as long as properly UL-classified PUF roof systems are specified.

Current guidelines for the design, specification, and installation of PUF roof systems are available in NCEL publications (Ref 10 and 11) and the Urethane Foam Contractors' Association (UFCA) publications (Ref 12). These guidelines can be used in advance of the issuance of Navy Facility Guide Specification (NFGS-07545), Sprayed Polyurethane Foam for Roof Systems (pending). Navy Type Specification TS-07540 covers the use of silicone rubber coatings for PUF protection. NCEL and NAVFAC (North Division) have recently developed suggested criteria for catalyzed urethane elastomeric coatings. In all cases, specifiers should insure that the total system, including the roof deck, PUF and protective coatings, have been correctly classified by UL to provide adequate fire protection.

FINDINGS AND CONCLUSIONS

Findings and conclusions presented below are based on the fire testing of PUF roof systems applied to metal roof decks at Underwriters Laboratories.

1. With one exception, all five of the polyurethane foam roof systems included in the tests met UL criteria for application over standing seam galvanized steel, corrugated, and fluted steel metal decks. The one exception resulted from an improper use of the foam; therefore the results of this system were considered not representative.

2. PUF roof systems that have been classified by UL under one of their Roof Deck Constructions (i.e., RDC No. 136 for Butlerib II galvanized steel, No. 181 for galvanized steel corrugated, and No. 206, 74, and 82 for fluted steel metal) can be specified and used over the specified metal decks at Naval Shore Activities under existing DOD and Navy criteria.

3. PUF roof systems formulated for fire retardance perform either as well as, and in some cases better than, many conventional BUR systems when exposed to the standardized laboratory fire test.

4. Additional PUF roof systems or different metal roof decks can receive Roof Deck Construction classifications by meeting UL criteria UL790 (exterior fire exposure) and UL Subject 1256 (interior fire exposure) tests.

RECOMMENDATIONS

On the basis of the results obtained from these fire tests, it is recommended that, wherever appropriate, steel metal roofs on structures at Naval Shore Activities be foamed with UL-classified PUF roof systems for energy savings and to prevent intrusion of water into the building.

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Table 1. Description of Systems Tested

System Number	Foam		Coating				Granules (50 lb/100 ft^2)
	Description	Thickness (in.)	Description	No. of Coats	Coverage (gal/100 ft^2)	Approximate Thickness (mils)	
1	CPR Upjohn 480-2.5 (PUF1)	3	Dow-Corning Silicone 3-5000 (C1)	2	1.5	20+	yes
2	Witco Isofoam SS-0545 (PUF2)	3	Dow-Corning Silicone 3-5000 (C1)	2	1.5	20+	yes
3	CPR Upjohn 480-2.5 (PUF1)	3	United Coatings Diathon (C2)	2	1.5	30	yes
4	Witco Isofoam SS-0545 (PUF2)	3	United Coatings Diathon (C2)	2	1.5	30	yes
5	FSC 234 (PUF3)[a]	2	FSC Ureflex 100 FSC Ureflex 200 (C3)	2 1	3.0 1.5	20 10	no no

[a]Total coating thickness is approximately 30 mils.

Table 2. Results of UL790 Tests, Phase I

System Number	Description		Maximum Flamespread (ft)	Classification
	Foam Density (lb/ft^3)	Coating		
UL Criteria			6	Class A
1	2-1/2	Silicone	4-1/2	Class A
			4-1/2	Class A
2	3	Silicone	11-1/2	Class C[a]
			12	(with Class A flame)
3	2-1/2	Acrylic	5	Class A
			5	Class A
4	3	Acrylic	4-1/2	Class A
			5-1/2	Class A

[a]Retest by coating manufacturer resulted in Class A classification.

Table 3. Results of UL Subject 1256 Test (25-ft Tunnel) of Foam Over Standing Seam Galvanized Steel Metal Deck - Phase 1

System Number	Description		Maximum Underdeck Flame Propagation (ft) for Test Times of--		Foam Char at 23-1/2 ft
	Foam Density (lb/ft^3)	Coating	10 min	30 min	
UL Criteria for Class A			10	14	None
1	2-1/2	Silicone	10-1/2 8-1/2	10-1/2 9	None[a] None[a]
2	3	Silicone	9-1/2 7-1/2	9-1/2 2-1/2	None[a] None[a]
3	2-1/2	Acrylic	9-1/2 6-1/2	12-1/2 6-1/2	None[a] None[a]
4	3	Acrylic	5-1/2 5	5-1/2 5	None[a] None[a]

[a]Foam shows some discoloration.

Table 4. Results of UL White House Test - Phase 1

System No.	Maximum Underdeck Flame Propagation (ft)	Char Near 100-ft End
UL Criteria	60	None
1	40	None (1/2 to 3/4 in. discolored foam)

Table 5. Results of UL Subject 1256 Test (25-ft Tunnel) of Foam Over Corrugated Metal Deck - Phase 2

System Number	Description		Maximum Underdeck Flame Propagation (ft) for Test Times of--		Foam Char at 23-1/2 ft
	Foam Density (lb/ft^3)	Coating	10 min	30 min	
UL Criteria			10	14	None
1	2-1/2	Silicone	2.0 8.5	2.0 8.5	None[a] None[a]
4[b]	3	Acrylic	0 4.5	0 4.5	None[a] None[a]

[a]Foam shows varying degrees of discoloration.

[b]Designated as System 2 in Appendix B.

Table 6. Results of UL Subject 1256 (25-ft Tunnel) of Foam Over Fluted Metal Deck - Phase 3

System Number	Description		Flute Treatment[a]	Maximum Underdeck Flame Propagation (ft) for Test Times of--		Foam Char at 23-1/2 ft
	Foam Density (lb/ft^3)	Coating		10 min	30 min	
UL Criteria			All	10.0	14.0	None
1	2-1/2	Silicone	1	8.0 9.0	8.0 9.0	None[b]
1	2-1/2	Silicone	2	5.5 4.0	5.5 4.0	None[b]
1	2-1/2	Silicone	3	9.0 8.0	9.0 8.0	None[b]
1	2-1/2	Silicone	4	4.5 4.5	4.5 4.5	None[b]
4	3[c,d]	Acrylic	1	15.0 19.5	--- ---	---- ----
5	3[c]	Urethane	1	8.0	8.0	None[b]

[a]Flute Treatments consisted of:
No. 1 - Foam sprayed directly onto fluted metal deck.
No. 2 - Flutes filled with cementitious fill 7 days before applying foam.
No. 3 - Flutes taped with polyester tape before applying foam.
No. 4 - Cut PUF board stock friction fit into flutes before applying foam.

[b]Foam showed varying degrees of discoloration.

[c]Nominally expected foam density; actual density reported as 4.3 lb/ft^3.

[d]Foam material did not rise properly; results were not considered representative.

Table 7. Underwriters Laboratories, Inc. Classifications - Roof Deck Construction No. 136, Spray-Applied Urethane Foam and Coating Roof Covering Materials Systems Applied Directly to Standing Seam Metal Decks (January 1983)

Foam			Coating				Slope[a] (in./ft)
Manufacturer	Name	Thickness (in.)	Manufacturer	Name	Coverage (gal/100 ft²)	Granules (50 lb/100 ft²)	
Carpenter Chemical Co.	C-375B/C-100A	2.0	Carpenter Chemical Co.	Silver "Richcoat" Silver "Richcoat"	1.0 1.0	No	1.0
Carpenter Chemical Co.	C-375B/C-100A	2.0	Carpenter Chemical Co.	Silver "Richcoat" White "Richcoat"	1.4 1.0	No	1.0
Carpenter Chemical Co.	C-375B/C-100A	2.0	Carpenter Chemical Co.	Gray "Richcoat" White "Richcoat"	1.75 1.0	No	2.0
Carpenter Chemical Co.	C-375B/C-100A	2.0	Dow Corning Corp.	3-5000 3-5000	1.0 1.0	No	2.0
Carpenter Chemical Co.	C-375B/C-100A	2.0	Dow Corning Corp.	3-5000 3-5000	1.0 1.0	Yes	5.0
Carpenter Chemical Co.	C-375B/C-100A	2.0	General Electric Co.	SCM 3300 Series SCM 3300 Series	1.0 1.0	No	2.0
Carpenter Chemical Co.	C-375B/C-100A	2.0	3M Corporation	Scotchbrand Foam Roof Coating 5762, 5747	 1.5-2.5 1.0	No	0.5-2.0[b]
Carpenter Chemical Co.	C-375B/C-100A	2.0	United Coatings, Inc.	Diathon Diathon	1.5 1.5	No	0.5

continued

Table 7. Continued

Foam			Coating				Slope[a] (in./ft)
Manufacturer	Name	Thickness (in.)	Manufacturer	Name	Coverage (gal/100 ft²)	Granules (50 lb/100 ft²)	
Carpenter Chemical Co.	C-375B/C-100A	2.0	United Coatings, Inc.	Diathon Diathon	1.5 1.5	Yes	1.5
CPR-Upjohn	CPR 480-2.5	2.0	Carboline	Chem-Elast 2819S	2.0	No	1.5
CPR-Upjohn	CPR 480-2.5	2.0	Carboline	Chem-Elast 5011 Chem-Elast 5011	2.5 2.5	No	3.0
CPR-Upjohn	CPR 480-2.5	2.0	Carboline	Chem-Elast 5012 Chem-Elast 5011	2.5 1.0	No	2.5
CPR-Upjohn	CPR 480-2.5	2.0	Carboline	Chem-Elast 5226	2.5	No	0.75
CPR-Upjohn	CPR 480-2.5	2.0	Carboline	Chem-Elast 5501 Chem-Elast 2820-1FR	2.5 0.75	No	2.0
CPR-Upjohn	CPR 480-2.5	2.0	Carboline	Chem-Elast 5501 Chem Elast 5011	2.0 1.0	No	2.5
CPR-Upjohn	CPR 480-2.5	2.0	Carboline	Primer 9002 Chem-Elast 1522	Mist Coat 4.0-7.5	No	2.0
CPR-Upjohn	CPR 480-2.5	2.0	Conklin Co., Inc.	Rapid Roof Rapid Roof	2.0 1.0	Yes	3.0
CPR-Upjohn	CPR 480-2.5	3.0	Dow-Corning Corp.	3-5000 3-5000	1.5 1.5	Yes	3.5
CPR-Upjohn	CPR 480-2.5	3.0	General Electric Co.	SCM 3300 Series SCM 3300 Series	1.0 1.0	No	1.0
CPR-Upjohn	CPR 480-2.5	3.0	General Electric Co.	SCM 3300 Series SCM 3300 Series	1.0 1.0	Yes	1.0

continued

Table 7. Continued

Foam			Coating				Slope[a] (in./ft)
Manufacturer	Name	Thickness (in.)	Manufacturer	Name	Coverage (gal/100 ft²)	Granules (50 lb/100 ft²)	
CPR-Upjohn	CPR 480-2.5	1.5	H.B. Fuller Co.	Atrelar (White or Gray)	5.0	No	2.0
CPR-Upjohn	CPR 480-2.5	2.0	H.B. Fuller Co.	Duralar Duralar	1.75 1.75	No	1.5
CPR-Upjohn	CPR 480-2.5	2.0	Neogard Corp.	Permagard 7416 Permagard 7416 Neogard 7430	2.0 2.0 6.75	Yes (30 lb)	0[c]
CPR-Upjohn	CPR 480-2.5	2.0	3M Corporation	Scotch Brand Roof Coating 5762 5747	 1.5-2.5 1.0	 No	2.0
CPR-Upjohn	CPR 480-2.5	3.0	United Coatings Co.	Diathon Diathon	1.5 1.5	 Yes	3.5
CPR-Upjohn	CPR 832	2.0	Carboline	Chem-Elast 2819S	2.0	No	0
CPR-Upjohn	CPR 832	2.0	Carboline	Chem-Elast 2819S Chem-Elast 2820	2.0 0.5	 No	0.75
CPR-Upjohn	CPR 832	2.0	Carboline	Chem-Elast 2837 Chem-Elast 2819S	1.5 0.75	 No	
CPR-Upjohn	CPR 832	2.0	Carboline	Chem-Elast 5012 Chem-Elast 5011	2.5-3.0 1.0-1.33	 No	2.5
CPR-Upjohn	CPR 832	2.0	Carboline	Chem-Elast 5226	2.5-3.5	No	0.5
CPR-Upjohn	CPR 832	2.0	Carboline	Chem-Elast 5501 Chem-Elast 2820	2.33-2.5 0.5	 No	0

continued

Table 7. Continued

Foam			Coating				Slope[a] (in./ft)
Manufacturer	Name	Thickness (in.)	Manufacturer	Name	Coverage (gal/100 ft²)	Granules (50 lb/100 ft²)	
CPR-Upjohn	CPR 832	2.0	Carboline	Chem-Elast 5501	2-2.67	No	2.5
				Chem-Elast 5011	1-1.33		
CPR-Upjohn	CPR 832-3	3.0	Dow Corning Corp.	3-5000	1.5		
				3-5000	1.5	Yes	3.5
CPR-Upjohn	CPR 832-3	3.0	General Electric Co.	SCM 3300 Series	1.0	No	2.5
				SCM 3300 Series	1.0	No	
CPR-Upjohn	CPR 832-3	3.0[b]	General Electric Co.	SCM 3300 Series	1.0		Unlimited[d]
				SCM 3300 Series	1.0	Yes	
CPR-Upjohn	CPR 832	2.0	Geocel Corp.	Geotherm Elastomer FR	1.5	No or	1.5
				Geotherm Elastomer FR	1.5	Yes (45)	2.5
CPR-Upjohn	CPR 832	2.0	Neogard Corp.	Permagard 7420	1.0		1.0
				Permagard 7420	1.0		
				Permagard 7441 or Permathane FR 7481	0.75	No	
CPR-Upjohn	CPR 832-3	3.0	United Coatings Co.	Diathon	1.5		3.5
				Diathon	1.5	Yes	
Foam Seal, Inc.	526 CW/FSA or 526 R/FSA	2.0	Conklin Co., Inc.	Polymate Basecoat	1.5		1.5
				Polymate Topcoat	0.5	No	
Foam Seal, Inc.	526 CW/FSA or 526 R/FSA	2.0	Dow Corning Corp.	3-5000	1.25		
				3-5000	1.25	No	3.0
Foam Seal, Inc.	526 CW/FSA or 526 R/FSA	2.0	Futura Coatings, Inc.	Futura-Flex 500	2.0		3.0
				Futura-Flex 550	1.0	No	

continued

Table 7. Continued

Foam			Coating				Slope[a] (in./ft)
Manufacturer	Name	Thickness (in.)	Manufacturer	Name	Coverage (gal/100 ft²)	Granules (50 lb/100 ft²)	
FSC (Foam Systems Corp.)	FSC234	2.0	Futura Coatings, Inc.	Acrobond 440	2.0	No	3.5
FSC	FSC234	2.0	Futura Coatings, Inc.	Acrobond 440	3.0	Yes	No maximum
FSC	FSC234	2.0	FSC	Acryflex-1	2.0		3.5
				Acryflex-1	3.0	Yes	
FSC	FSC234	2.0	General Electric Co.	SCM 3300 Series	2.0	No	3.0
FSC	FSC234	2.0	FSC	Ureflex	2.0	No	1.0
FSC	FSC234	2.0	FSC	Ureflex	2.5	Yes	2.0
FSC	FSC27	2.0	FSC	Ureflex 100	2.0		
				Ureflex 200	1.0	No	2.0
North Carolina Foam Industries	NCFI 774	2.0	Carboline	Chem-Elast 2819S	2.0	No	0
North Carolina Foam Industries	NCFI 774	2.0	Carboline	Chem-Elast 5012	2.5-3.0		
				Chem-Elast 5011	1.0-1.33	No	2.5
North Carolina Foam Industries	NCFI 774	2.0	Carboline	Chem-Elast 5226	2.5-3.5	No	0.5
North Carolina Foam Industries	NCFI 774	2.0	Carboline	Chem-Elast 5501	2.33-2.5		
				Chem-Elast 2820	0.5	No	0
North Carolina Foam Industries	NCFI 774	2.0	Carboline	Chem-Elast 5501	2.0-2.67	No	2.5

continued

Table 7. Continued

Foam			Coating				Slope[a] (in./ft)
Manufacturer	Name	Thickness (in.)	Manufacturer	Name	Coverage (gal/100 ft²)	Granules (50 lb/100 ft²)	
North Carolina Foam Industries	NCFI 774	1.5	Dow Corning Corp.	3-5000 3-5000	1.25 1.25	 No	1.0
North Carolina Foam Industries	NCFI 774	1.5	H.B. Fuller Co.	Atrelar (White or Gray)	5.0	No	2.0
North Carolina Foam Industries	NCFI 774	1.5	H.B. Fuller Co.	Monolar II Monolar II	3.0 3.0	 No	e
North Carolina Foam Industries	NCFI 774	1.5	Futura Coatings, Inc.	Futura-Flex 500 Futura-Flex 550	2.0 0.5	 No	0.5
North Carolina Foam Industries	NCFI 774	2.0	Gaco Western	Gacoflex A5411 Gacoflex A5411 Gacoflex A5400	1.0 1.0 1.0	 No	0.5
North Carolina Foam Industries	NCFI 774	2.0	Gaco Western	Gacoflex U-66 Gacoflex U-66 Gacoflex U-66	1.0 1.0 1.0	 No	1.0
North Carolina Foam Industries	NCFI 774	1.5	General Electric Co.	SCM 3300 Series SCM 3300 Series	1.0 1.0	 No	1.5
North Carolina Foam Industries	NCFI 774	1.5	United Coatings, Inc.	Diathon Diathon	1.5 1.5	 No	0.5
Reichold Chemicals, Inc.	Polylite 34-841/90-594	2.0	Carboline	Chem-Elast 2819S	2.0	No	0
Reichold Chemicals, Inc.	Polylite 34-841/90-594	2.0	Carboline Carboline	Chem-Elast 5012 Chem-Elast 5011	2.5-3.0 1.0-1.33	 No	2.5
Reichold Chemicals, Inc.	Polylite 34-841/90-594	2.0	Carboline	Chem-Elast 5226	2.5-3.5	No	0.5

continued

Table 7. Continued

Foam			Coating				Slope[a] (in./ft)
Manufacturer	Name	Thickness (in.)	Manufacturer	Name	Coverage (gal/100 ft²)	Granules (50 lb/100 ft²)	
Reichold Chemicals, Inc.	Polylite 34-841/90-594	2.0	Carboline	Chem-Elast 5501 Chem-Elast 2820	2.33-2.5 0.5	 No	0
Reichold Chemicals, Inc.	Polylite 34-841/90-594	2.0	Carboline	Chem-Elast 5501 Chem-Elast 5011	2.0-2.67 1.0-1.33	 No	2.5
Reichold Chemicals, Inc.	Polylite 34-841/90-594	1.0	General Electric Co.	SCM 3300 Series SCM 3300 Series	1.0 1.0	 No	2.5
Reichold Chemicals, Inc.	Polylite 34-841/90-594	1.0	Geocel Corp.	Geotherm Elastomer FR Geotherm Elastomer FR	1.5 1.5	 No	1.5
Urethane Chemical Co.	UCHEMCO 3231-2.5	2.0	Carboline	Chem-Elast 2819S	2.0	No	0.5
Urethane Chemical Co.	UCHEMCO 3231-2.5	2.0	Carboline	Chem-Elast 5012 Chem-Elast 5011	2.5-3.0 1.0-1.5	 No	3.0
Urethane Chemical Co.	UCHEMCO 3231-2.5	2.0	Carboline	Chem-Elast 5226	2.5-3.5	No	0.5
Urethane Chemical Co.	UCHEMCO 3231-2.5	2.0	Carboline	Chem-Elast 5501 Chem-Elast 2820	2.33-2.5 0.5	 No	0
Urethane Chemical Co.	UCHEMCO 3231-2.5	2.0	Carboline	Chem-Elast 5501 Chem-Elast 5011	2.0-2.67 1.0-1.33	 No	2.5
Urethane Chemical Co.	UCHEMCO 3231-2.5	3.0	United Coatings, Inc.	Diathon Diathon	1.5 1.5	 No	1.0
Urethane Chemical Co.	UCHEMCO 3231-2.5	3.0	United Coatings, Inc.	Elastall Fast Cure 900FR/875FR	2.25	No	1.5
Witco Chemical Corp.	Isofoam SS-545	2.0	Carboline	Chem-Elast 2819S	2.0	No	0.5

continued

Table 7. Continued

Foam			Coating				Slope[a] (in./ft)
Manufacturer	Name	Thickness (in.)	Manufacturer	Name	Coverage (gal/100 ft²)	Granules (50 lb/100 ft²)	
Witco Chemical Corp.	Isofoam SS-545	2.0	Carboline	Chem-Elast 5012	2.5-3.0		2.5
				Chem-Elast 5011	1.0-1.33	No	
Witco Chemical Corp.	Isofoam SS-545	2.0	Carboline	Chem-Elast 5226	2.5-3.5	No	0.5
Witco Chemical Corp.	Isofoam SS-545	2.0	Carboline	Chem-Elast 5501	2.33-2.5		0
				Chem-Elast 2820	0.5	No	
Witco Chemical Corp.	Isofoam SS-545	2.0	Carboline	Chem-Elast 5501	2.0-2.67		2.5
				Chem-Elast 5011	1.0-1.33	No	
Witco Chemical Corp.	Isofoam SS-545	2.0	Dow Corning Corp.	3-5000	1.5		3.5
				3-5000	1.5	Yes	
Witco Chemical Corp.	Isofoam SS-545	1.0	General Electric Co.	SCM 3300 Series	1.0		1.5
				SCM 3300 Series	1.0	No	
Witco Chemical Corp.	Isofoam SS-545	1.5-2.0	Geocel Corp.	Ceotherm Elastomer FR	1.5		0.5
				Geotherm Elastomer FR	1.5	No	
Witco Chemical Corp.	Isofoam SS-545	2.0	Geocel Corp.	Geotherm Elastomer FR	1.5		
				Geotherm Elastomer FR	1.5	Yes (45)	2.5
Witco Chemical Corp.	Isofoam SS-545	2.0	Neogard Corp.	Permagard 7416	1.0		0
				Permagard 7416	1.0		
				Hypalon NO 7365 or 7010-7799	1.25	No	

continued

Table 7. Continued

Foam			Coating				Slope[a] (in./ft)
Manufacturer	Name	Thickness (in.)	Manufacturer	Name	Coverage (gal/100 ft²)	Granules (50 lb/100 ft²)	
Witco Chemical Corp.	Isofoam SS-545	2.0	3M Corporation	Scotchbrand Foam Roof Coating			
				5762	1.5-2.5		1.5
				5747	1.0	No	
Witco Chemical Corp.	Isofoam SS-545	3.0	United Coatings, Inc.	Diathon	1.5		3.5
				Diathon	1.5	Yes	

[a] Allowable slope as determined by UL790.

[b] Slope for coverage of 2.5 gal/100 ft² of basecoat and 1.0 gal/100 ft² of topcoat is 0.5 in./ft; slope for coverage of 1.5 gal/100 ft² of basecoat and 1.0 gal/100 ft² of topcoat is 2.0 in./ft.

[c] Class B - limited to noncombustible roof decks.

[d] Unlimited slope applicable only with foam thicknesses up to 2.0 inches.

[e] No slope listed.

Table 8. Underwriters Laboratories, Inc. Classifications - Roof Deck Construction No. 181, Spray-Applied Urethane Foam and Coating Roof Covering Materials Systems Applied Directly to Corrugated Metal Decks (January 1983)

Foam			Coating				Slope[a] (in./ft)
Manufacturer	Name	Thickness (in.)	Manufacturer	Name	Coverage (gal/100 ft²)	Granules (50 lb/100 ft²)	
CPR-Upjohn	CPR 480-2.5	3.0	Dow Corning Corp.	3-5000 3-5000	1.5 1.5	Yes	3.5
CPR-Upjohn	CPR 480-2.5	2.0	Neogard Corp.	Permagard 7416 Permagard 7416 Permagard 7430	2.0 2.0 0.75	Yes (30 lb/100 ft²)	0[b]
CPR-Upjohn	CPR 480-2.5	3.0	United Coatings, Inc.	Diathon Diathon	1.5 1.5	Yes	3.5
CPR-Upjohn	CPR 480-2.5	3.0	United Coatings, Inc.	Elastall Fast Cure 900FR/985FR Aluminum	2.25	No	1.0
FSC	FSC 27	2.0	FSC	Ureflex 100 Ureflex 200	2.0 1.0	No	2.0
Witco Chemical Co.	Isofoam SS-0545	3.0	Dow Corning Corp.	3-5000 3-5000	1.5 1.5	Yes	3.5
Witco Chemical Co.	Isofoam SS-0545	3.0	United Coatings, Inc.	Diathon Diathon	1.5 1.5	Yes	3.5
Witco Chemical Co.	Isofoam SS-0545	3.0	United Coatings, Inc.	Elastall Fast Cure 900 FR/985FR Aluminum	2.25	No	c

[a] *Allowable slope as determined by UL790.*

[b] Slope for coverage of 2.5 gal/100 ft² of basecoat and 1.0 gal/100 ft² of topcoat is 0.5 in./ft; slope for coverage of 1.5 gal/100 ft² of basecoat and 1.0 gal/100 ft² of topcoat is 2.0 in./ft.

[c] No slope listed.

Table 9. Underwriters Laboratories, Inc. Classifications - Roof Deck Construction No. 206, Spray-Applied Urethane Foam and Coating Roof Covering Materials Systems Applied Directly to Fluted Metal Decks (January 1983)

Foam			Coating				Slope[a] (in./ft)
Manufacturer	Name	Thickness (in.)	Manufacturer	Name	Coverage (gal/100 ft²)	Granules (50 lb/100 ft²)	
CPR-Upjohn	CPR 480-2.5	3.0	Dow Corning Corp.	3-5000	1.5		3.5
				3-5000	1.5	Yes	
CPR-Upjohn	CPR 480-2.5	3.0	United Coatings, Inc.	Diathon	1.5		3.5
				Diathon	1.5	Yes	
CPR-Upjohn	CPR 832	3.0	Dow Corning Corp.	3-5000	1.5		3.5
				3-5000	1.5	Yes	
CPR-Upjohn	CPR 832	3.0	United Coatings, Inc.	Diathon	1.5		3.5
				Diathon	1.5	Yes	
FSC	FSC 234	2.0	FSC	Ureflex 100	1.5		
				Ureflex 100	1.5		b
				Ureflex 200	1.5	No	
Witco Chemical Co.	Isofoam SS0545	3.0	Dow Corning Corp.	3-5000	1.5		3.5
				3-5000	1.5	Yes	
Witco Chemical Co.	Isofoam SS0545	3.0	United Coatings, Inc.	Diathon	1.5		3.5
				Diathon	1.5	Yes	

[a] Allowable slope as determined by UL790.

[b] No slope listed.

Table 10. Underwriters Laboratories, Inc. Classifications - Roof Deck Construction No. 74, Spray-Applied Urethane Foam and Coating Roof Covering Materials Systems Applied Directly to Type B2 Fluted Metal Decks

Foam			Coating				Slope[a] (in./ft)
Manufacturer	Name	Thickness (in.)	Manufacturer	Name	Coverage (gal/100 ft²)	Granules (50 lb/100 ft²)	
CPR-Upjohn	CPR 832-2.5	3	Dow Corning Corp.	3-5000 3-5000	1.5 1.5	 Yes	3.5
CPR-Upjohn	CPR 832-2.5	3	United Coatings, Inc.	Diathon Diathon	1.5 1.5	 Yes	3.5

[a]Allowable slope as determined by UL790.

Table 11. Underwriters Laboratories, Inc. Classifications - Roof Deck Construction No. 82, Spray-Applied Urethane Foam and Coating Roof Covering Materials Systems Applied to Type B2 Fluted Metal Decks[a]

Foam			Coating				Slope[b] (in./ft)
Manufacturer	Name	Thickness (in.)	Manufacturer	Name	Coverage (gal/100 ft²)	Granules (50 lb/100 ft²)	
CPR-Upjohn	CPR 832-2.5	3	Dow Corning Corp.	3-5000 3-5000	1.5 1.5	 Yes	3.5
CPR-Upjohn	CPR 832-2.5	3	United Coatings, Inc.	Diathon Diathon	1.5 1.5	 Yes	3.5

[a]CPR Type 9501 foam plastic formed to configuration of panel used in panel valleys (flutes).

[b]Allowable slope as determined by UL790.

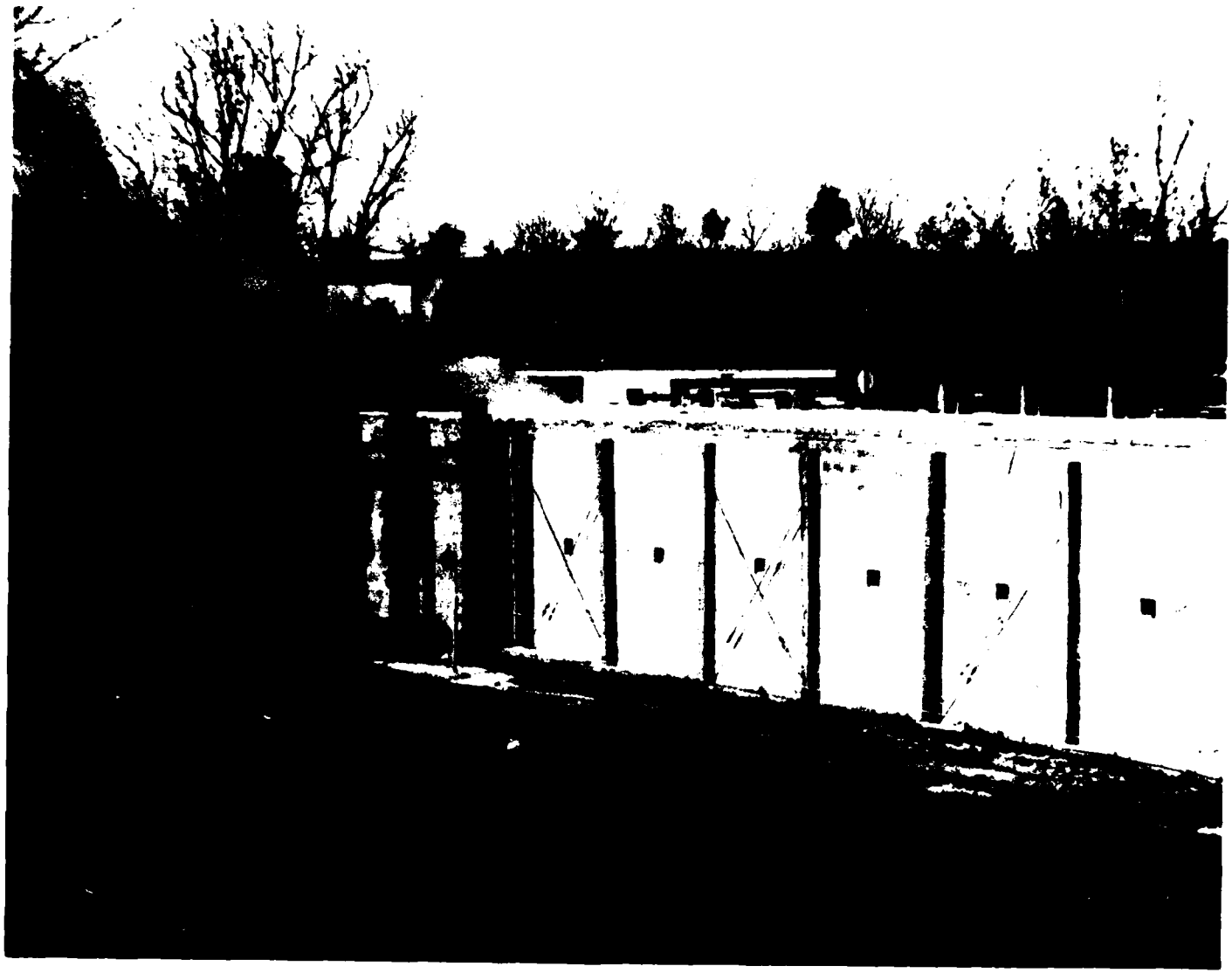


Figure 1. Exterior view of White House structure showing roof during the test.

Figure 2. Burners of White House Test viewed from flue (100 ft) end about 10 minutes after test initiation. Burners are nearly obscured by dense smoke.

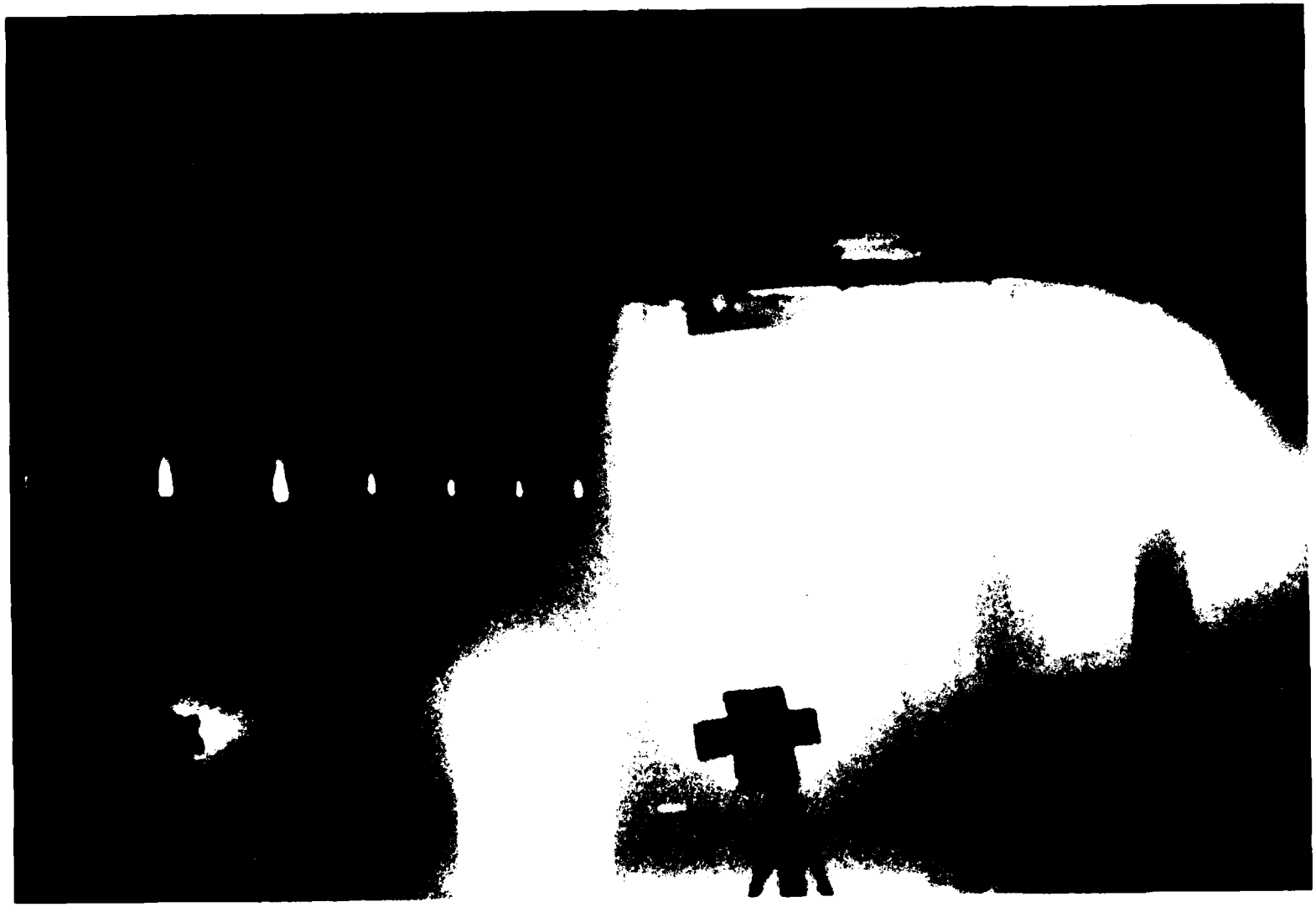
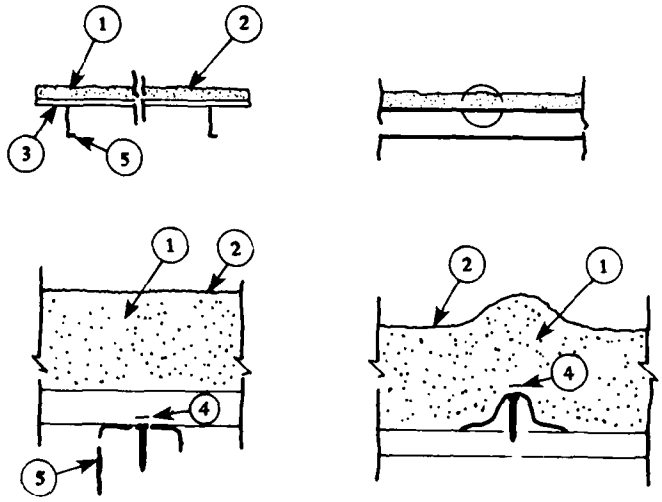


Figure 3. Burners of White House Test viewed from flue (100 ft) end about 20 minutes after test initiation. Smoke has dissipated inside of structure, allowing good visibility for the full 100-foot length.



CONSTRUCTION NO. 136

1. **Foamed Plastics*** – Formed by simultaneous spraying of two liquid components at thicknesses indicated below following the contour of the metal roof deck panels. To be applied according to manufacturer's instructions.

2. **Roof Coatings*** – A fluid-applied roof coating applied in one or more coats at a specified rate in accordance with the following combinations to be applied according to manufacturer's instructions.

3. **Metal Roof Deck Panels** –*(Unclassified) – No. 26 MSG min galv steel, nom 1 in. deep min. Ribbed on 12 in. longitudinal centers, 24 in. min sheet coverage. Panels continuous two or more spans. End laps may be continuous and must occur over purlins with panels overlapped 6 in. and lap centered over purlin flange.

Classified Metal Roof Deck Panels* – No. 26 MSG min galv steel, 1½ in. deep, 36 in. wide. Ribbed on 12 in. longitudinal centers.

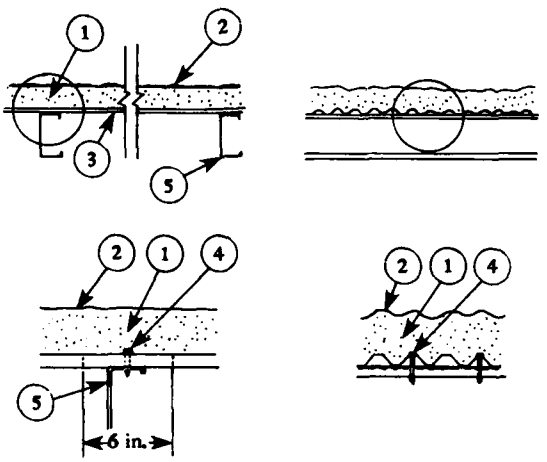
4. **Fasteners** – No. ¼-14 by 1-¼ in. self-drilling, self-tapping, hex-head plated steel fasteners. Fastened to purlins on 12 in. centers located between major ribs. For panel-to-panel connections, fasteners to be located on 20 in. max centers. In addition, two fasteners are to be used at end laps at each major rib, one on each side of the purlin.

5. **Purlins** – No. 14 MSG min gauge steel. Max spacing as specified for metal roof deck panel.

6. (Not Shown) – Optional adhesive prime coating directly applied to roof deck panels, prior to foamed plastic application, in accordance with coating manufacturer's instructions.

*Bearing the UL Classification Marking

Figure 4. Details for UL Roof Deck Construction No. 136 (standing seam).



CONSTRUCTION NO. 181

1. **Foamed Plastic*** – Formed by the simultaneous spraying of two liquid components at thicknesses indicated below following the contour of the metal roof deck panels. To be applied according to manufacturer's instructions.

2. **Roof Coatings*** – A fluid-applied roof coating applied in one or more coats at a specified rate in accordance with the following combinations. To be applied according to manufacturer's instructions.

3. **Metal Roof Deck Panels** – (Unclassified) – No. 26 MSG min galv steel, nom 9/16 in. deep min corrugated on nom 2½ in. centers, 30 in. min sheet coverage. Panels continuous two or more spans. End laps may be continuous and must occur over supports with panels overlapped 6 in. and lap centered over support. Side laps must be two corrugation overlap, min.

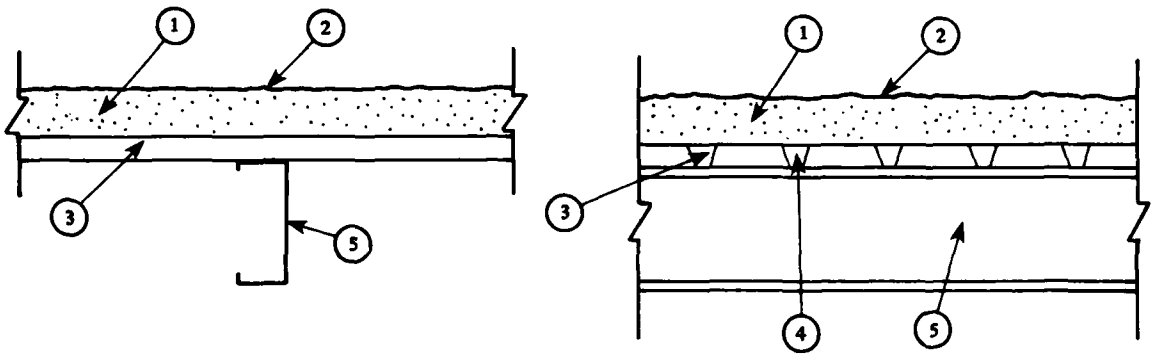
4. **Fasteners** – 3/16 in. by 1½ in. self-drilling self-tapping hex-head plated steel fasteners. Fasteners max spacing 10 in. at the supports and 40 in. max at side lap.

5. **Supports** – Structural steel or other materials acceptable to the authorities having jurisdication.

6. (Not Shown) – Optional adhesive prime coating directly applied to roof deck panels, prior to foamed plastic application, in accordance with coating manufacturer's instructions.

*Bearing the UL Classification Marking

Figure 5. Details for UL Roof Deck Construction No. 181 (corrugated metal).



CONSTRUCTION NO. 206

1. **Foamed Plastic*** – Formed by simultaneous spraying of two liquid components at thicknesses indicated below. To be applied according to manufacturer's instructions.

2. **Roof Coatings*** – A fluid-applied roof coating applied in one or more coats at a specified rate in accordance with the following combinations to be applied according to manufacturer's instructions.

3. **Metal Roof Deck Panels** – (Unclassified) – No. 22 MSG min intermediate rib coated steel deck, 1½ in. deep min with no perforations. Welded or mechanically fastened to supports in accordance with deck manufacturer's recommendations.

4. **Flute Treatment** (Optional) – Prepared in any of the following methods:

   A. 4 in. wide self-adhesive polyester tape placed longitudinally across the flutes to provide a flat deck surface.

   B. Foamed plastic board stock,* with a flame spread classification of 25 or less, cut to the flute configuration, friction fit into the flutes to provide flat deck surface.

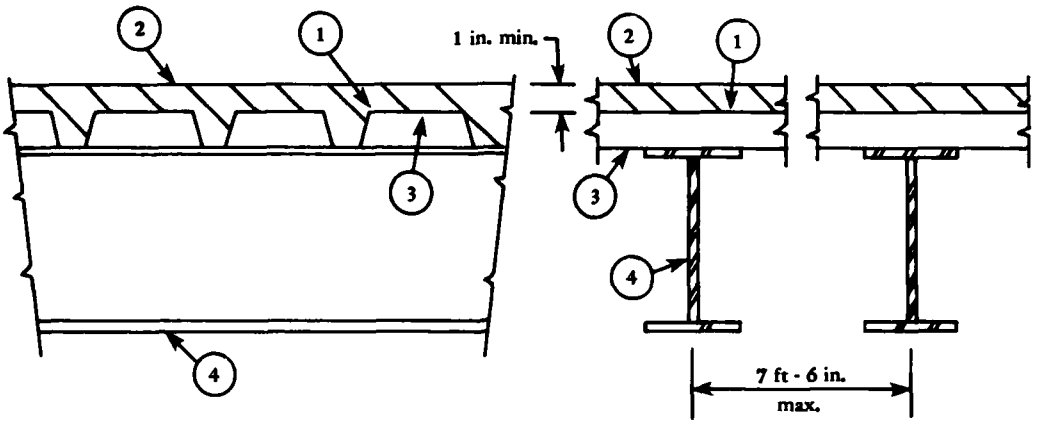
   C. Cemetitious mixture.* Prepared in accordance with manufacturer's recommendations. Place in the flutes and screened level with deck to provide a flat deck surface.

5. **Supports** – Structural steel or other materials acceptable to the authorities having jurisdiction.

6. (Not shown) – Optional adhesive prime coating directly applied to roof deck panels, prior to foamed plastic application, in accordance with coating manufacturer's instructions.

*Bearing the UL Classification Marking

Figure 6. Details for UL Roof Deck Construction No. 206 (fluted metal).



CONSTRUCTION NO. 74

1. **Foamed Plastic*** – Formed by simultaneous spraying of two liquid components, isocynate and resin. Thickness to be 1 in. min. 3 in. max. To be applied according to manufacturer's instructions.

2. **Roof Coating*** – Silicone construction coating. Applied in two differently colored coats. Each coat to be applied at a rate of 1.5 gal per 100 sq ft. No. 11 roofing granules to be embedded into the wet top coat at a rate of 50 lbs per 100 sq ft.

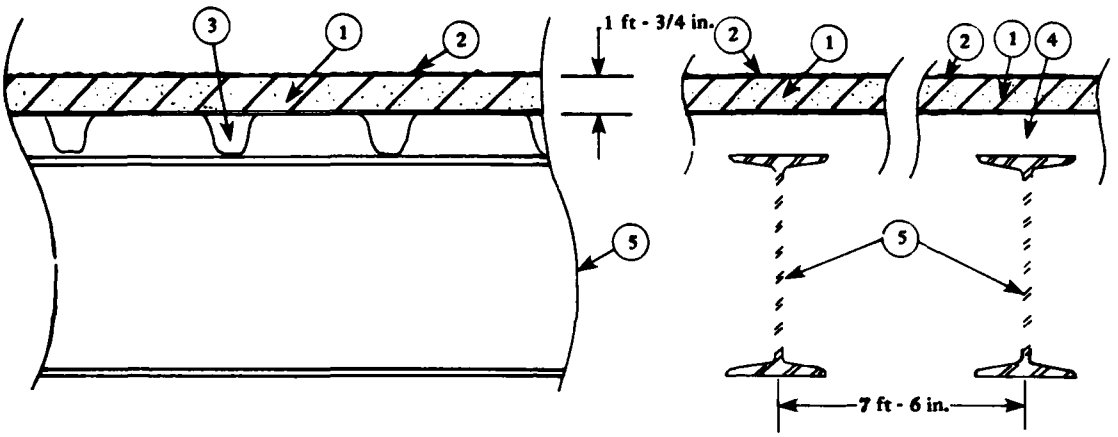
3. **Metal Roof-Deck Panels** – Type B2 No. 20 gauge, MSG min coated steel, welded to supports 12 in. O.C. utilizing welded washers. End laps to occur over supports, overlapped 2 in. and welded to supports 6 in. O.C. Side laps to be connected with No. 12-14 by 1 in. self-drilling, self--tapping coated steel screws spaced a max 30 in. O.C.

4. **Steel Beams** – Spaced not more than 7 ft 6 in. O.C. welded to supports. Min size W8X13. Refer to General Information, Roof-Deck Constructions (Building Materials Directory) for items not evaluated.

5. (Not Shown) – Optional adhesive prime coating directly applied to roof deck panels in accordance with manufacturer's instructions prior to foamed plastic application. (Fire Classified Only)

*Bearing the UL Classification Marking

Figure 7. Details for Roof Deck Construction No. 74 (fluted metal).



CONSTRUCTION NO. 82

1. **Foamed Plastic*** – Formed by simultaneous spraying of two liquid components isocyanate and resin. Thickness to be 1 in. min. 3 in. max. To be applied according to manufacturer's instructions.

2. **Roof Coating** Silicone construction coating. Applied in two differently colored coats. Each coat to be applied at a rate of 1.5 gal per 100 sq ft. No. 11 roofing granules to be embedded into wet top coat at a rate of 50 lbs per 100 sq ft.

3. **Foamed Plastic Filler Strips*** – Used in panel valleys and formed to configuration of panel.

4. **Metal Roof Deck Panels** – Type B-2, No. 20 MSG min gauge coated steel welded 12 in. O.C. except at supports adjacent to end laps where the spacing is 6 in. O.C. Weld washers are to be utilized. Butt joints to occur over supports with panels overlapped 2 in. Side joints connected with No. 12-14 by 1 in. self-drilling fasteners spaced 30 in. O.C.

5. **Steel Beams** – Min size W8 x 13 spaced not more than 7 ft, 6 in. O.C. and welded to supports ASTM A36 steel. Refer to General Information, Roof Deck Constructions (Building Materials Directory), for items not evaluated.

6. (Not Shown) – Optional adhesive prime coating directly applied to roof deck panels in accordance with manufacturer's instructions prior to foamed plastic application. (Fire Classified Only)

*Bearing the UL Classification Marking

Figure 8. Details for Roof Deck Construction No. 82 (fluted metal).

Appendix A

UL TEST REPORT
ON

FIRE TESTS OF POLYURETHANE FOAM
ROOF DECK CONSTRUCTION ON STEEL DECKS

December 29, 1978

UNDERWRITERS LABORATORIES INC.
CHICAGO · NORTHBROOK, ILL. · MELVILLE, N.Y. · SANTA CLARA, CALIF.
an independent, not-for-profit organization testing for public safety

File USNC77
Project 77NK11796

December 29, 1978

REPORT

on

FIRE TESTS OF POLYURETHANE FOAM ROOF DECK CONSTRUCTION ON STEEL DECKS STATEMENT OF WORK 77-0054

Department of the Navy, Civil Engineering Laboratory
Port Hueneme, California

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A B S T R A C T

Fire tests were conducted on built-up roof assemblies specified by the Navy consisting of spray-applied polyurethane foamed plastic covered with specified elastomeric coatings. The Standard UL 790 entitled "Tests For Fire Resistance Of Roof Covering Materials," was utilized to measure the resistance to fire originating from sources outside a building on which they may be installed. A 20 ft by 100 ft building ("White House") was used to evaluate the ability of the built-up roof assembly to resist spread of fire on the underside as a result of fire originating from interior sources. Prior to the White House test, 25 ft tunnel tests and small-scale furnace tests were conducted to 1) provide data for screening and selection of candidate systems likely to perform successfully in the "White House" test and 2) provide additional data on underdeck spread of flame and damage for comparison with performance characteristics of "Fire Classified" assemblies.

As a result of these fire tests and comparisons with previous results for other assemblies, three candidate systems are eligible for Underwriters Laboratories Inc.'s Classification and Follow-Up Service as "Fire Classified' Roof Deck Constructions.

L I S T O F I L L U S T R A T I O N S

File USNC77 Issued: 12-29-78

	ILL. No.
Post Test 25 Ft Tunnel Flue End	20
Exterior of Structure (White House)	21
Interior of Structure (White House)	22
Burner Assembly	23
Fire Test (White House)	24-29
Post Test (White House)	30-31

I N T R O D U C T I O N

The Civil Engineering Laboratory (CEL) has an interest in roof systems for Navy installations throughout the world, including spray-applied polyurethane foam surfaced with fluid-applied elastomeric coatings and ceramic granules. This type of assembly would be particularly advantageous when applied directly to steel roofs of buildings.

Concern for fire safety as well as requirements of the Department of Defense resulted in recommending only those systems which are Classified as Class A, B or C Built-Up Roof Coverings as evaluated in accordance with the Standard of Underwriters Laboratories Inc. UL 790, "Tests For Fire Resistance Of Roof Covering Materials." The application of the foamed plastic directly to steel deck without thermal barrier protection may create the potential for the built-up roof covering to contribute to fire spread and damage as a result of fire originating from the interior of the building.

UL Classifications in the Roof Deck Construction category, wherein assemblies are evaluated with respect to internal fire exposures, are predicated on performance in datum tests conducted on full-scale constructions in a 20 by 100 ft building, hereinafter called the "White House." However, for certain roof deck systems, correlation of the results from the White House Test and tests in the 25-ft tunnel furnace has been developed, and Classifications have been established on the basis of 25 ft tunnel results. Information on the use of the 25 ft tunnel for such Classifications is described in the Subject 1256 "Outline Of The Proposed Investigation For Roof Deck Constructions." White House Test data on systems where foamed plastic insulation is spray-applied directly to the steel deck had not been developed. Thus, the use of the 25 ft tunnel furnace alone was not sufficient for Classification of such systems.

In this investigation, tests were conducted on four systems in accordance with UL 790 to establish Class C (or better) Classifications under the Built-Up Roof Covering Materials category. Each roof system consisted of a spray applied polyurethane foam covered with an elastomeric coating, both specified by the Navy. Following the UL 790 evaluations, 25 ft tunnel and small-scale furnace underdeck fire exposure tests were conducted on the four built-up roof systems utilizing both corrugated and ribbed steel deck.

Selection of the system for the White House Test was based on analysis of data obtained in the small-scale furnace and 25 ft tunnel underdeck fire exposure tests so as to be the most representative of these built-up roof systems.

File USNC77 Issued: 12-29-78

F I R E T E S T S

GENERAL:

The investigation consisted of 1) exterior fire exposure tests conducted in accordance with UL 790, "Tests For Fire Resistance Of Roof Covering Materials," 2) 25-ft tunnel furnace underdeck fire exposure tests, 3) small-scale furnace underdeck fire exposure tests and 4) a White House test. Two polyurethane foam materials, intended for spray application, and two elastomeric coating systems were utilized to form four built-up roof covering systems. For purposes of this report the foam materials will be referred to as "PUF 1" (2-1/2 pcf density) and "PUF 2" (3 pcf density). The coating systems will be referred to as "C1" (Silicone) and "C2" (Acrylic elastomer).

MATERIAL IDENTIFICATION

The foamed plastic material identified as PUF2 did not bear the label of Underwriters Laboratories for Classified Built-Up Roof Covering Materials. However, analysis verified that the material received was of the same basic composition as the material Classified by the Laboratories. The coating materials and the PUF1 foamed plastic material were produced under the Follow-Up Service Program as evidenced by the Classification Marking of Underwriters Laboratories for Classified Built-Up Roof Covering Materials.

BUILT-UP ROOF COVERING SYSTEMS

The following is a description of the four built-up roof covering systems utilized for this investigation as referenced in the "Statement of Work 77-0054."

System 1

A nominal 3 in. thick foamed plastic was formed by the simultaneous spraying of two liquid components (PUF1). The foamed plastic was coated with a two coat system (C1). Both the base coat and the top coat were applied at the nominal rate of 1-1/2 gal per 100 sq ft. (Total 3 gal per 100 sq ft). With the top coat still wet, No. 11 mineral roofing granules were applied at a nominal rate of 50 lb per 100 sq ft.

System 2

A nominal 3 in. thick foamed plastic was formed by the simultaneous spraying of two liquid components (PUF2). The foamed plastic was coated with a two coat (system (C1). Both the base coat and the top coat were applied at the nominal rate of 1-1/2 gal per 100 sq ft. (Total 3 gal per 100 sq ft). With the top coat still wet, No. 11 mineral roofing granules were applied at a nominal rate of 50 lb per 100 sq ft.

System 3

A nominal 3 in. thick foamed plastic was formed by the simultaneous spraying of two liquid components (PUF1). The foamed plastic was coated with a two coat system (C2). Each coat was applied at the nominal rate of 1-1/2 gal per 100 sq ft (total 3 gal per 100 sq ft). With the second coat still wet, No. 11 mineral roofing granules were applied at a nominal rate of 50 lb per 100 sq ft.

System 4

A nominal 3 in. thick foamed plastic was formed by the simultaneous spraying of two liquid components (PUF2). The foamed plastic was coated with a two coat system (C2). Each coat was applied at the nominal rate of 1-1/2 gal per 100 sq ft (total 3 gal per 100 sq ft). With the second coat still wet, No. 11 mineral roofing granules were applied at a nominal rate of 50 lb per 100 sq ft.

EXTERIOR FIRE EXPOSURE UL 790 TESTS:

SAMPLES

The built-up roof covering systems were applied to 13 ft long by 40 in. wide plywood decks. The systems were prepared by craftsmen contracted by the Laboratories in accordance with instructions provided by each materials supplier. The assemblies were allowed to cure at an ambient temperature of 70 F for a minimum of 27 days prior to the fire tests.

METHOD I

The fire tests were conducted in accordance with the Standard Tests For Fire Resistance Of Roof Covering Materials, UL 790. The test apparatus is shown by ILL. 1. At the conclusion of the spread-of-flame tests, the requirements are that the flaming shall not have spread beyond 6 ft for Class A, 8 ft for Class B and 13 ft (the top of the deck) for Class C.

RESULTS

The Spread-Of-Flame Tests were conducted with a Class A gas flame applied continuously for 10 min. The test decks were positioned at an incline of 3-1/2 in. per horizontal foot. The flame spread results are tabulated below:

System	Maximum Flame Spread (Ft)	Time Of Maximum Flame Spread (Min:Sec)
1	4-1/2	3:20
1	4-1/2	2:30
2	11-1/2	4:10
2	12	4:30
3	5	4:00
3	5	3:15
4	4-1/2	5:00
4	5-1/2	4:00

No flying or flaming brands of roof covering material nor exposure of the roof deck occurred during any of the above tests. Systems 1, 3 and 4 comply with Class A requirements when applied to non-combustible decks. System 2 complies with Class C requirements when applied to non-combustible decks.

UNDERDECK FIRE EXPOSURE - 25 FT TUNNEL FURNACE TEST"

SAMPLES

The spray applied foamed plastic and coating built-up roof covering systems were applied to nominal 2 by 8 ft sections of 26 gauge galvanized steel deck (raised rib and corrugated) with a longitudinal centerline seam. The joint detail, support and fastener schedule are shown by ILL. 2. A chlorinated rubber primer was used to provide a recommended bond coat for the foamed plastic material to the steel deck.

For each test, three sections of deck were joined with a 1-1/2 in. overlap of the steel deck. Because of the manner in which the corrugated decks contacted the tunnel ledges a duplicate set of tests was conducted with 1 in. mineral wool insulation positioned on the tunnel ledges to provide a more positive seal. These tests will be identified with the letter "I" in the results below. The foamed plastic material was allowed to cure for a minimum of 16 days prior to testing. The coating systems were allowed to cure for a minimum of 7 days prior to testing.

METHOD

The fire tests were conducted in accordance with the methods described under the Laboratories' Subject 1256 "Outline Of The Proposed Investigation For Roof Deck Construction." The 25 ft tunnel furnace is shown by ILLS. 3 and 4.

Test Procedure

The test assemblies were subjected to a 30 min fire exposure. After 10 min, the maximum distance of flame propagation was recorded. After 20 min more of exposure to flame (30 min total), the maximum distance of flame propagation was again recorded.

Observations were made during the testing from the open fire end and side of the tunnel furnace with respect to flammability characteristics of the assemblies.

Following the exposure period the assemblies were removed for examination with respect to damage.

The guideline criteria for "Fire Classified" assemblies are as follows:

1. The flame propagation on the underside of each assembly tested shall not exceed the following limits within the designated time periods:

A. 10 feet (3.04 m) in 10 min

B. 14 feet (4.26 m) in 30 min

2. Examination of fire tested assemblies shall show the following, with respect to the extent of damage of component materials of the construction:

A. Thermal degradation (i.e., damage in the form of charring, loss of integrity, etc.) shall not extend to the downstream extremity of the test deck.

B. Damage shall diminish at increasing distance from the immediate fire exposure area to the extent that material located beyond the area of degradation could be judged acceptable for further use.

RESULTS

Underdeck Flame Spread

Roof Covering System	Steel Deck	Maximum Flame Spread (Ft)+ After 10 Min	Maximum Flame Spread (Ft)+ After 30 Min
System 1	Ribbed	10-1/2	10-1/2
System 1	Ribbed	8-1/2	9
System 2	Ribbed	9-1/2	9-1/2
System 2	Ribbed	7-1/2	7-1/2
System 3	Ribbed	9-1/2	12-1/2
System 3	Ribbed	6-1/2	6-1/2
System 4	Ribbed	5-1/2	5-1/2
System 4	Ribbed	5	5
System 1	Corrugated	19-1/2 at 5 min, 48 sec	-
System 1(I)	Corrugated	8-1/2	8-1/2
System 2	Corrugated	3-1/2	4
System 2(I)	Corrugated	8-1/2	19-1/2 at 17 min, 24 sec
System 3	Corrugated	12-1/2	12-1/2
System 3(I)	Corrugated	19-1/2 at 7 min, 45 sec	-
System 4	Corrugated	13-1/2	13-1/2
System 4(I)	Corrugated	6-1/2	6-1/2

+ - Flame travel recorded during test minus 4-1/2 ft igniting flame.

(I) - Mineral wool insulation positioned on the tunnel ledges.

Observations During Test

System 1 (Ribbed Deck) - Ignition of the roof deck assemblies at the centerline joint occurred after elapsed times of 1 min, 10 sec and of 1 min, 36 sec, respectively, for the two tests. The underdeck flaming in the first test progressed 4-1/2 ft, followed by intermittent flashes of flame, which started after 3-1/2 min of elapsed time, and ceased after 7 min. In the second test the initial underdeck flaming progressed to 8 ft, followed by intermittent flashes of flame which started after 9-1/2 min of elapsed time and ceased after 10-1/2 min. After termination of the tests there was no residual flaming.

System 2 (Ribbed Deck) - Ignition of the roof deck assemblies at the centerline joint occurred after elapsed times of 1 min, 30 sec and of 1 min, 40 sec, respectively, for the two tests. The underdeck flaming progressed 5-1/2 to 6-1/2 ft early in the tests followed by intermittent flashes of flame outward to the maximum recorded extent of flame spread. After 10 min the intermittent flashes of flame had ceased in both tests. After termination of the test a slight amount of residual flaming at the fire-end of the first deck section was noted in the first test. No residual flaming was noted in the second test.

System 3 (Ribbed Deck) - Ignition of the roof deck assemblies at the centerline joint occurred after elapsed times of 45 sec and of 1 min, 15 sec, respectively, for the two tests. The underdeck flaming progressed 5 to 6 ft early in the test followed by intermittent flashes of flame outward to the maximum recorded extent of flame spread. In the first test the intermittent flashes of flame continued through 18 min, whereas in the second test the flashes ceased prior to 10 min of elapsed test time. After termination of the tests there was no residual flaming.

System 4 (Ribbed Deck) - Ignition of the roof deck assemblies at the centerline joint occurred after elapsed times of 1 min and of 58 sec, respectively, for the two tests. The underdeck flaming progressed 4-1/2 to 5 ft early in the test. Momentary flashes of flame occurred at 5 min, 22 sec and at 6 min, 32 sec, respectively, for the two tests. These resulted in the maximum recorded spreads of flame. After termination of the tests there was no residual flaming.

System 1 (Corrugated Deck) - Ignition of the roof deck assemblies at the centerline joint occurred after elapsed times of 1 min, 12 sec and of 1 min, 13 sec, respectively, for the two tests. In the first test, the underdeck flaming progressed over the end of the furnace at 5 min, 48 sec and the test was terminated after 8 min. In the second test the underdeck flaming progressed to 8-1/2 ft early in the test and receded shortly afterward. After termination of the test there was no residual flaming.

System 2 (Corrugated Deck) - Ignition of the roof deck assemblies at the centerline joint occurred after elapsed times of 3 min, 44 sec and of 41 sec, respectively, for the two tests. In the first test the underdeck flaming progressed 3-1/2 ft early in the test, retreated and then progressed to 4 ft shortly after 10 min. No flashes of flaming occurred. In the second test the underdeck flaming progressed 8-1/2 ft early in the test and retreated. After 15 min the underdeck flaming again progressed until it extended over the end of the tunnel at 17 min, 24 sec. The test was terminated after 18 min, 15 sec. In the first test there was no residual flaming after termination.

System 3 (Corrugated Deck) - Ignition of the roof deck assemblies at the centerline joint occurred after elapsed times of 1 min, 15 sec and of 1 min, 30 sec, respectively, for the two tests. In the first test the underdeck flaming progressed 8-1/2 ft early in the test, followed by intermittent flashes of flame outward to the maximum recorded spread of flame. The flashes of flame ceased after 10 min. In the second test the underdeck flaming progressed to 11-1/2 ft and retreated momentarily. Thereafter intermittent flashes of flaming occurred and eventually progressed over the end of the furnace at 7 min, 45 sec. There was no residual flaming after termination of either test.

System 4 (Corrugated Deck) - Ignition of the roof deck assemblies at the centerline joint occurred after elapsed times of 2 min, 10 sec and of 54 sec for the two tests. In the first test underdeck flaming progressed 13-1/2 ft, followed by intermittent flashes of flame outward to the maximum recorded extent of flame spread. The flashing ceased after 6-1/2 min. In the second test the initial underdeck flaming progressed 6-1/2 ft early in the test and receded. After termination of the tests there was no residual flaming.

Damage

The following table summarizes the damage to the foamed plastic material as noted through visual observation at distances of 16 ft and of 23-1/2 ft from the fire end of the assemblies. For purposes of this description damage will be defined according to two damage levels.

1. Char - Change due to thermal exposure resulting in significant loss in structural integrity and significant change in material texture.

2. Discoloration - Color change due to thermal exposure with some loss in structural integrity and some change in material texture.

Roof Covering System	Steel Deck	16 Ft		23-1/2 Ft	
		Depth(In.)	Discoloration Depth(In.)	Depth(In.)	Discoloration Depth(In.)
1	Ribbed	None	3/4	None	1/8
1	Ribbed	3/8	3/4	None	3/4
2	Ribbed	3/4	1/4	None	1/2
2	Ribbed	1/4	1/2	None	1/2
3	Ribbed	3/4	1/4	None	1/4
3	Ribbed	None	3/4	None	1/2
4	Ribbed	1/4	3/4	None	3/4
4	Ribbed	None	1/4	None	Trace
1	Corrugated	+	+	+	+
1(I)	Corrugated	1-1/2	1/2	5/8	1/2
2	Corrugated	1/2	1/2	None	1/4
2(I)	Corrugated	+	+	+	+
3	Corrugated	None	1	None	1/4
3(I)	Corrugated	2	1	None	1/4
4	Corrugated	None	1/2	None	1/8
4(I)	Corrugated	3/8	1/4	None	1/8

+ - Not recorded.

(I) - Mineral wool insulation positioned on the tunnel ledges.

UNDERDECK FIRE EXPOSURE - SMALL-SCALE FURNACE TEST:

SAMPLES

The built-up roof covering systems were applied to nominal 3 by 3 ft sections of steel deck with a longitudinal centerline seam. The joint detail, support and fastener schedule are shown by ILL. 5. A chlorinated rubber primer was used to provide a recommended bond coat for the foamed plastic material to the steel deck.

The foamed plastic material was allowed to cure for minimum of 16 days prior to testing. The coating systems were allowed to cure for a minimum of 7 days prior to testing.

METHOD

The small-scale furnace shown by ILL. 6 is intended to provide fire exposure conditions similar to those of UL 263, "Fire Tests Of Building Construction and Materials," but on smaller samples than are required by UL263. The small-scale furnace fire allows the same time-temperature curve specified by UL 263 as shown on ILL. 16. It is fired with a natural gas diffusion flame.

Additional exposure conditions were simulated by altering the firing rate of the gas flame to produce time-temperature curves with 850 and 500 F as upper temperature limits. These curves are shown by ILL. 7.

Test Procedure

Twelve fire tests were conducted on assemblies utilizing both ribbed and corrugated steel decks. Each of the four roof covering systems applied to ribbed deck were subjected to 1) the Standard Time Temperature Curve contained under UL 263 and 2) the time-temperature curve with an upper limit being 850 F after 30 min.

Tests were conducted on Systems 1 and 2 applied to corrugated steel deck and subjected to the Standard Time Temperature Curve.

Observations were made during the testing of flammability characteristics of the assemblies. Following the exposure period, the assemblies were removed for examination with respect to damage.

RESULTS

System 1 (Ribbed)

Standard Time Temperature - After 50 sec, emission of smoke began at the periphery. Underdeck flaming was first detected along the south edge of the sample after 5 min. Underdeck flaming occurred only at the periphery of the sample. Top surface flaming first occurred at the southwest corner and was immediately extinguished with water. Recurrences of the top surface flaming at the sample periphery were similarly extinguished. After 10 min and 30 sec, no further flaming (top surface or underdeck) occurred. The test was terminated at 30 min.

The top surface of the sample was discolored but intact (without fissures) except where peripheral flaming had occurred. The foamed plastic material was completely charred except for a thin film of the material which adhered to the surface coating.

850 F - After 2 min, smoke emission began at the periphery. Underdeck flaming first occurred at the northwest corner and at the center joint near the north edge after 10 min. Top surface flaming first occurred at 16 min and 40 sec at the southwest corner and was immediately extinguished with water. No further flaming action (top surface or underdeck) occurred. The test was terminated at 30 min.

The top surface was discolored only at the periphery. There were no fissures in the coating. The foamed plastic was charred in the center of the sample except for a 1/4 to 1/2 in. layer adhered to the coating. Outward toward the periphery of the sample the char and discoloration decreased. There was a 1-1/2 in. thick layer of unaffected foamed plastic at the periphery.

System 2 (Ribbed)

Standard Time Temperature - After 30 sec, smoke emission began at the periphery. Underdeck flaming was first detected at 5 min at the centerline joint near the south edge. Underdeck flaming occurred only at the periphery of the sample. Flaming of the top surface occurred along the west edge and the south edge after 11 min. This edge flaming was extinguished with water, but reoccurred throughout the test. The test was terminated at 30 min.

The top surface was discolored but intact (without fissures) in the center of the sample. The edges were charred due to the top surface edge flaming. The foamed plastic was completely charred except for a thin layer of the material adhered to the coating.

850 F - Underdeck ignition occurred only at the periphery and was first detected at 11 min and 30 sec along the west edge. Smoke emission was first observed after 19 min and 45 sec. No top surface flaming occurred until the gas ignition source was shut off at 30 min. At this time top surface flaming at the periphery began and was extinguished with water.

The top surface was discolored and charred only at the periphery. The foamed plastic was charred completely at the center of the sample except for a thin layer adhered to the coating. Toward the periphery the foamed plastic was discolored and charred 1-1/2 to 2 in.

500 F - After 3 min, smoke emission began at the periphery of the sample. Flashes of flame (outgassing) were observed at 5 min along the west edge of the sample and water was used to extinguish flaming. No further flaming action was observed. The test was terminated at 30 min.

The top surface was unaffected except for discoloration at the periphery. Char and discoloration of the foamed plastic extended 1-1/2 in. through the material.

System 3 (Ribbed)

Standard Time Temperature - After 1 min, smoke emission began at the sample periphery. Underdeck flaming was first detected at 2 min and 15 sec at the center joint near the south wall. After 4 min and 40 sec, underdeck flaming started at the center joint near the north wall. Flaming of the top surface first occurred at the north-west corner at 9 min and 30 sec and was extinguished immediately with water. Occasional recurrences of the top surface flaming at the sample periphery were similarly extinguished. Underdeck flaming was observed only at the periphery of the sample and did not spread to the middle along the center joint of the deck. At 27 min and 30 sec a crack in the top surface developed toward the center of the sample. No flaming was emitted through this crack. The test was terminated at 30 min.

The foamed plastic material was charred completely except for a thin film of the material which adhered to the surface coating. Fissures had developed in the top surface. The surface coating was discolored in the middle of sample and charred only at the periphery where top surface ignition had occurred.

850 F - After 1 min and 30 sec smoke emission began at the periphery. Underdeck flaming first occurred at the northwest corner at 8 min and 10 sec. The center joint began flaming near the south wall after 11 min. Underdeck flaming occurred only at the periphery of the sample. Flaming of the top surface first occurred at 19 min at the southeast corner and was extinguished with water. After 21 min, no further underdeck flaming was observed. The test was terminated at 30 min.

The top surface was discolored but intact (without fissures). Toward the center of the sample the foamed plastic was charred except for a 1/4 to 1/2 in. thick layer of the material which adhered to the surface coating. At the periphery there was approximately 1-1/2 in. thick layer of foamed plastic that had not charred or discolored.

500 F - The initial flaming surge of the furnace caused top surface ignition at the East edge of the sample at 3 min and 45 sec. This ignition was immediately extinguished with water. No further flaming action was observed. The test was terminated at 30 min.

The appearance of the top surface of the sample was unchanged. Char and discoloration extended approximately 1-1/2 in. into the foamed plastic material.

System 4 (Ribbed)

Standard Time Temperature - After 1 min, smoke emission began at the periphery. Underdeck flaming was first observed at the centerline joint near the south wall after 2 min and 30 sec. Underdeck flaming occurred only at the periphery of the sample. Top surface flaming first occurred at the northeast corner at 17 min and 50 sec and was immediately extinguished with water. A crack or fissure developed in the top surface near the center of the sample at 22 min and 45 sec. Flaming through this crack started at 25 min and 30 sec but was extinguished with water. The test was terminated at 30 min.

The top surface had two fissures which exposed the charred foamed plastic beneath. The foamed plastic over most of the sample area was charred completely except for a thin layer adhered to the coating.

850 F - After 2 min and 50 sec smoke emission began at the periphery. Underdeck flaming first occurred at the southwest corner at 10 min and 40 sec. Top surface flaming first occurred at 17 min and 40 sec at the southwest corner and was immediately extinguished with water. The test was terminated at 30 min.

The top surface was discolored only at the periphery. There were no fissures in the coating. The foamed plastic was charred in the center of the sample except for a 1/4 to 1/2 in. layer adhered to the coating. Outward toward the periphery of the sample the char and discoloration decreased. There was a 1-1/2 in. thick layer of unaffected foamed plastic at the periphery.

System 1 (Corrugated)

Standard Time Temperature - After 1 min, smoke emission began at the periphery of the sample. Underdeck flaming at the middle of the centerline joint began at 1 min and 30 sec. Top surface flaming first occurred at the southwest corner at 2 min and was immediately extinguished with water. The underdeck flaming at the centerline joint slackened after 2 min and 30 sec, however, the joint was severely distorted and open. The test was terminated at 10 min.

System 2 (Corrugated)

Standard Time Temperature - After 45 sec smoke emission began at the periphery of the sample. Underdeck flaming first occurred at the northeast and southwest corners at 2 min and 20 sec. Top surface flaming at the periphery (south and north edges) occurred at 4 min and 30 sec. At 10 min and 20 sec flaming occurred underdeck across the centerline joint (which had opened) and around the entire periphery such that the test was terminated at 10 min and 30 sec.

WHITE HOUSE TEST:

GENERAL

The test structure was erected by Laboratories' personnel. The foam and roof coating were applied by craftsmen in the employ of Underwriters Laboratories Inc. The firing equipment, instrumentation and fire suppression equipment were installed by Laboratories' personnel.

Built-up roof covering System 1 was selected for this test.

BUILDING STRUCTURE

The test structure was 20 ft wide, 100 ft long and 10 ft high (floor to steel decking), as shown in ILL. 8. The walls of the structure were constructed from nominal 8 in. thick concrete block. The walls of the first 40 ft were protected on the interior by a nominal 1 in. thickness of spray-applied cementitious mixture.

The flue end of the structure was closed with a sheet-metal breeching which diverted the exhaust gases from horizontal to vertical.

FIRING EQUIPMENT

The fire exposure was provided by heptane fuel pumped through two Sprayco 4C atomizing nozzles as shown on ILL. 9. A continuous pilot ignition was provided by LP-Gas torches and a high voltage spark ignitor. Flow of the heptane fuel was measured by pressure gauges and flow meters, while manual valves controlled the fuel flow rates.

The fuel used was heptane with a heat of combustion of 116,000 Btu per gallon per ASTM D2015 modified to use gelatin capsules.

Air for combustion was furnished by a blower and duct assembly located outside the test building as shown on ILL. 9. The air supply of 4700 cfm was delivered by four ducts through the fire-end wall.

ROOF DECK MATERIALS AND ASSEMBLY

Structural Supports - The primary supports of the roof deck assembly were W6 X 16 steel beams running in the north-south direction and spaced 20 ft O.C. The beams were supported at each end by the masonry walls. The second and fourth bays between the steel beams were cross-braced using 1/2 in. diameter steel rods with turnbuckles.

Purlins - The purlins used in the roof deck assembly were C-shaped channels formed from No. 14 gauge steel. The purlins were 7 in. deep with 2-1/2 in. flanges and 3/4 in. stiffening flanges and were supplied in nominal 25 ft lengths.

The purlins were installed perpendicular to the W6 X 16 steel beams, spaced 40 in. O.C., as shown in ILL. 8. The purlins were secured to the beams with welds. Adjoining lengths of purlins were overlapped 4 ft, 11-1/4 in. over the steel beams, as shown in ILL. 10, and were secured together near the ends of each overlap with steel bolts with nuts. In addition, a 1-1/2 by 1-1/2 by 1/8 in. thick steel angle, 6 in. long, was welded to the steel beam upper flange and the purlin web at each beam/purlin intersection (seven per beam) as shown in ILL. 8. Nominal 3/8 in. diameter steel rods, 48 in. long with threaded ends, were used as bridging between purlins at the center of each purlin span as shown in ILLS. 8 and 10.

Metal Roof Deck Panels - The metal roof deck panels were 24-1/4 in. wide (24 in. cover width) and were formed from No. 26 gauge galvanized steel. Each panel contained a nominal 1 in. high rib along its longitudinal centerline and ribbed side edges. The panels were installed perpendicular to and screw-attached to the purlins with No. 1/4-14 by 1-1/4 in. long self-drilling, self-tapping hex-head steel fasteners as shown in ILLS. 11 and 12. Each row of panels contained one end lap joint with the ends lapped 6 in. as shown in ILLS. 11 and 12.

Spray-Applied Foamed Plastic - The two component foamed plastic was spray-applied over the metal roof deck panels. Prior to application of the foam, the metal roof deck panels were given a light coat of primer. The foam was then spray-applied following the contour of the metal roof deck panels, to a nominal thickness of 3 in. over the entire roof assembly. The thickness was continually checked by probing covered areas. The spray-application of the foam was completed 36 days prior to the fire test.

Coating System - The fluid-applied silicone elastomeric roof coating was spray-applied over the foamed plastic. The coating was applied in two layers. The base coat was applied at a nominal rate of 1.5 gal per 100 sq ft. The top coat was also applied at a nominal rate of 1.5 gal per 100 sq ft. The roof was surfaced with No. 11 mineral granules embedded in the wet top coat at a nominal rate of 50 lb per 100 sq ft. The application of the coating system was completed 14 days prior to the fire test.

End Closures - Prior to the spray-application of the foamed plastic, end closures consisting of courses of common brick with mortar joints and beds were laid atop the north, west and south masonry walls as shown in ILL. 8.

METHOD

Furnace Fire

The following firing rate of heptane as used for this test was originally selected through experimentation so as to produce temperatures in the first 20 ft of the building to approximate the Standard Time Temperature Curve (UL263).

Time (Min)	Flow (GPM) Both Nozzles	Fuel Total (Gal)
0-2	1.0	2.0
2-4	1.5	5.0
4-7	2.0	11.0
7-17	2.5	36.0
17-30	2.7	71.1

Instrumentation

The thermocouples used to monitor temperatures in the fire end were enclosed in black pipe and supported with concrete pylons. These "Control" thermocouples, shown on ILL. 13, were positioned to provide a 1 ft radial clearance from the bottom of the steel decking and support members.

To gather general fire information, twenty-two No. 20 gauge chromel-alumel thermocouples were installed at locations shown on ILL. 14. In addition, two calorimeters for heat flux measurements were mounted in the roof 40 and 60 ft from the fire end, as shown in ILLS. 14 and 15. Heat flux measurements could assist observations of flame progression at those distances.

Observations

Four observers recorded events at specified locations during the conduct of the test. One observer was on scaffolding located near the flue end to observe the top of the roof. Two observers viewing the underside of the roof moved laterally, one along each exterior side of the structure, as the test developed. Another observer was located at the flue end of the structure at ground level. Transcribed voice records of these observers appear in App. B through E of this Report. In addition, the test development was recorded on film with both still and movie cameras, and on video tape.

Fire Suppression

A system of sprinklers was installed inside the structure as can be seen in ILL. 22. Two hose streams were provided for exterior application.

RESULTS

Exposure Fire

The average fire control temperature is shown on ILL. 16 along with the firing rates.

Observations During Test

Interior - The test was started with ignition of the gas-fired burners. The burner flames projected outward approximately 4 ft from the end wall of the structure with light impingement on the underside of the roof deck by 2-1/2 min. Some of the liquid fuel dropped to the floor of the structure where it burned for about 2 min. The outward projection of the burner flames increased as the flow rate of heptane was increased. At the maximum heptane flow rate (2.7 GPM at 17 min and beyond), the outward projection of the burner flames was approx 20 ft from the end wall of the structure.

Smoke began issuing from joints in the underside of the roof at 4 min. The smoke became very dense after 8 min such that vision by the flue end observer was obscurred. The smoke cleared after 11-1/2 min as reported by the flue end observer. The density of the smoke fluctuated as the test progressed but did not further obscure vision.

Flaming on the underside of the deck commenced at 4 min and extended from the fire end wall of the structure to approximately the 8 ft mark. By 5 min the underdeck flaming was observed to 18 ft and burning was present at the transverse deck sidelap joints located 4, 6 and 10 ft from the fire end wall of the structure. The underdeck flaming was observed outward to 30 ft at 8 min, outward to 34 ft at 9-1/4 min, and outward to 40 ft at 11 min. Underdeck flaming receded to approx 20 ft by 15 min. Except for sporadic flaming at the transverse deck sidelap joints at the 22 ft mark, the underdeck flaming ceased after 17 min. No further underdeck flaming was observed in the interior of the structure during the remainder of the test.

At 23 min the center purlins in the first span rotated at their midspans. At 27-3/4 min a sharp report was heard, apparently emanating from the first bay. The cause was not known.

Exterior - Beginning at 3 min into the test, light smoke issued from the roof edges around the perimeter of the fire end out to the 8 ft mark of the north and south walls. By 4-1/4 min the smoke intensity had increased, partially obscuring visibility over the burner region.

At 6-1/4 min, flaming was emitted from between the end closure bricks along the perimeter of the fire end out to the 10 ft mark of the north wall. By 7-1/4 min the edge flaming along the north wall had extended to the 13 ft mark. By 8 min, the roof flaming had progressed to the 18 ft mark along the north edge and extended southward half way across the roof. By 8-3/4 min, the roof flaming extended across the entire roof up to the 18 ft mark. By 10-1/4 min the roof flaming had progressed to the 21 ft mark across the width of the roof. By 14 min the flame front was at the 23 ft mark across the width of the roof. At that time it appeared that the roof was flaming along the three walls and at the flame front while the flaming in the encircled area had ceased. By 14-1/2 min the flame front was at the 28 ft mark across the width of the roof. By 16 min, the flame front had progressed to the 31 ft mark in the center of the roof. At that time, the majority of the flaming was at 31 ft mark while the flaming between the 5 and 30 ft marks had ceased.

By 18 min, the flame front across the width of the roof was angled due to the wind gusting at 26 mph from the northwest. At that time, the flame front was at the 36 ft mark at the south edge and at the 32 ft mark at the north edge. By 19-3/4 min, the flame front was at the 41 ft mark at the south edge, the 38 ft mark near the center, and at the 30 ft mark at the north edge. By 22-3/4 min, the flame front near the center and at the south edge was at the 45 ft mark near the center, and at the 38 ft mark at the north edge. By 29-3/4 min, the flame front was at the 53 ft mark at the south edge, the 50 ft mark near the center, and at the 45 ft mark at the north wall. No further progress was recorded.

At 23-3/4 min, a large bubble or blister, approximately 8 in. high, was observed between the 60 and 70 ft marks which extended across the entire width of the roof. At 27-1/4 min, the roof in the center of the first bay in the burner region was deflected downward approximately 18 in.

Termination Of Test

The fuel pump was shut-off at 30 min, thereby extinguishing the heptane fire. The residual flaming of the roof assembly was quenched at 30-1/2 min by activating the sprinkler heads within the structure and by application of a hose stream on the exterior of the structure.

Temperatures

The temperatures recorded by the thermocouples are tabulated in App. A. This temperature data was used to prepare the more specific measurements shown under the following illustrations:

ILL. 16 - Time-temperature plot of control thermocouples.

ILL. 17 - Graph of average flue temperature versus Standard assembly.

Further discussion of these temperatures and those obtained in the test of the Standard roof assembly are presented under the Discussion of this Report.

Heat Flux

A graph of the readings is shown on ILL. 18. Malfunctions of the two calorimeters occurred at 18 min and 7 sec and at 29 min and 47 sec at the 40 ft and 60 ft locations, respectively. The calorimeter at the 40 ft location was engulfed in the flaming of the built-up roof system at the time of the malfunction. The cause of the malfunction of the calorimeter at the 60 ft location, late in the test, was not determined.

Observations After Test

The locations of the affected areas, exterior and interior, are depicted graphically in ILL. 19.

Exterior - At the firing end of the structure, the spray-applied foam and fluid-applied coating were consumed, exposing the metal roof deck panels. Beyond the exposed metal roof deck panels, the spray-applied foam and fluid-applied coating were charred through their entire thickness and appeared intumesced. Beyond the charred area to the flue end of the structure, the roof covering was bubbled in several locations but was not discolored.

Interior - At the firing end of the structure, the steel purlins were rotated and deflected downward. The amount of purlin rotation ranged from approximately 15 deg near the north wall to approximately 80 deg near the south wall. The center purlin and the two purlins immediately south of the center purlin experienced the greatest rotation and lateral snaking. The downward deflection of the purlins in the first beam bay was approximately 6 to 8 in. Beyond the first beam span, the steel purlins exhibited no significant distortion.

In the area beneath the consumed roof covering, the metal roof deck panels were discolored and wrinkled and several sidelap joints were separated such that openings were present in the steel roof deck. Due to the rotation and deflection of the purlins in the south half of the first beam bay at the firing end of the structure, the fasteners securing the metal roof deck panels to the purlins tore through, leaving holes in the metal roof deck panels. In the area beneath the charred roof covering, the metal roof deck panels were wrinkled and discolored. In the area beneath the bubbled roof covering, the metal roof deck panels appeared unchanged except for smoke discoloration.

Damage

A sketch showing the overall post test observations of damage is shown by ILL. 19. Cross-sections were taken to visually observe the extent of damage to the foamed plastic material. The cross-sections taken nearer the fire end of the structure were reduced in thickness due to the fire exposure. The table below summarizes these observations as defined according to three damage levels.

1. Char - Change due to thermal exposure resulting in significant loss in structural integrity and significant change in material texture.

2. Discoloration - Color change due to thermal exposure with some loss in structural integrity and some change in material texture.

3. Unaffected - Original color with no apparent loss in structural integrity nor change in material texture.

Cross-Section	Unaffected (In.)	Discoloration (In.)	Char (In.)
1	2-1/2	1/2	None
2	2-1/2	1/2	None
3	2-1/4	3/4	None
4	2-1/4	3/4	None
5	2-1/2	1/2	None
6	2-1/4	3/4	None
7	2-1/2	1/2	None
8	2-1/2	1/2	None
9	2-1/4	3/4	None
10	1-1/2	3/4	Trace
11	1-1/4	1/2	1/8
12	1-1/4	1	Trace
13	1	1/2	1/8
14	1-1/2	1/2	1/8
15	1	1/2	1/4

D I S C U S S I O N

EXTERIOR FIRE EXPOSURE - UL 790 TESTS:

The results of the spread of flame tests indicate that System Nos. 1, 3 and 4 meet the requirements of Class A built-up roof covering systems as applied to noncombustible deck at inclines not exceeding 3-1/2 in. to the horizontal foot. Whereas, the results of the spread of flame tests indicate that System No. 2 meet the requirements of Class C built-up roof covering system as applied to noncombustible deck at inclines not exceeding 3-1/2 in. to the horizontal foot.

Since System No. 2 showed considerably less resistance to flame spread from exterior fire exposures than did System Nos. 1, 3 and 4. In order to maximize the test information developed with regard to underdeck flame spreading, Systems 1, 3 and 4 were selected for further screening as potential candidates for use on the "White House" Test.

UNDERDECK FIRE EXPOSURE - 25 FT TUNNEL FURNACE TEST:

UNDERDECK FLAME SPREAD

Ribbed Deck

In the tunnel tests, the spread of underdeck flaming of the four roof systems applied to the raised ribbed steel deck compared favorably with the Laboratories current requirements contained in Subject 1256 "Outline Of The Proposed Investigation For Roof Deck Construction." Only one test (System No. 1) resulted in an underdeck flame spread, which exceeded the guideline limit of 10 ft in the first 10 min. All test results were within the guideline limit of 14 ft after 30 min.

Corrugated Deck

Of the eight tunnel tests conducted on the four built-up roof systems applied to corrugated deck, five exceeded the flame spread limits prescribed by the Subject 1256 Outline.

Damage

For all tests utilizing the ribbed steel deck panels, the extent of damage to the foamed plastic was judged to comply with the intent of the statements related to damage contained in the Subject 1256 Outline.

For the tests utilizing the corrugated steel deck panels, three were considered as not in compliance with the damage requirements. One test showed a 1-1/4 in. char of the foamed plastic at the extremity and two were not recorded due to extent of flaming and early termination of the test.

UNDERDECK FIRE EXPOSURE - SMALL SCALE FURNACE:

The tests conducted utilizing the three exposure conditions showed increasing flaming and damage with increasing intensity of exposure conditions. The increased propensity for System No. 2 to support exterior flaming (top surface) as compared to System Nos. 1, 3 and 4 was evident in the difficulty of controlling exterior flaming that occurred at the periphery of the samples.

The C1 coating system demonstrated in the testing that it is more resistive than the C2 coating system against thermal degradation and flaming break-through.

In the two tests utilizing the corrugated steel deck, the joints tended to open under the Standard Time Temperature fire exposure such that early termination was necessary.

WHITE HOUSE TEST:

GENERAL

When subjected to this test in the past, an assembly consisting of a metal deck with 1 in. plain vegetable fiberboard attached by mechanical fasteners and with a built-up (tar or asphalt) roof covering and gravel surface produced underdeck flame spread to approximately 60 ft with occasional flashes of flame extending to approximately 72 ft. Beyond 60 ft, damage to the fiberboard diminished and only a light char of the fiberboard occurred at the far end of the structure. This performance, judged on the basis of underdeck fire spread and damage, has served as the basis for judging other roof assemblies. The assembly is referred to in this Report as the Standard roof assembly.

UNDERDECK FLAMING

The maximum spread of underdeck flaming was 40 ft which is to be compared to a maximum spread of underdeck flaming of approximately 60 ft with flashes of flame extending to 72 ft as recorded in the test of the Standard roof assembly.

Air temperatures measured at the flue end of the White House for this and the Standard roof assembly are compared on ILL. 14. The temperatures after 4 min into the test are significantly lower than those recorded for the test of the Standard assembly.

DAMAGE

Inspection of the spray-applied foamed plastic roof insulation after the test showed a nominal 1/2 to 3/4 in. of discoloration near the 100 ft flue end of the structure

CORRUGATED STEEL DECK

The results of the 25 ft tunnel and small-scale furnace, interior exposure, fire tests using 26 gauge corrugated galvanized steel deck suggests that additional laboratory scale and/or White House tests would be required to establish the qualification of this type of deck for use in "Fire Classified" assemblies. All the tests conducted were predicated on the fastening, support recommendations, and manner of use associated with the raised ribbed deck sections.

S U M M A R Y

Based upon the data presented herein, the following specific summarization statements can be made:

1. The foamed plastic built-up roof coverings identified in this Report as System Nos. 1, 3 and 4 are eligible for Classification and Follow-Up Services by Underwriters Laboratories Inc., through its promulgation procedure, as Class A Built-Up Roof Coverings as applied to "noncombustible" deck at inclines not exceeding 3-1/2 in. to the horizontal foot.

2. The foamed plastic built-up roof coverings identified in this Report as System No. 2 are eligible for Classification and Follow-Up Services by Underwriters Laboratories Inc., through its promulgation procedure, as Class C Built-Up Roof Coverings as applied to "noncombustible" deck at inclines not exceeding 3-1/2 in.to the horizontal foot.

3. The foamed plastic built-up roof coverings identified in this Report as System Nos. 1, 3 and 4 are eligible for Classification and Follow-Up Services by Underwriters Laboratories Inc., through its promulgation procedure including Fire Council advisement, as Roof Deck Construction Materials for use in a Roof Deck Construction utilizing specified raised rib steel roof deck panels in accordance with recommended support and fastener practices.

4. The information contained in this Report provides a data base upon which evaluations of roof systems of the type described herein can be conducted, for Classification by Underwriters Laboratories Inc. as "Roof Deck Construction Materials," using Standardized laboratory-scale fire testing procedures.

File USNC77

Issued: 12-29-78

Report by:

KENNETH RHODES
Senior Project Engineer
Fire Protection Department

Reviewed by:

G. T. CASTINO
Managing Engineer
Fire Protection Department

KR:GTC:SJ

CONTROL TEMPERATURES

Time, Min

TC No.	1	2	3	4	5	6	7	8	9	10
1C	100	150	260	400	570	740	875	1065	1215	1280
2C	95	180	370	590	940	1170	1280	1530	1655	1625
3C	100	140	240	420	835	1215	1385	1640	1700	1735
4C	90	130	215	335	480	635	740	920	1080	1150
5C	85	120	200	340	530	680	785	930	1070	1160
6C	105	175	350	520	785	980	1100	1260	1360	1385
A	96	149	273	434	690	903	1028	1224	1347	1389

	11	12	13	14	15	16	17	18	19	20
1C	1275	1280	1285	1290	1300	1310	1330	1360	1400	1420
2C	1605	1595	1585	1590	1595	1590	1620	1695	1720	1745
3C	1715	1745	1720	1705	1725	1780	1795	1855	1885	1880
4C	1170	1170	1180	1185	1200	1220	1235	1285	1315	1335
5C	1190	1200	1205	1205	1200	1250	1265	1315	1370	1410
6C	1390	1405	1405	1410	1420	1440	1450	1525	1575	1580
Avg	1391	1399	1397	1398	1407	1432	1449	1506	1544	1562

	21	22	23	24	25	26	27	28	29	30
1C	1445	1440	1435	1435	1420	1425	1430	1430	1440	1430
2C	1750	1725	1725	1715	1705	1720	1740	1730	1745	1710
3C	1900	1915	1925	1915	1905	1910	1905	1910	1900	1865
4C	1360	1365	1370	1375	1380	1380	1380	1385	1385	1370
5C	1425	1450	1455	1470	1510	1500	1495	1490	1485	1470
6C	1600	1600	1600	1600	1595	1600	1605	1605	1600	1585
Avg	1580	1583	1585	1585	1586	1589	1593	1592	1593	1572

TEMPERATURES

Time (Min)	Thermocouple 1	2	3	4	5	6
1:00	215	130	90	215	95	120
2:00	315	165	90	370	95	160
3:00	470	250	90	545	95	225
4:00	620	360	89	725	95	310
5:00	830	480	91	855	95	405
6:00	1040	545	99	970	94	510
7:00	1130	700	98	1105	91	610
8	1220	810	96	1255	90	710
9:00	1250	895	95	1285	90	780
10:00	1280	975	100	1290	90	835
11:00	1270	995	295	1290	90	855
12:00	1265	1015	525	1285	90	865
13:00	1260	1030	1020	1295	90	870
14:00	1260	1055	1410	1300	90	875
15:00	1270	1105	1325	1325	90	875
16:00	1320	1160	1105	1335	90	875
17:00	1420	1230	565	1305	90	880
18:00	1450	1275	230	1290	245	885
19:00	1420	1320	230	1330	990	895
20:00	1390	1330	270	1350	1540	945
21:00	1360	1310	355	1330	1550	1165
22:00	1335	1270	420	1305	1425	1305
23:00	1310	1240	460	1270	1000	1155
24:00	1310	1210	480	1250	950	1080
25:00	1310	1195	490	1245	1370	1155
26:00	1310	1185	495	1250	1510	1160
27:00	1305	1185	490	1255	1355	1065
28:00	1295	1180	490	1255	995	1000
29:00	1285	1180	485	1255	500	960
30:00	850	715	470	950	295	855
Maximum Temp.	1450	1330	1410	1350	1550	1305
T	18:00	20:00	14:00	20:00	21:00	22:00

TEMPERATURES

Time (Min)	Thermocouple 7	8	9	10	11
1:00	230	195	110	95	200
2:00	390	325	150	95	340
3:00	540	455	190	98	480
4:00	680	580	260	98	620
5:00	800	685	335	98	740
6:00	885	750	410	95	785
7:00	970	820	490	92	830
8:00	1055	890	560	93	920
9:00	1100	935	625	95	995
10:00	1115	945	680	95	985
11:00	1125	950	725	92	980
12:00	1125	955	755	90	990
13:00	1120	960	755	90	1000
14:00	1120	960	790	90	995
15:00	1120	965	800	90	1000
16:00	1120	970	810	90	1005
17:00	1125	975	820	85	1010
18:00	1130	980	825	80	1015
19:00	1130	990	830	85	1025
20:00	1140	1000	840	90	1040
21:00	1180	1005	845	95	1045
22:00	1225	1010	850	98	1055
23:00	1265	1015	850	690	1060
24:00	1290	1020	870	1315	1065
25:00	1250	1020	1085	955	1065
26:00	1210	1020	1240	660	1065
27:00	1180	1020	1080	1070	1060
28:00	1160	1020	955	1420	1050
29:00	1150	1020	930	1515	1050
30:00	900	875	870	1410	1000
Maximum T[illegible]	1290	1020	1240	1515	1065
Time	24:00	24:00	26:00	29:00	24:00

TEMPERATURES

Thermocouple

Time (Min)	12	13	14	15	16	17
1:00	160	100	95	130	120	95
2:00	270	100	130	245	200	95
3:00	385	100	165	365	285	95
4:00	495	100	210	470	365	90
5:00	600	100	260	570	445	95
6:00	640	100	305	630	495	95
7:00	685	100	350	680	530	95
[illegible]0	740	100	410	720	575	95
0	795	100	460	765	630	95
10:00	800	100	500	780	645	95
11:00	805	100	545	795	650	95
12:00	815	95	575	800	665	95
13:00	820	90	605	810	680	90
14:00	825	95	630	815	685	90
15:00	830	95	650	820	695	90
16:00	830	95	665	820	700	90
17:00	830	95	675	820	700	85
18:00	840	90	680	825	705	85
19:00	845	90	690	830	715	85
20:00	850	90	705	840	720	85
21:00	850	90	715	845	730	90
22:00	860	90	725	850	735	85
23:00	860	90	735	855	740	85
24:00	860	90	740	855	740	85
25:00	865	90	745	855	740	85
26:00	865	90	750	855	745	85
27:00	870	90	750	850	745	85
28:00	870	90	755	850	750	85
29:00	865	93	755	850	745	85
30:00	870	95	755	850	745	85
Maximum Temp.	870	100	755	855	750	95
At [illegible]e	27:00	1:00	28:00	23:00	28:00	1:00

TEMPERATURES

Time (Min)	Thermocouple 18	19	20	21	22
1:00	90	90	145	140	140
2:00	115	185	200	200	205
3:00	140	285	220	220	215
4:00	175	380	230	235	225
5:00	215	470	215	215	215
6:00	255	545	210	205	210
7:00	295	590	230	225	230
9	340	630	250	250	250
0	380	670	285	280	280
10:00	415	690	310	310	300
11:00	450	695	310	310	305
12:00	470	705	325	325	305
13:00	495	715	320	320	305
14:00	519	720	325	325	315
15:00	530	720	330	330	330
16:00	545	725	350	350	345
17:00	560	730	370	370	360
18:00	575	735	390	390	380
19:00	590	745	415	415	410
20:00	605	750	430	430	425
21:00	620	755	440	440	430
22:00	630	760	440	445	445
23:00	640	760	445	450	455
24:00	650	765	475	465	460
25:00	655	770	505	480	470
26:00	655	770	495	475	480
27:00	660	770	485	470	485
28:00	670	770	470	450	465
29:00	670	760	450	430	445
30:00	665	735	425	400	390
Maximum Temp.	670	770	505	480	485
At e	28:00	25:00	25:00	25:00	27:00

KR:GTC:SJ

TOPSIDE OBSERVATION OF THE WHITE HOUSE TEST

Time (Min:Sec)	Observation
1:00	No topside action as of yet
3:00	No topside action
3:50	Light wispy smoke appears to be emitted from between the bricks around the perimeter of the test deck up to 8 ft
4:20	Heavy smoke appears to be emitted from between the bricks that surround the perimeter of the test deck on the north side of the building. Topside observation is being partially obscured due to the heavy smoke that is emitting from the bricks surrounding the perimeter of the building
5:20	Very heavy smoke at the fire end of the test deck is being emitted from between bricks surrounding the perimeter of the test deck
6:00	There is very light wispy smoke in the middle of the test deck at 40 ft (calorimeter location)
6:10	Flames are being emitted from around the perimeter of the test deck between the bricks up to 10 ft (north side of the building)
6:45	Very heavy smoke is obscuring the topside observer's view, however, there are flames being emitted at the 10 ft level from between the bricks that surround the perimeter of the test deck

Time (Min:Sec)	Observation
7:15	Flames on the north end of the building are being observed up to about 13 ft which are caused by the emission of the flames from between the bricks that surround the perimeter of the test deck. The flames appear to have ignited the roof and are progressing to about 2 ft inward from around the perimeter of the test deck at the 10 to 13 ft level. (North side of the building)
8:00	The flaming is progressing and has now engulfed the north end of the test deck up to about 18 ft half way across the test deck. Also at this time the bricks surrounding the perimeter of the test deck appear to be separating and opening at the fire end of the test deck
8:50	The flames up to 18 ft appear to be across the complete width of the test deck
9:30	The surface flames have progressed down to approximately 20 ft across the width of the building
10:15	The surface flames have progressed to approximately 21 ft across the entire width of the building. Also, the flames appear to be extending approximately 5 ft into the air
10:50	When the smoke clears you can see that there are large blisters in the roof up to approximately 20 ft

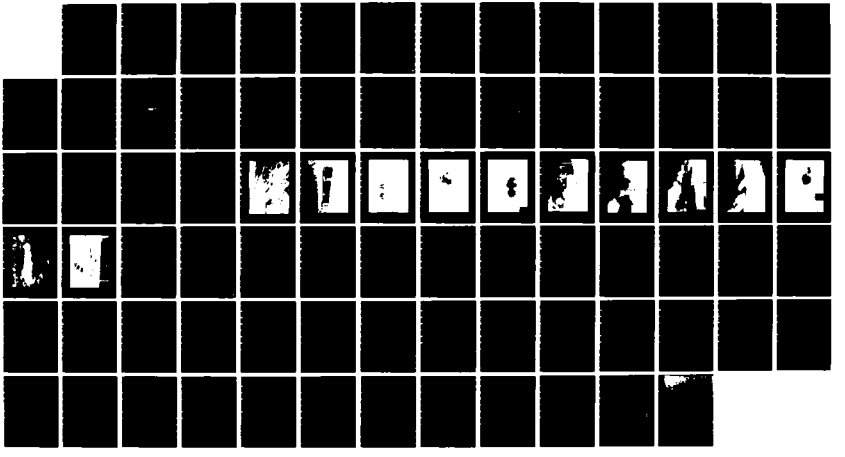
Time (Min:Sec)	Observation
12:00	The surface flames still appear to be at 21 ft (on the top of the test deck across the width of the building)
12:25	Very large blisters are being observed at the flue end perimeter of the flaming area. The blisters appear to be approximately 8 in. to 1 ft high
13:15	The surface flames appear to have progressed to approximately 23 ft across the width of the test deck
14:00	When the wind changes you can see the test deck and the flaming appears to be around the perimeter forward, aft and on both sides. The flames in the center of the test deck appear to have extinguished themselves
14:35	The flames appear to be progressing up to approximately 28 ft across the width of the test deck with flames extending approximately 5 ft into the air. Very heavy smoke is being emitted from the topside of the test deck
15:30	The flames appear to be progressing to approximately 30 ft at the center of the test deck
16:00	The flames appear to be progressing to approximately 31 ft at the center of the test deck. The majority of the heavy flaming is at the 31 ft level with the flaming at the fire end of the test structure being very light. The flames between the 5 and 30 ft level appear to have extinguished themselves

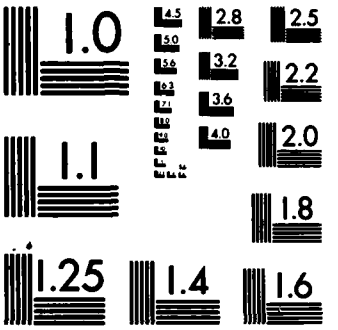
Time (Min:Sec)	Observation
17:15	The flames appear to have progressed to approximately 32 ft in the center and the south side of the test deck
18:00	On the south side of the structure the flames appear to have progressed up to approximately 36 ft. The flames on the far edge of the north side of the building are still at approximately 32 ft this being due to the wind direction which is coming out of the northwest
19:00	The flames on the south side of the building appear to be at approximately 40 ft
19:45	The flames are progressing approximately 41 ft on the south side of the building, approximately 38 ft in the center of the building and approximately 30 ft on the north side of the building
20:00	Again, you can observe large blistering around the perimeter of the test deck in the fire area
21:00	When the wind direction changes you can see that there are flames at approximate the 42 ft level at the very far extreme south side of the structure
22:00	The surface flames appear to have progressed to approximately 43 ft from the center to the south side of the building

Time (Min:Sec)	Observation
22:45	The surface flames on the center and south sides of the building appear to have progressed to approximately 45 ft
23:50	There appears to be a very large blister between the 60 and 70 ft mark. It appears to be extending approximately the width of the building and approximately 8 in. high
24:00	The surface flames have progressed to approximately 49 ft on the south side of the building, however, the flames on the north side of the building appear to be at 38 ft with the flames in the center of the building at 45 ft
25:45	No change in the surface action
26:40	The flames on the south side of the building appear to be out to approximately 50 ft
27:15	After looking back over the fire end of the test deck you can see that the test deck has sunken outward to approximately 12 ft, it appears to have sunken approximately 1-1/2 ft
28:00	The large blister from the 60 to 70 ft mark in the test deck still has not opened
29:00	The flames still appear to be up to approximately 50 ft on the south side of the building
29:30	The flames on the south side of the building appear to have progressed to approximately 52 ft

AD-A140 153 UNDERWRITERS LABORATORIES FIRE TESTS OF SPRAYED POLYURETHANE FOAM APPLIED..(U) NAVAL CIVIL ENGINEERING LAB PORT HUENEME CA R L ALUMBAUGH ET AL. DEC 83 2/2

UNCLASSIFIED NCEL-TN-1683 F/G 11/9 NL





Time (Min:Sec)	Observation
29:40	The flames on the south side of the building appear to be up to approximately 53 ft, to 50 ft in the center of the building and to 45 ft on the north side of the building
30:00	Test terminated

KR:GTC:SJ

SOUTH SIDE OBSERVATION OF WHITE HOUSE TEST

Time (Min:Sec)	Observation
0:45	Flames from the burners are extending out about 2 ft; there is some flaming of residual fuel on the floor extending about 7 or 8 ft from the burners. Some flaming on the pylon on the north side
1:30	Balls of flame from burners are slightly higher, about 2 ft in diameter. Burning on the floor is about the same. Slight discoloration of the underside of the deck above the burners
2:30	Flames from the burners are very bright yellow with orange tint and extend out about 4 ft from the nozzles. Discoloration on the underside of deck is about the same as the last comment
4:00	There is ignition on the underside of deck down to about 8 ft
4:20	Flaming on the underside of deck is down to about 16 ft
4:45	Smoke on south side from top is getting a little heavy
5:00	Underside flaming extends down to about 18 ft
5:40	Was forced to evacuate the south side due to heavy smoke affecting breathing
6:10	Surface flames are visible at the northwest corner of assembly on the outside

Time (Min:Sec)	Observation
8:45	Have switched to the north side to avoid the smoke
9:45	Underside flames from the north side appear to extend down to about 28 ft
9:55	The tongues of flame on underside extent to about 33 ft
10:30	Flaming extends to about 38 ft down the center on underside of the assembly
11:55	Perimeter flaming on surface extends to about 12 ft from fire end
12:30	There are spasmodic flames from transverse joints in the deck noted at 30 and 34 ft. Main body of flame extends to roughly 25 ft
14:10	Underside of flames are extending to about 25 ft. No flaming noted beyond that point
15:30	The underside flaming is about the same to about 20 ft. Underside smoking seems to be diminishing
17:20	There was spasmodic underside flaming at a transverse joint at roughly 22 ft
19:25	Flames from burners extend down to about 18 ft but no underside flaming is visible
21:45	Still no apparent flaming on underside of deck, flame from the burners is extending out to about 16-18 ft

Time (Min:Sec)	Observation
23:00	Once again tried to make observations from south side. Was able to look in port at 15 ft and could see no underside flaming
25:15	There appears to be no change in underside flaming. Flames from the burners extend out to about the same distance, 16-18 ft
28:15	Still no visible sign of flaming on underside of deck at any point. Flames from the burners coming out to about 20 ft
29:15	Still no change on underside. The test was terminated at 30 min as scheduled. At that time there was still no underside flaming visible

KR:GTC:SJ

NORTH SIDE OBSERVATION OF WHITE HOUSE TEST

Time (Min:Sec)	Observation
0:00	Test start
0:20	Both burners in operation
0:45	Burning of fuel on floor at 12 ft
1:30	Burning of fuel on floor at 14 ft
4:00	Slight burning at transverse joints in steel decking at 4 ft
4:30	Burning at transverse joint in steel decking at 6 ft
5:15	Burning at transverse joint in steel decking at 10 ft
5:21	Dark gray smoke exiting from roof/wall joint from zero to 2 ft
6:00	Flames on ceiling of structure at 18 ft
6:30	Flames at roof/wall joint from zero to 10 ft
7:25	Flames on ceiling of structure at 26 ft
8:00	Flames on ceiling of structure at 30 ft
9:15	Flames on ceiling of structure at 34 ft
9:49	Flames on ceiling of structure at 38 ft
11:00	Flames on ceiling of structure at 38 to 40 ft at longitudinal butt joints in steel decking

Time (Min:Sec)	Observation
14:00	The amount of smoke being produced is not inhibiting the view of the steel decking
17:00	No apparent flaming on ceiling of structure beyond 20 ft
23:00	Igniting fire out to about 18 to 20 ft on ceiling
24:20	Popping and cracking sounds from interior at 16 ft mark
28:00	Igniting fire out to about 16 to 20 ft on ceiling. No apparent flaming on steel decking
29:00	Same comments as at 28 min
30:00	Test extinguished

KR:GTC:SJ

FLUE END OBSERVATION OF WHITE HOUSE TEST

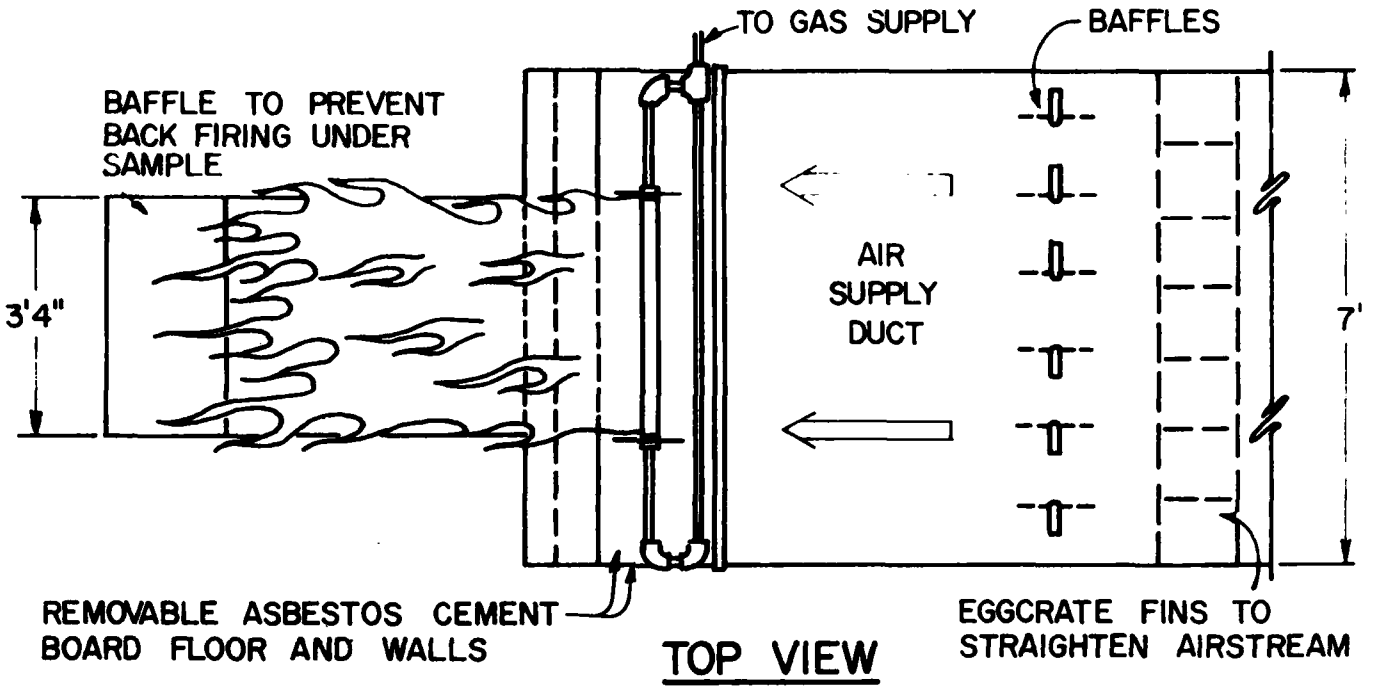
Time (Min:Sec)	Observations
0:47	Heptane flaming on floor
1:39	Ignition rising flame 1 to 2 ft above the burner port
2:30	The north burner is impinging on ceiling
3:32	North burner appears to be producing larger flame than south burner
3:51	Underdeck ignition (north side)
4:40	Smoke density increasing near ceiling
4:45	Flaming from deck on north side spreading across width of structure
5:56	Dense smoke stratified downward from ceiling 3 to 4 ft
7:09	Smoke is building within structure
7:28	Odor of burning urethane can be detected
8:15	The only visible flaming is from the ignition source due to density of smoke
9:51	Flaming of the deck has spread to far east side of structure
10:22	Flaming has been reported to be at 38 ft mark
11:59	Smoke has cleared such that the ceiling can be easily seen the full length of structure. There is still flickering flames from the deck near the first I-beam (nominal 20 ft outward).

Time (Min:Sec)	Observations
12:42	The deck appears to be flaming only at points located near the first beam (nominal 20 ft outward). This is isolated flickers of flaming
13:30	The flickers of flaming continue near first beam (nominal 20 ft outward). The ignition flames from the burners appear to be of equal intensity
14:08	Flickers of underdeck flaming can be seen along the longitudinal channel members on the north side
14:38	The intermittent flickers of underdeck flaming continues along the longitudinal channel members on the north side
15:55	The smoke density is increasing again
17:00	Color of flaming has changed to a dark orange, impinging on the ceiling. No underdeck flaming can be seen
18:00	Ignition flames are now bright orange. No observed underdeck flaming
20:00	Same
21:00	Same
22:50	The ignition flames are still bright orange. The center longitudinal channel can be seen warping eastward

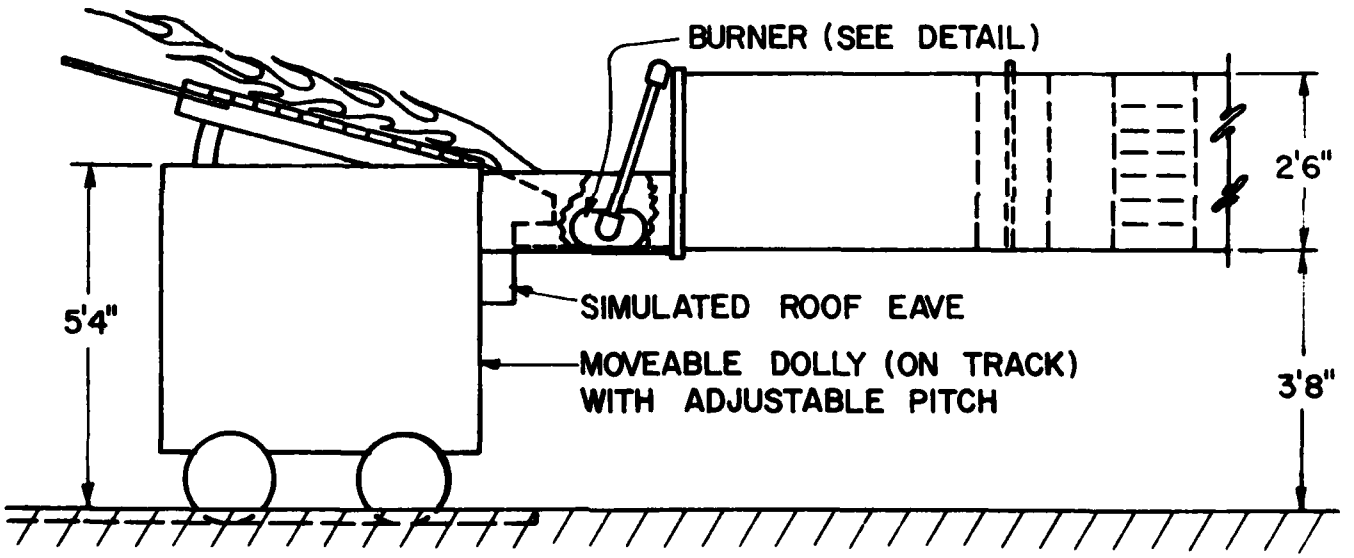
Time (Min:Sec)	Observations
23:00	The longitudinal channel adjacent and north of the center channel can be seen warping northward
23:40	Large amounts of dark smoke appear to be coming from north side of structure (area under direct flame impingement from north ignition burner). The flaming from the interior of the structure seems hotter with more smoke emission
25:30	Flaming from the burners is dark orange in color. Smoke emission on north side is greater than south side
26:32	Flaming from north burner appears to be more intense than south burner. The center longitudinal channel is warped southward
27:40	A loud noise and vibration was heard inside the structure
28:47	Flaming from north burner appears more intense than south burner. Smoke emission from north side greater than south side of structure
30:00	Burners extinguished and sprinkler system was activated

KR:GTC:SJ

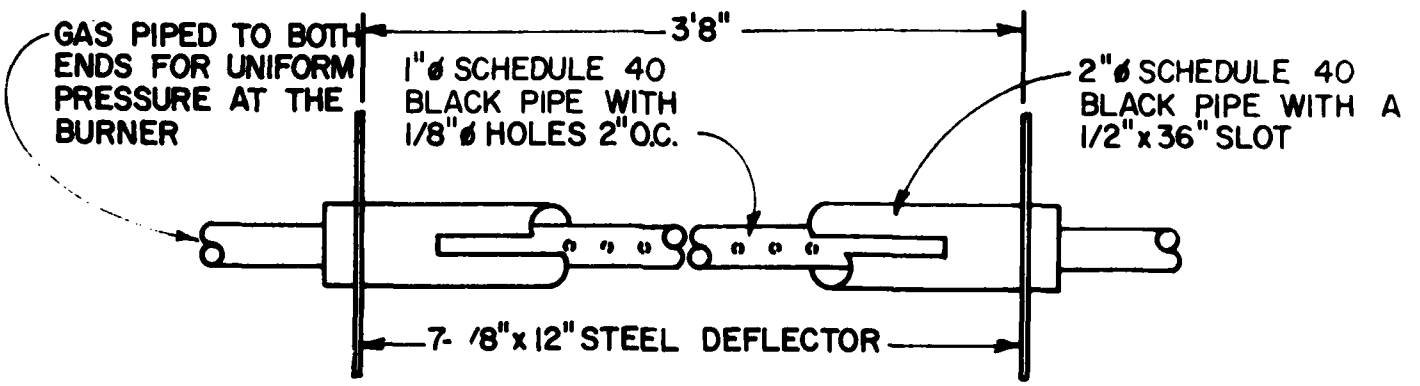
ROOFING TEST APPARATUS - SCHEMATIC



TOP VIEW



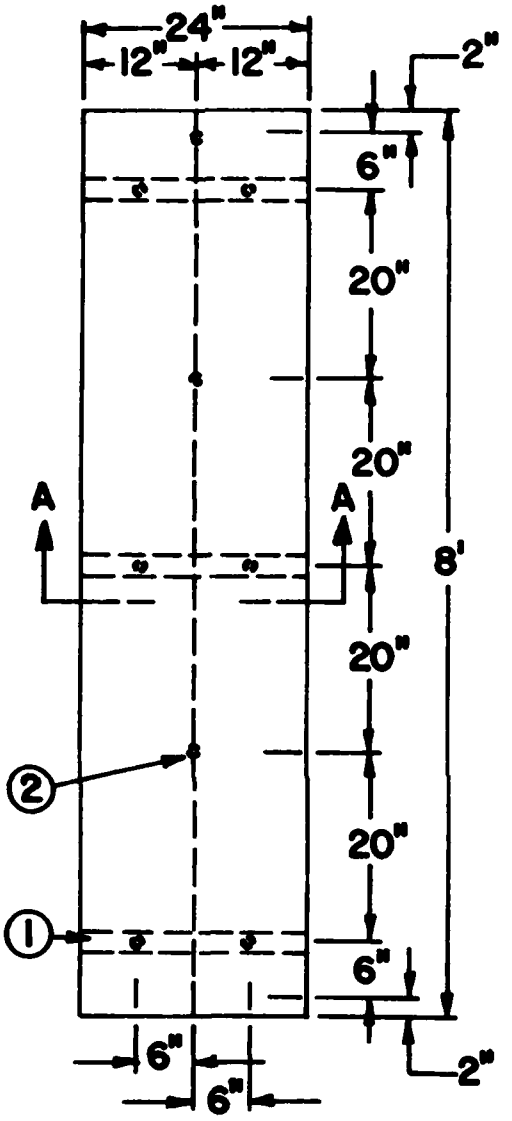
PLAN VIEW



BURNER DETAIL

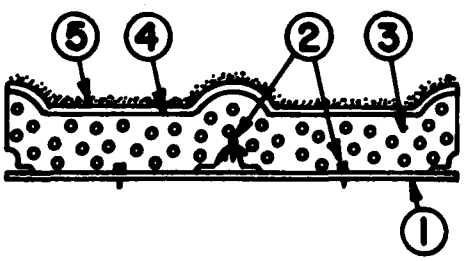
ILL.1
USNC77

TUNNEL TEST SAMPLES

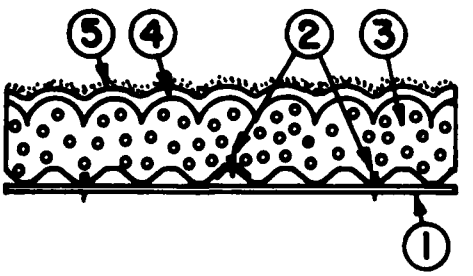


① 2-1/2" WIDE, 14 GA. STL. BAR
② NO. 1/4-14x1-1/4" TEKS/3
③ 3" SPRAY-APPLIED FOAM
④ FLUID-APPLIED COATING
⑤ NO. 11 ROOFING GRANULES

ILL. 2
USNC77

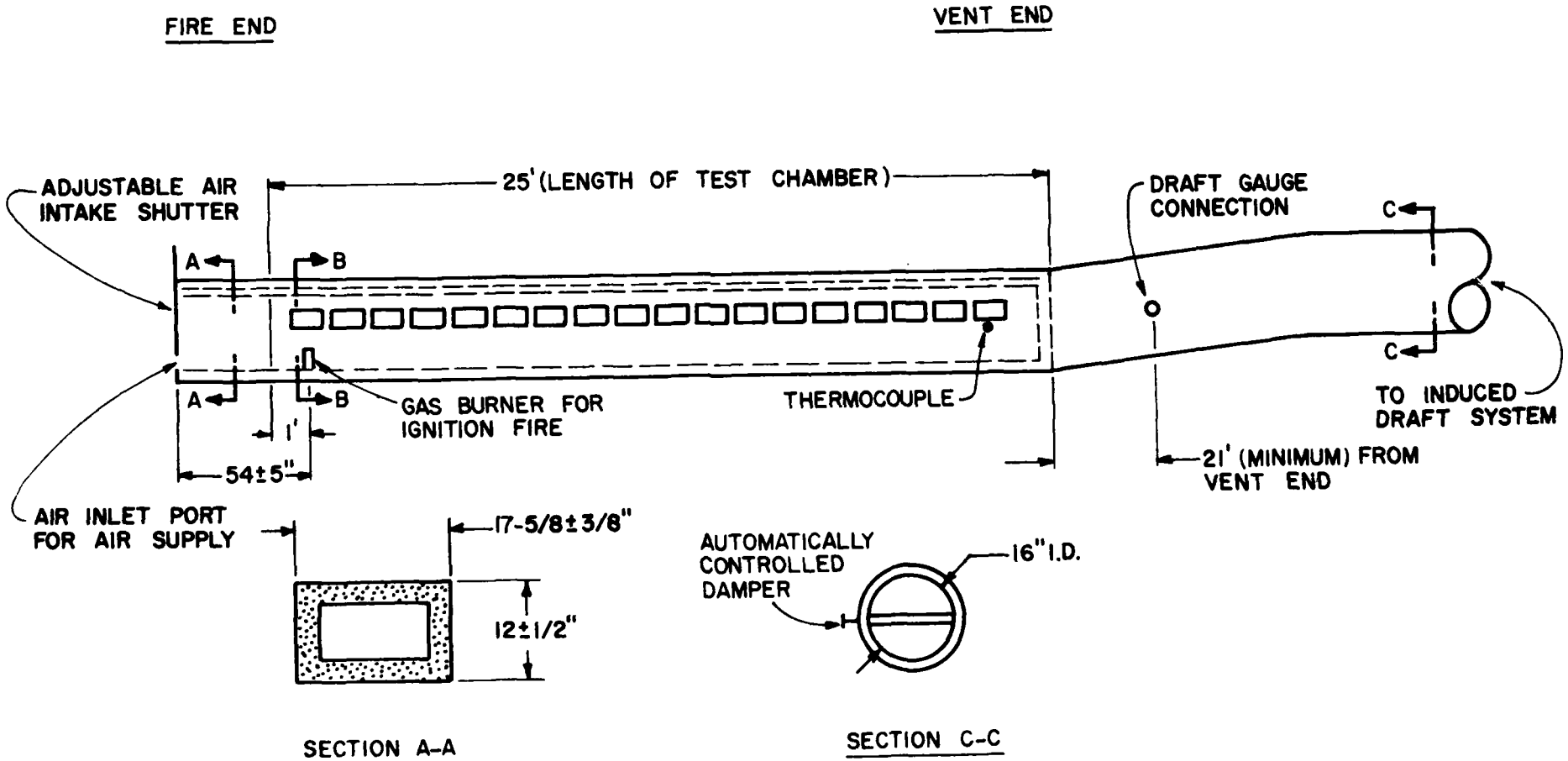


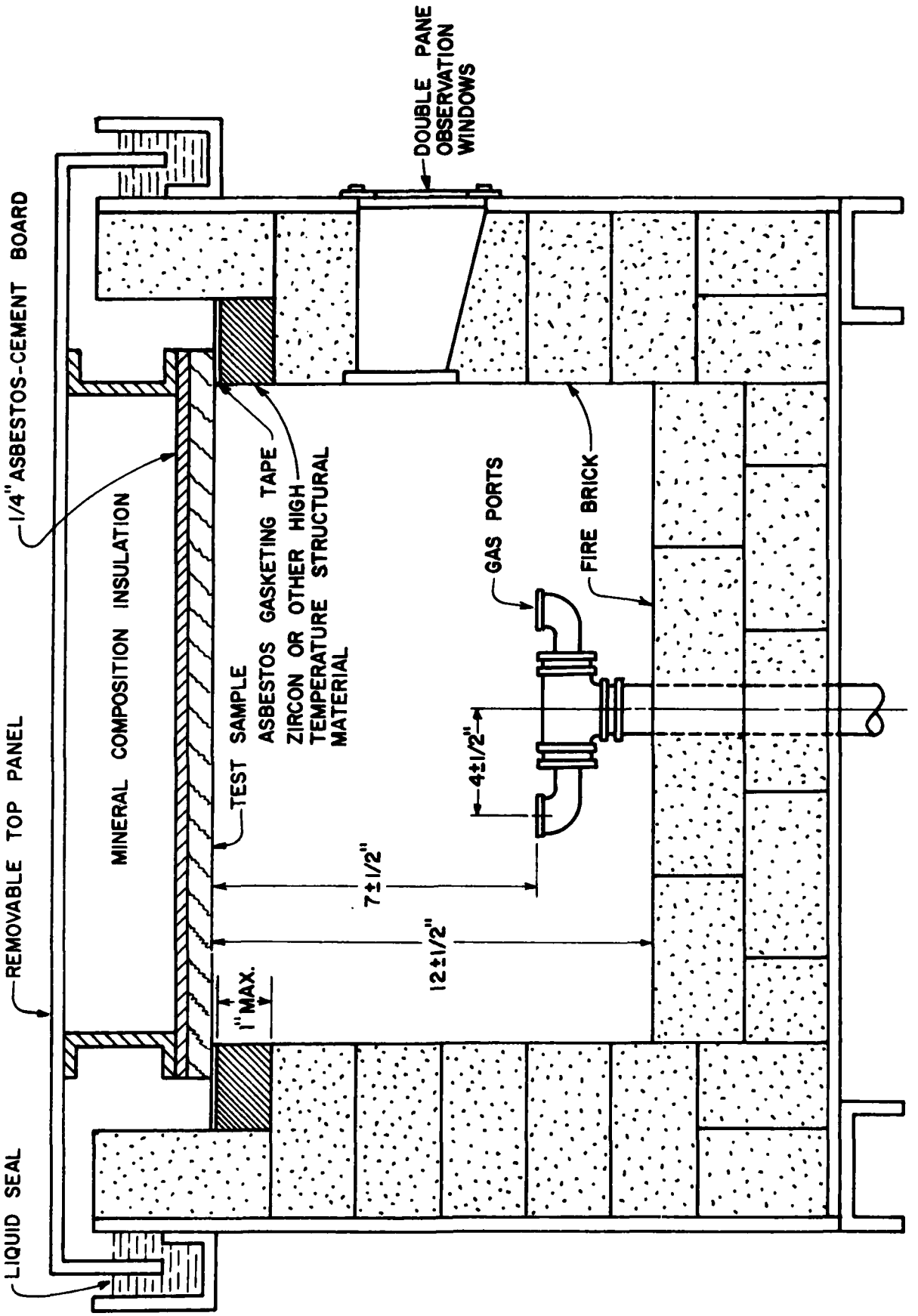
SECTION A-A
(RIB PANELS)



SECTION A-A
(9/16" CORRUGATED DECK)

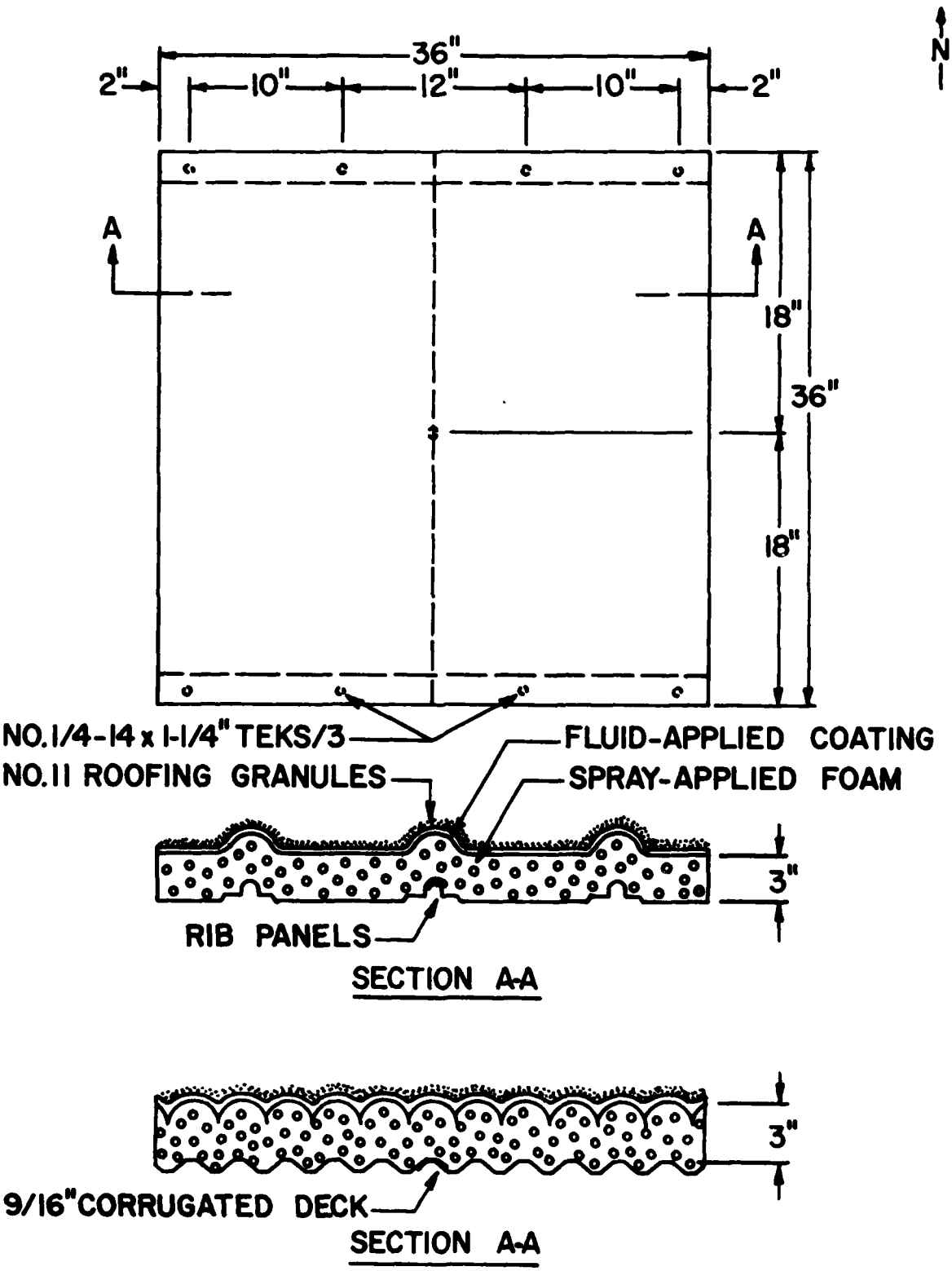
DETAILS OF TEST FURNACE




SECTION B-B
DOUBLE PANE OBSERVATION WINDOWS
1/4" ASBESTOS-CEMENT BOARD
MINERAL COMPOSITION INSULATION
REMOVABLE TOP PANEL
LIQUID SEAL
TEST SAMPLE
ASBESTOS GASKETING TAPE
ZIRCON OR OTHER HIGH TEMPERATURE STRUCTURAL MATERIAL
GAS PORTS
FIRE BRICK
4±1/2"
7±1/2"
12±1/2"
1" MAX.

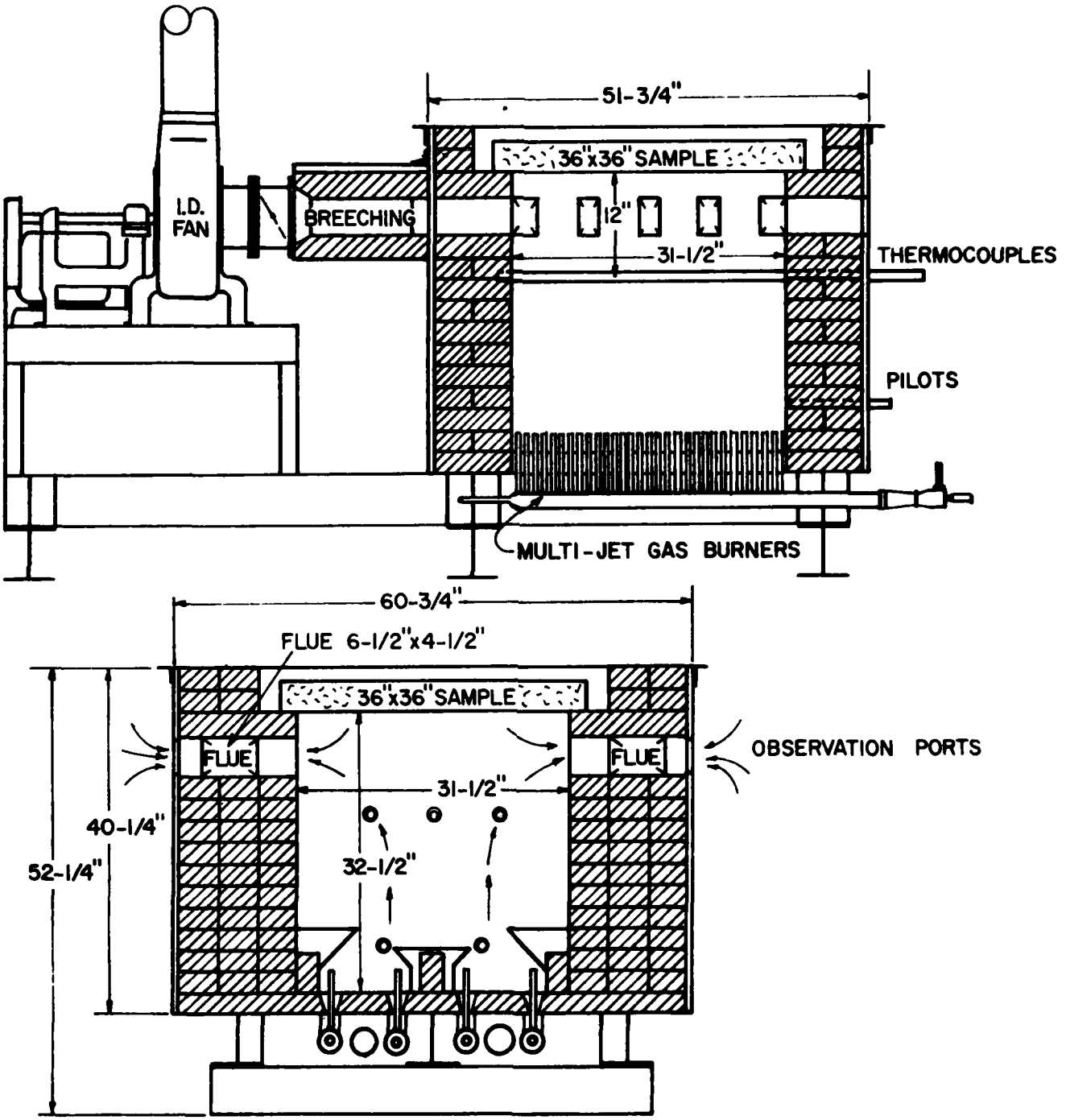
ILL.4
USNC77

SMALL SCALE FIRE TEST SAMPLES

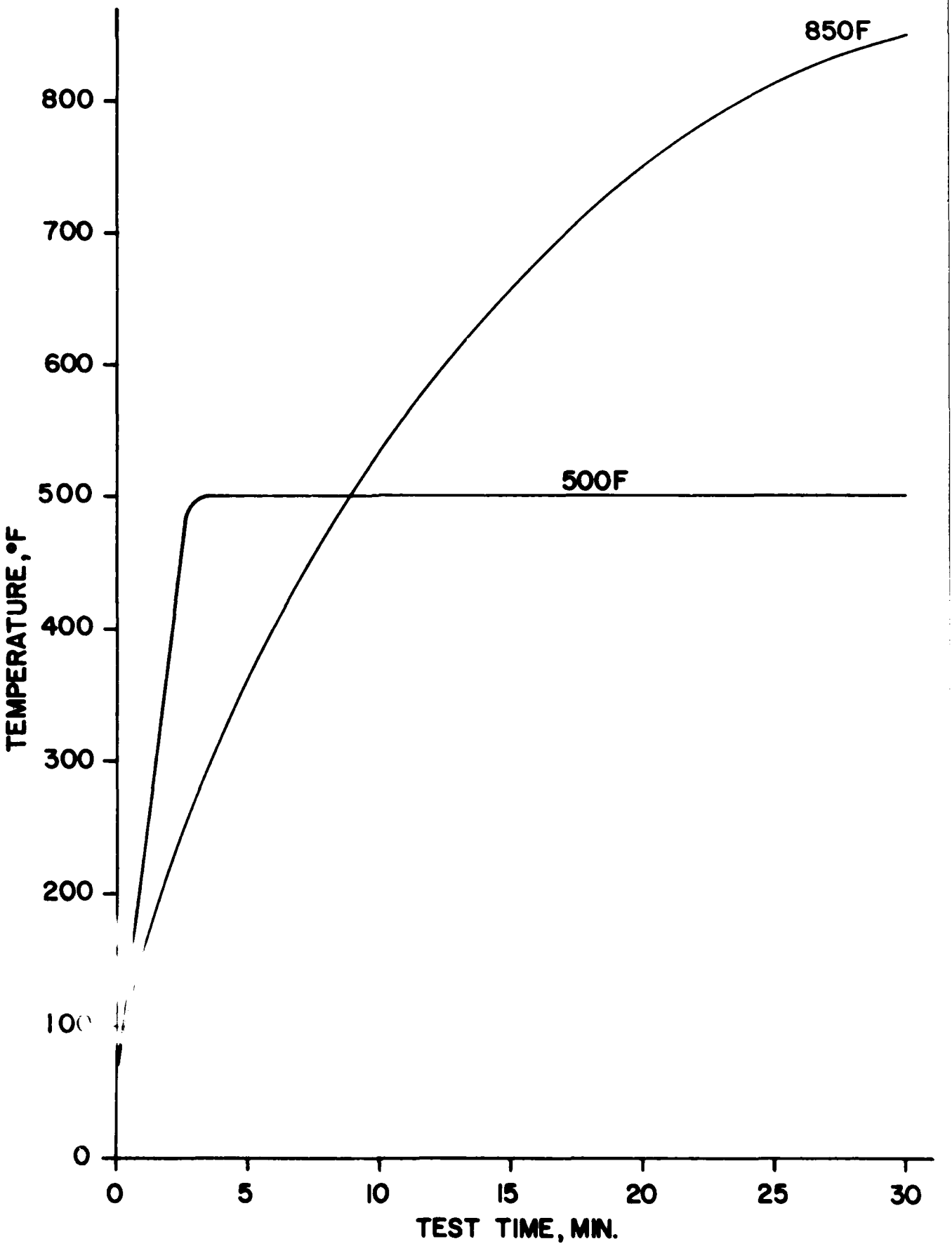


ILL.5
USNC77

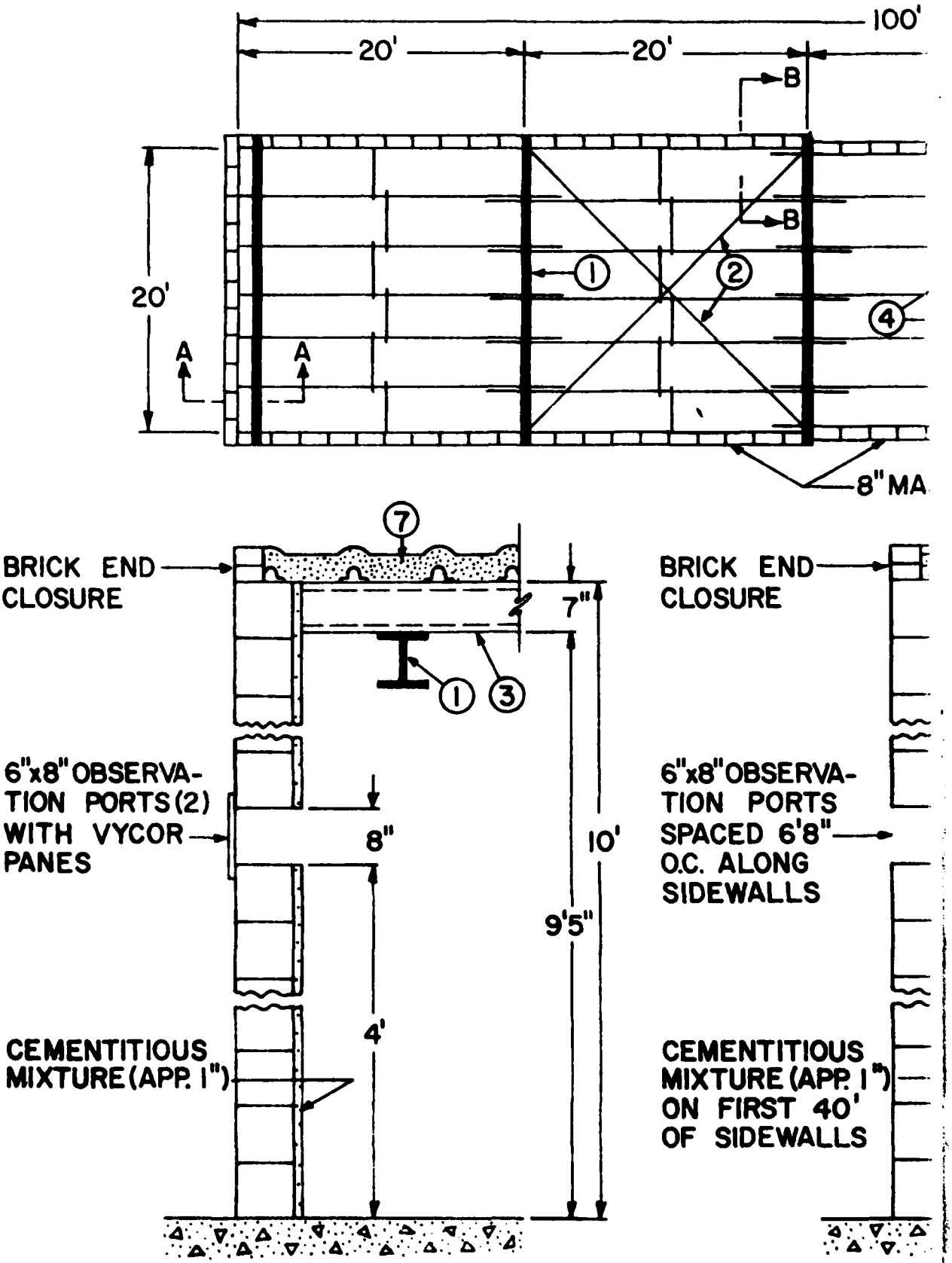
SMALL SCALE HORIZONTAL EXPOSURE FURNACE



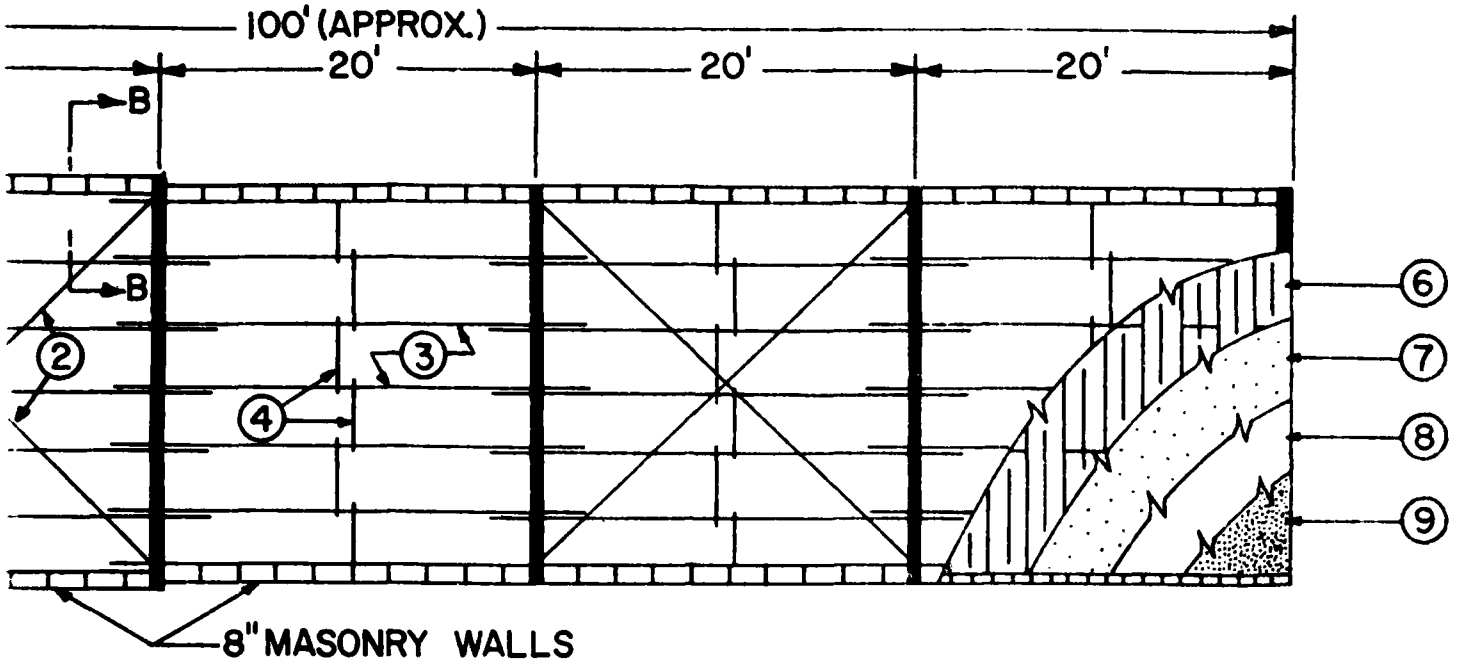
ILL.6
USNC77

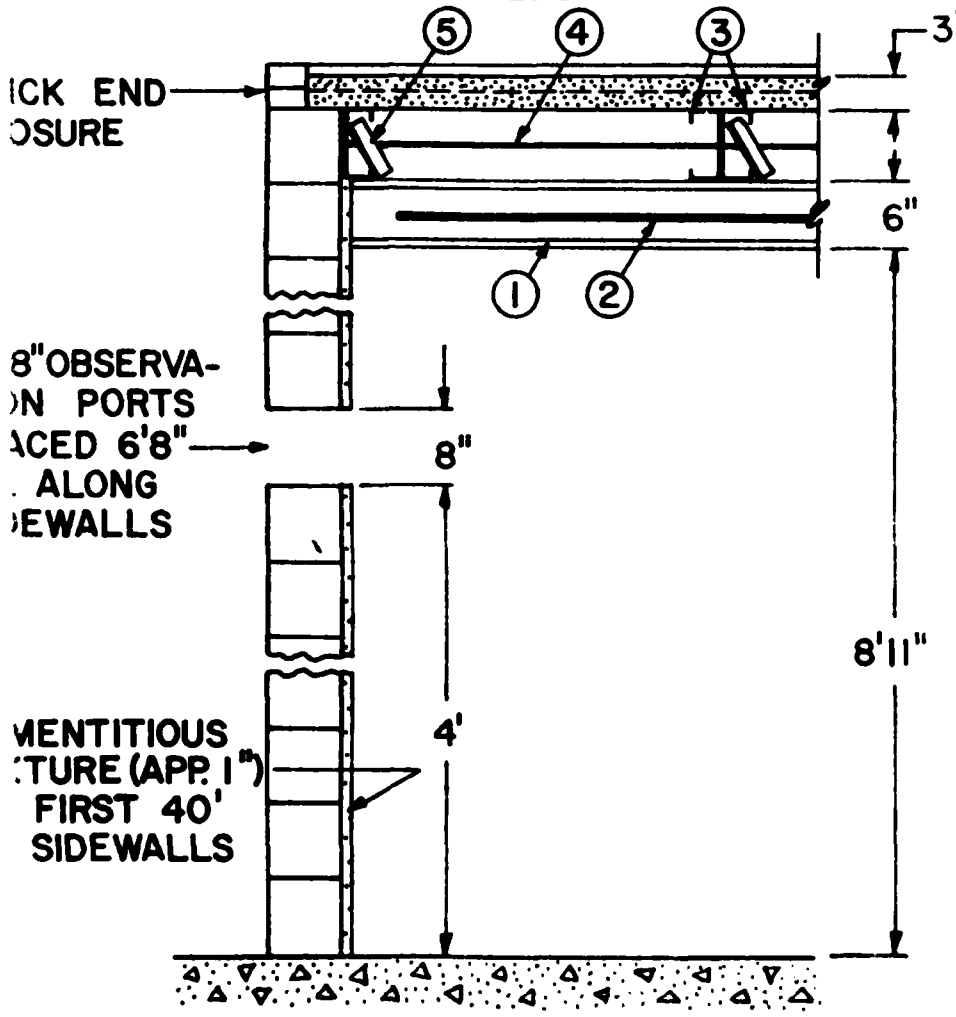

850F
500F
800
700
600
500
400
300
200
100
0
TEMPERATURE, °F
0
5
10
15
20
25
30
TEST TIME, MIN.

ILL. 7
USNC77


100'
20'
20'
B
B
20'
A
A
1
2
4
8" MA
7
BRICK END CLOSURE
7"
1
3
6"x8" OBSERVATION PORTS (2) WITH VYCOR PANES
8"
10'
9'5"
4'
CEMENTITIOUS MIXTURE (APP. 1")
BRICK END CLOSURE
6"x8" OBSERVATION PORTS SPACED 6'8" O.C. ALONG SIDEWALLS
CEMENTITIOUS MIXTURE (APP. 1") ON FIRST 40' OF SIDEWALLS

SECTION A-A





ICK END
OSURE

8"OBSERVA-
)N PORTS
ACED 6'8"
. ALONG
)EWALLS

MENTITIOUS
:TURE (APP. 1")
FIRST 40'
SIDEWALLS

① W6X16 STEEL BEAM

② 1/2"Ø STEEL ROD WITH

③ 7" DEEP, 14 GA. STEEL C
PURLINS, 24'11-1/4" LONG,

④ 3/8"Ø STEEL BRIDGING

⑤ 1-1/2"x1-1/2"x1/8"x6" LONG
WELDED TO BEAM AND

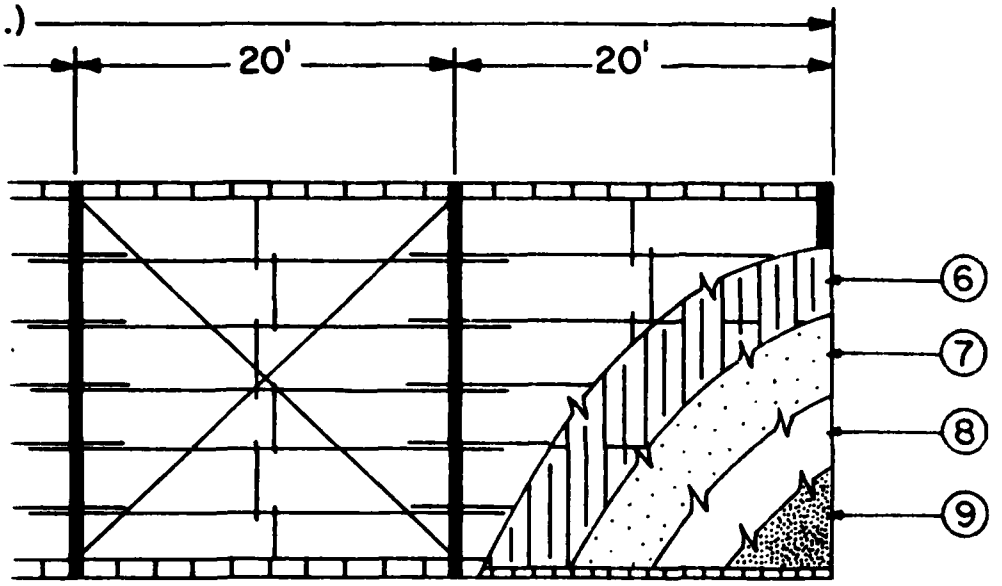
⑥ RIB METAL ROOF DECK
GALV. STEEL, 24" WIDE

⑦ SPRAY-APPLIED FOAM, 3

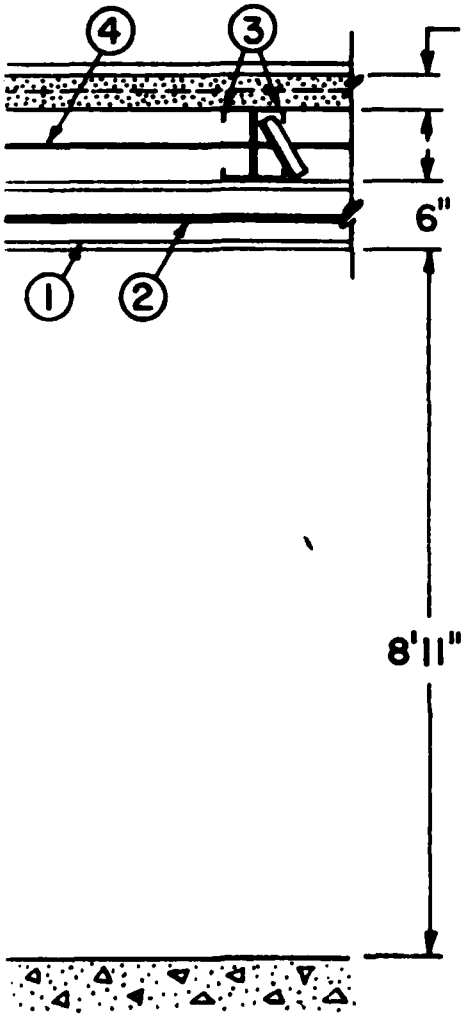
⑧ FLUID-APPLIED COATING,
APPLIED AT A RATE O
SQ FT FOR EACH COAT

⑨ NO. 11 ROOFING GRANUL
A RATE OF 50 LB/100

SECTION B-B



/ALLS



1—W6X16 STEEL BEAM

2—1/2"Ø STEEL ROD WITH TURNBUCKLES

3—7" DEEP, 14 GA. STEEL CHANNEL-SHAPED PURLINS, 24'11-1/4" LONG, SPACED 40" O.C.

4—3/8"Ø STEEL BRIDGING RODS

5—1-1/2"x1-1/2"x1/8"x6" LONG STEEL ANGLE, WELDED TO BEAM AND PURLIN (7/BEAM)

6—RIB METAL ROOF DECK PANELS, 26 GA. GALV. STEEL, 24" WIDE

7—SPRAY-APPLIED FOAM, 3" THICK

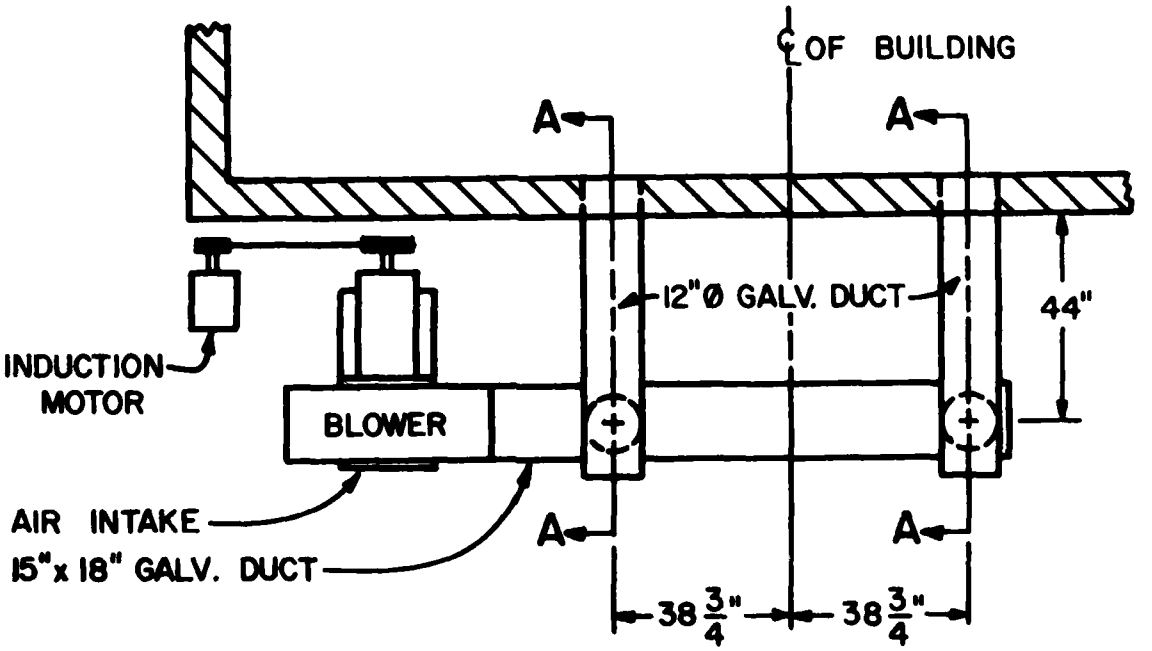
8—FLUID-APPLIED COATING, TWO COATS APPLIED AT A RATE OF 1.5 GAL/100 SQ FT FOR EACH COAT

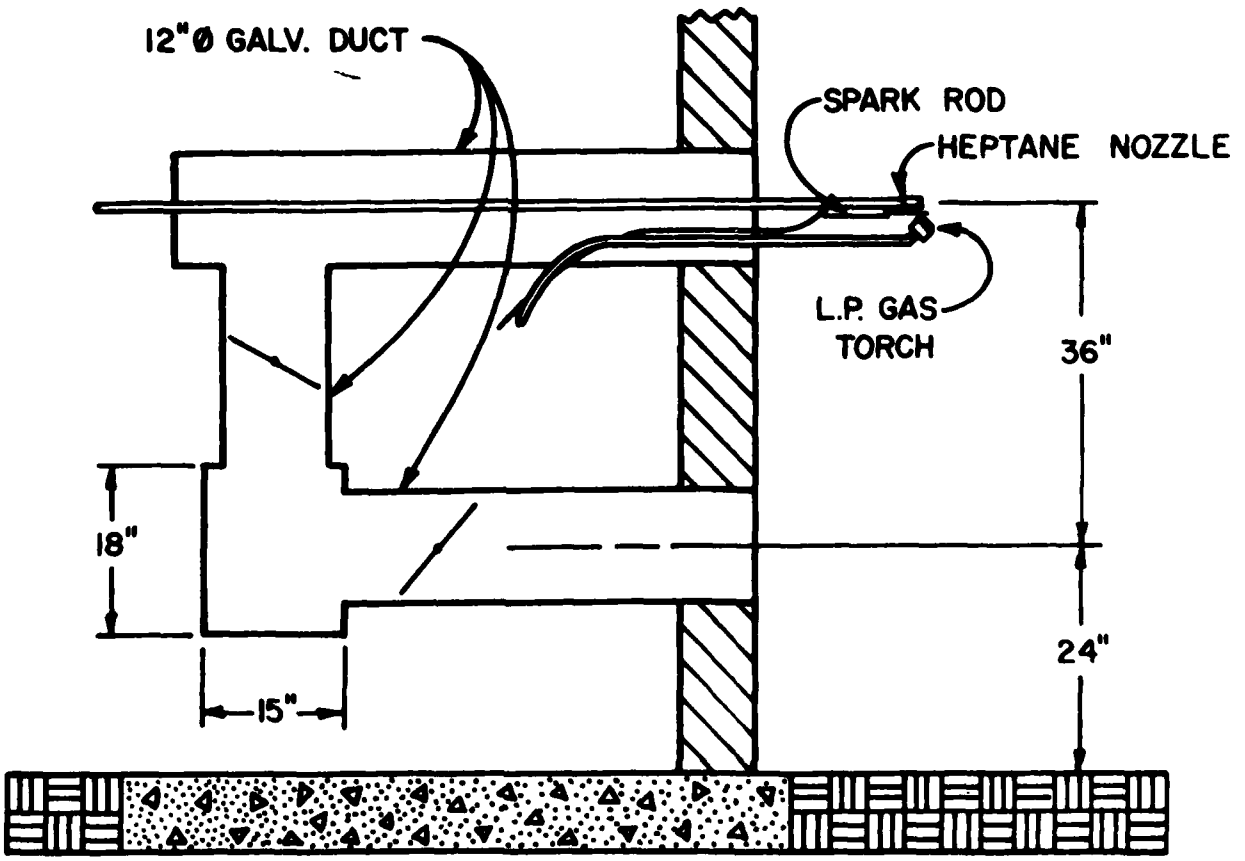
9—NO. 11 ROOFING GRANULES APPLIED AT A RATE OF 50 LB/100 SQ FT

ECTION B-B

ILL.8
USNC77

BLOWER AND IGNITION DETAILS

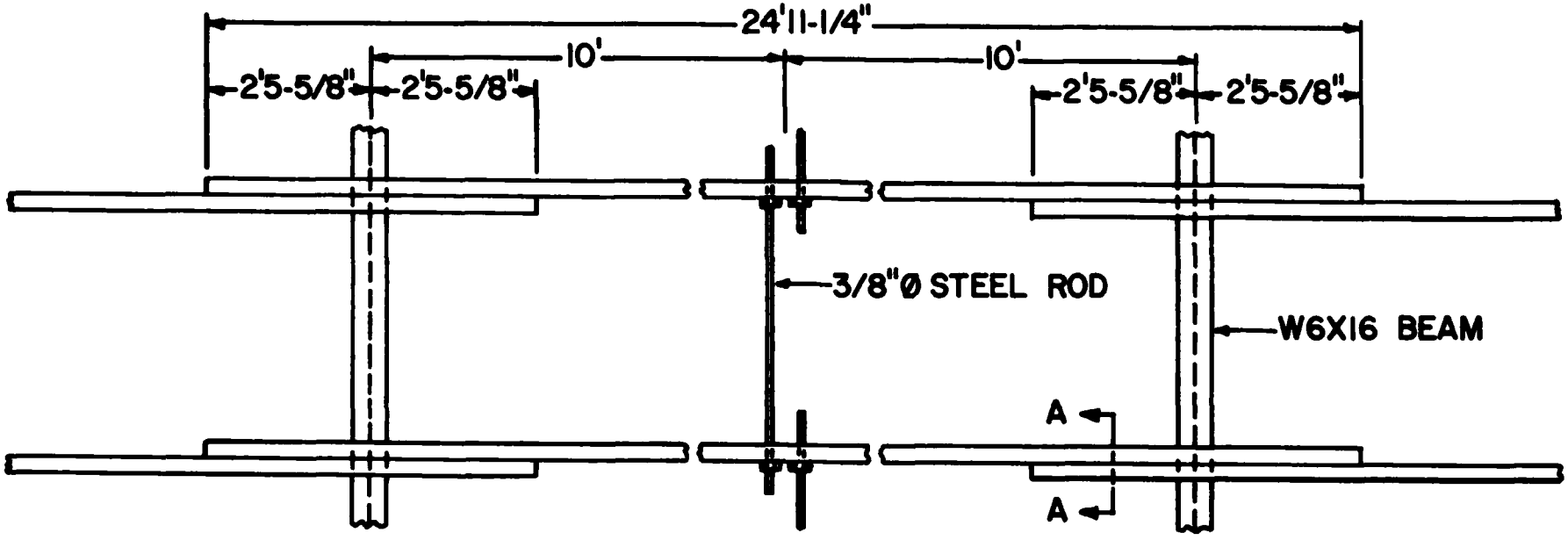


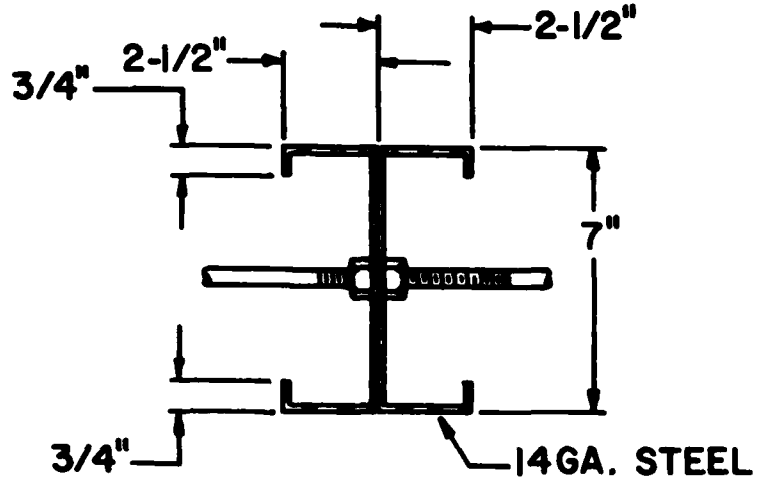


SECTION A-A

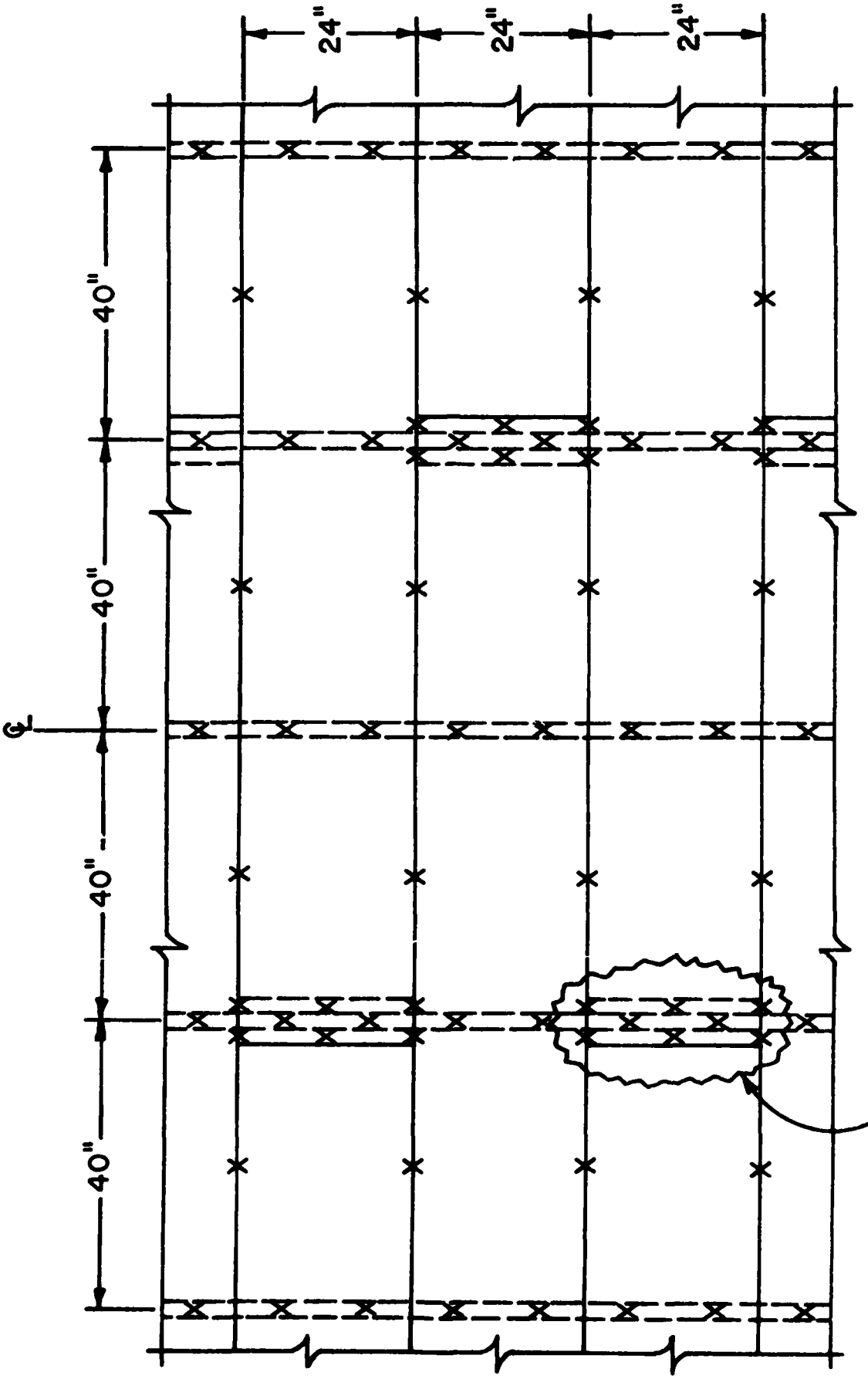
A-77

ILL.9
USNC77


24'11-1/4"
10'
10'
2'5-5/8"
2'5-5/8"
2'5-5/8"
2'5-5/8"
3/8"Ø STEEL ROD
W6X16 BEAM
A
A

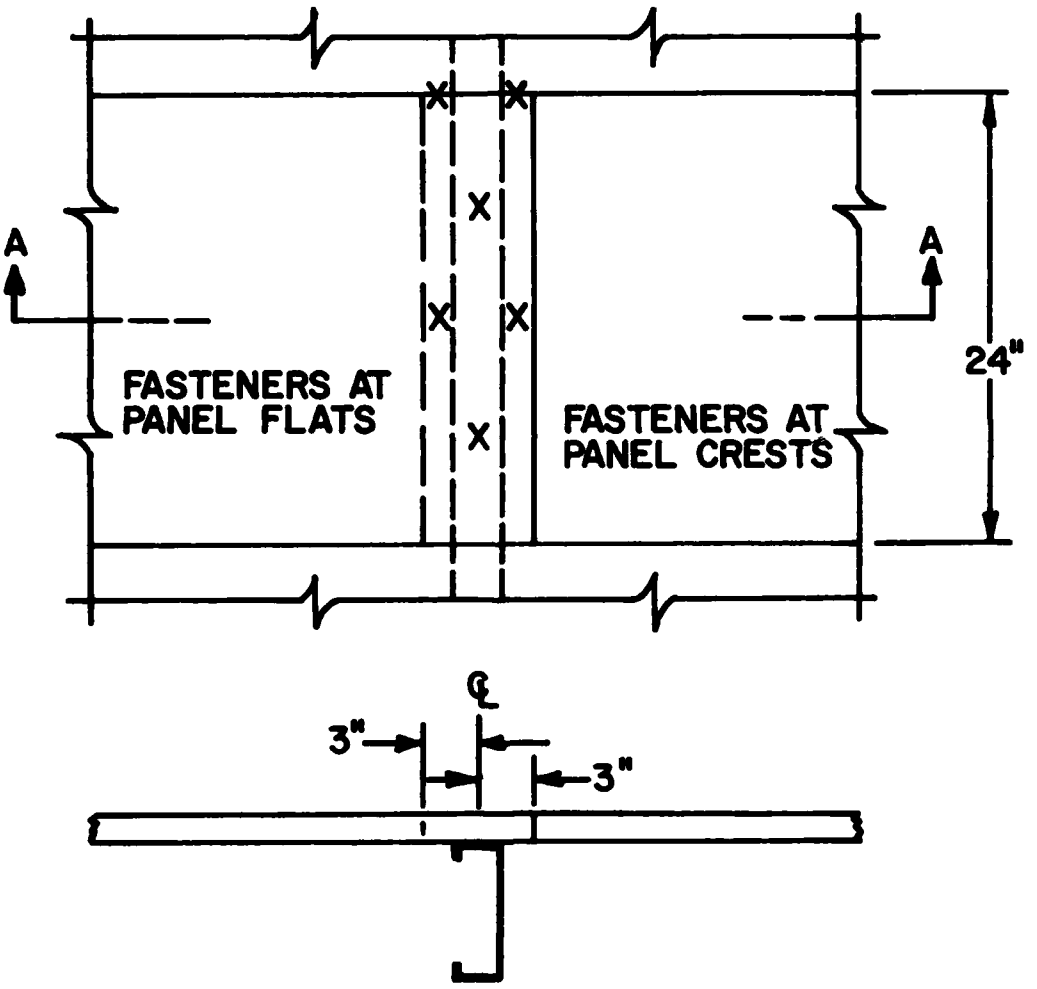

2-1/2"
2-1/2"
3/4"
7"
3/4"
14GA. STEEL

SECTION A-A



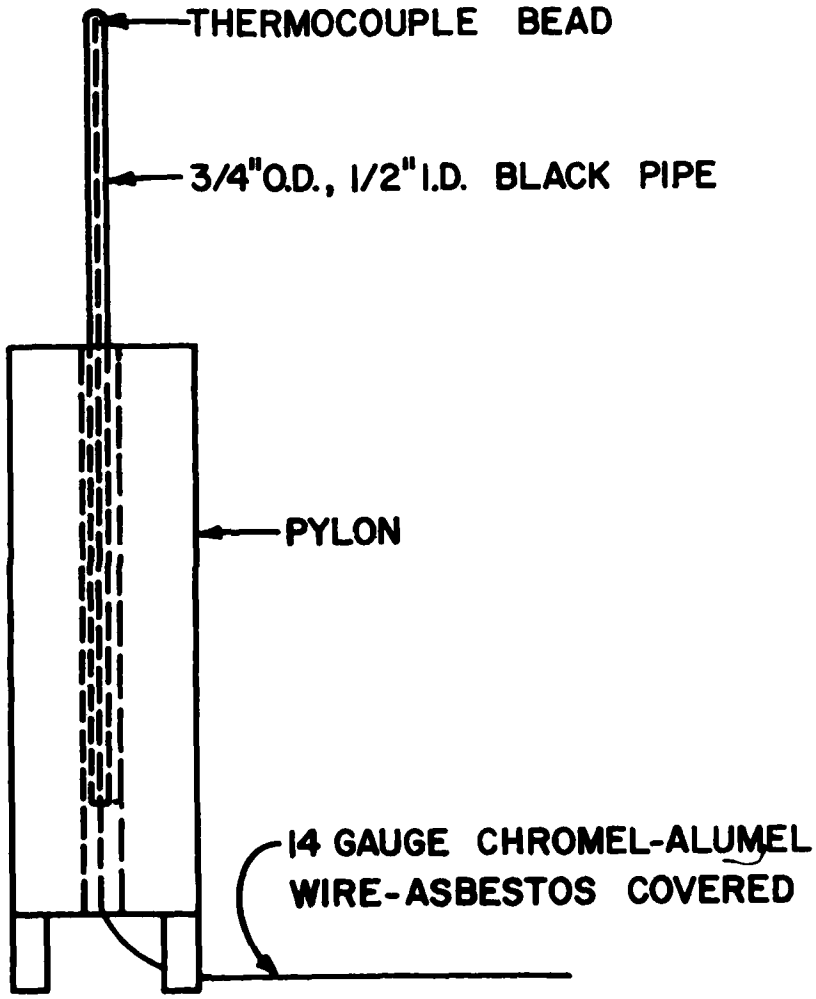
ILL.11
USNC77

DETAIL A



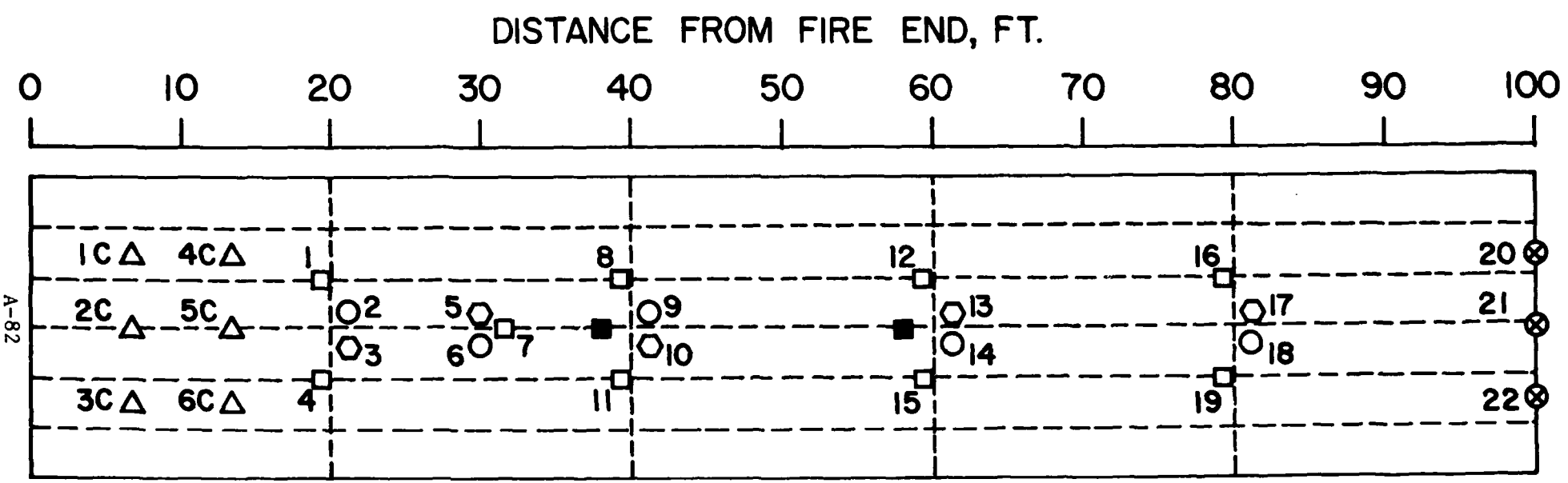
SECTION A-A

ILL.12
USNC77



ILL.13
USNC77

THERMOCOUPLE & CALORIMETER LOCATIONS



A-82

THERMOCOUPLE KEY

■ CALORIMETER

△ FIRE CONTROL (NOS. 1C-6C)

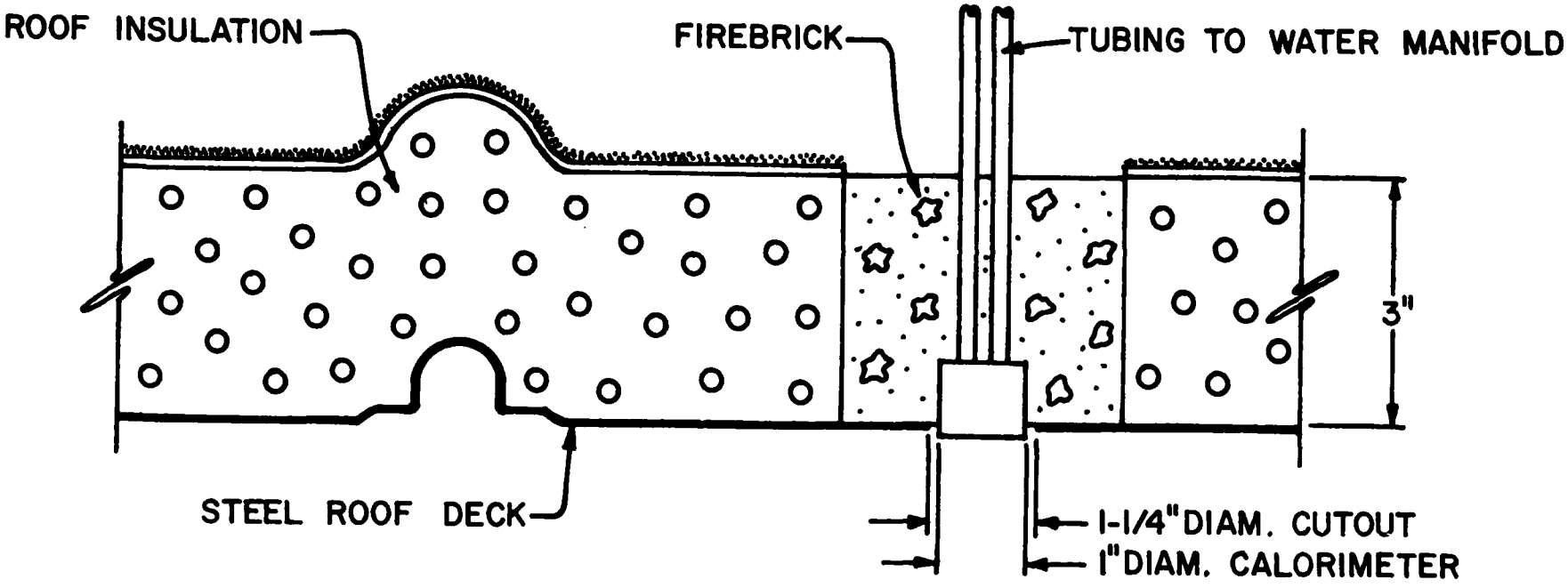
□ IN AIR 2" BELOW PURLIN (NOS. 1,4,8,11,12,15,16,19)

○ TOP OF STEEL ROOF DECK (NOS. 2,6,9,14,18)

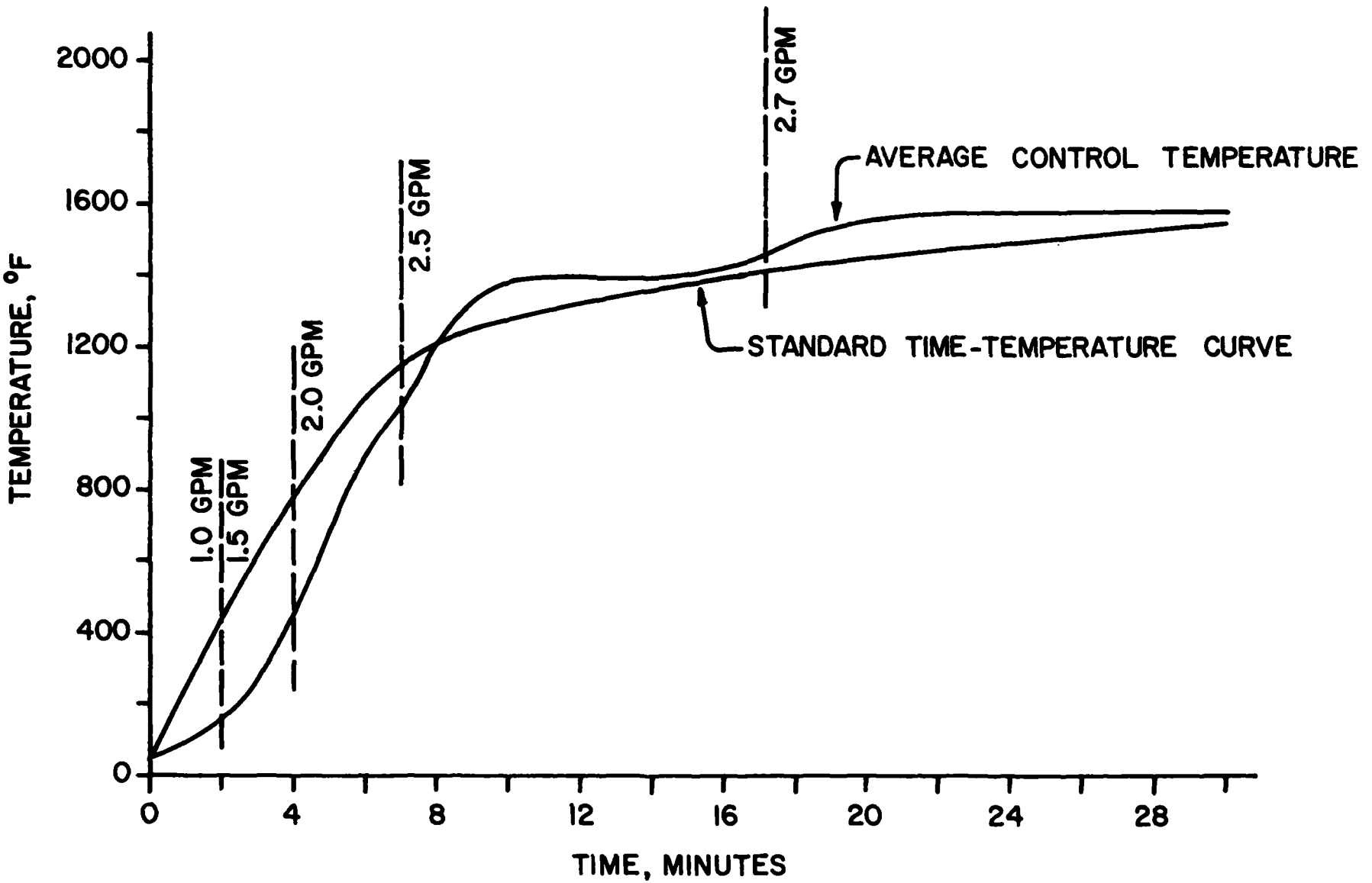
⬡ TOP OF ROOF DECK ASSEMBLY (NOS. 3,5,10,13,17)

⊗ IN AIR 3' BELOW STEEL ROOF DECK (NOS. 20,21,22)

ILL. 14
USNC77



CALORIMETER DETAIL



ILL.16
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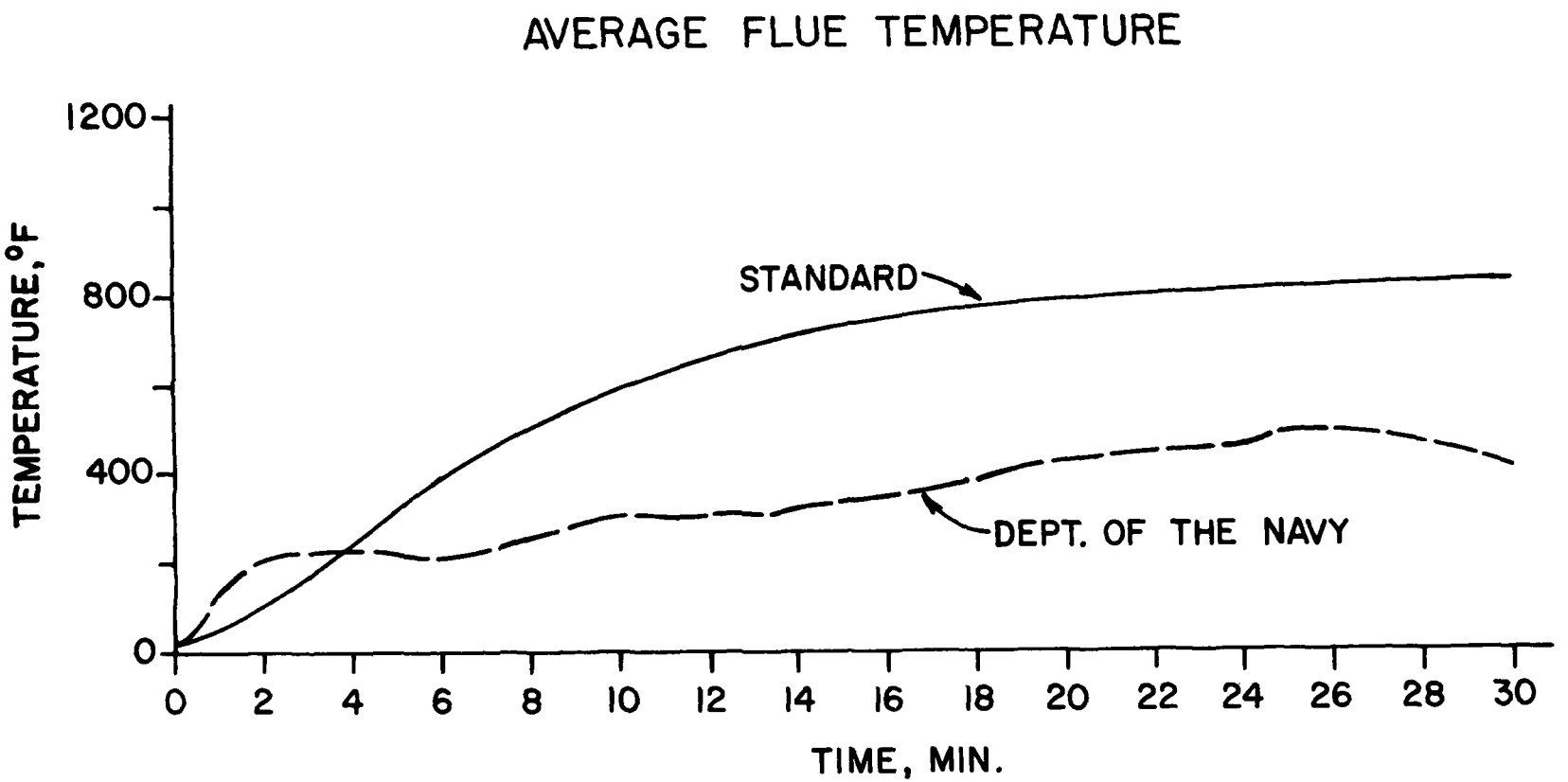
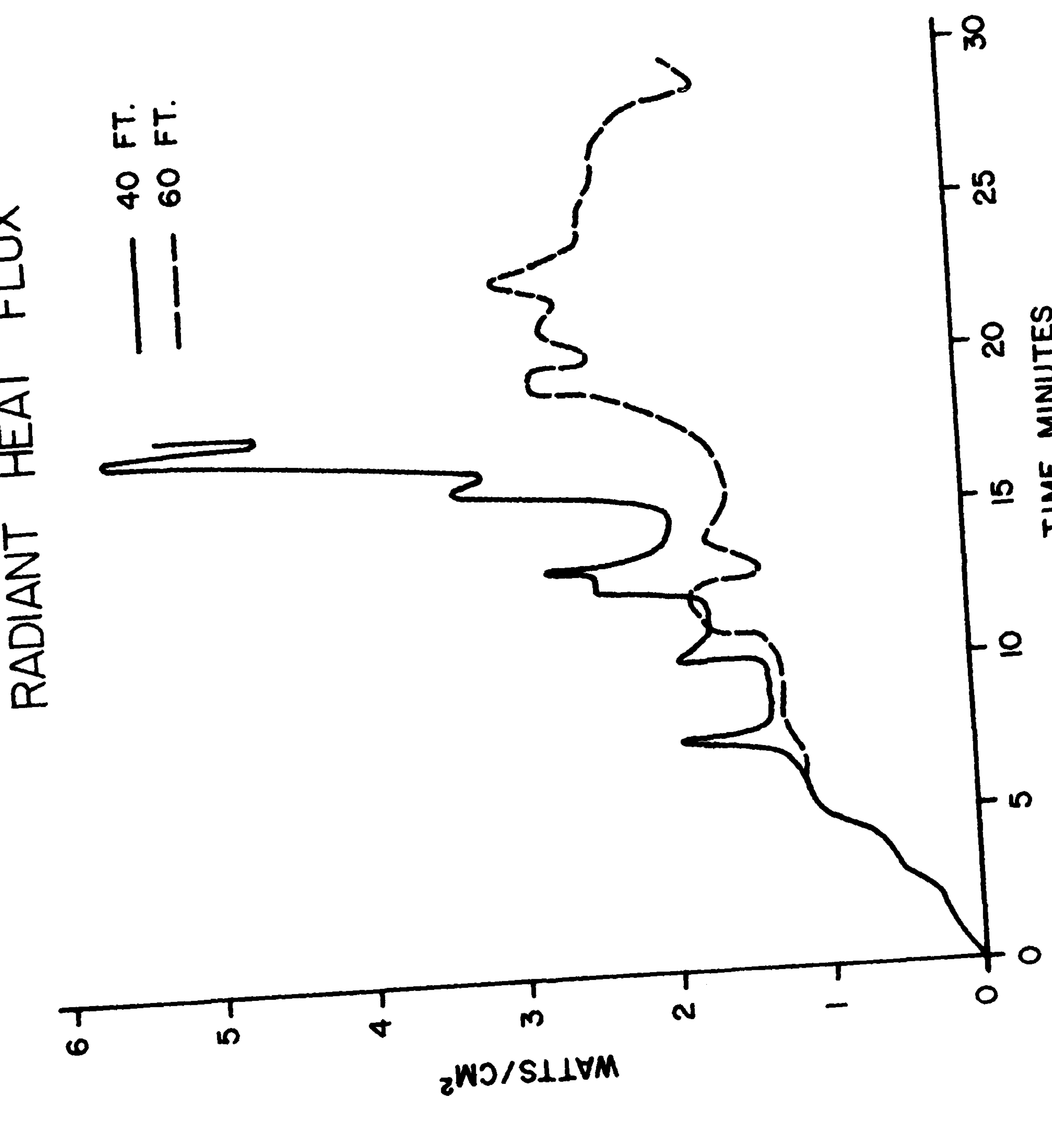
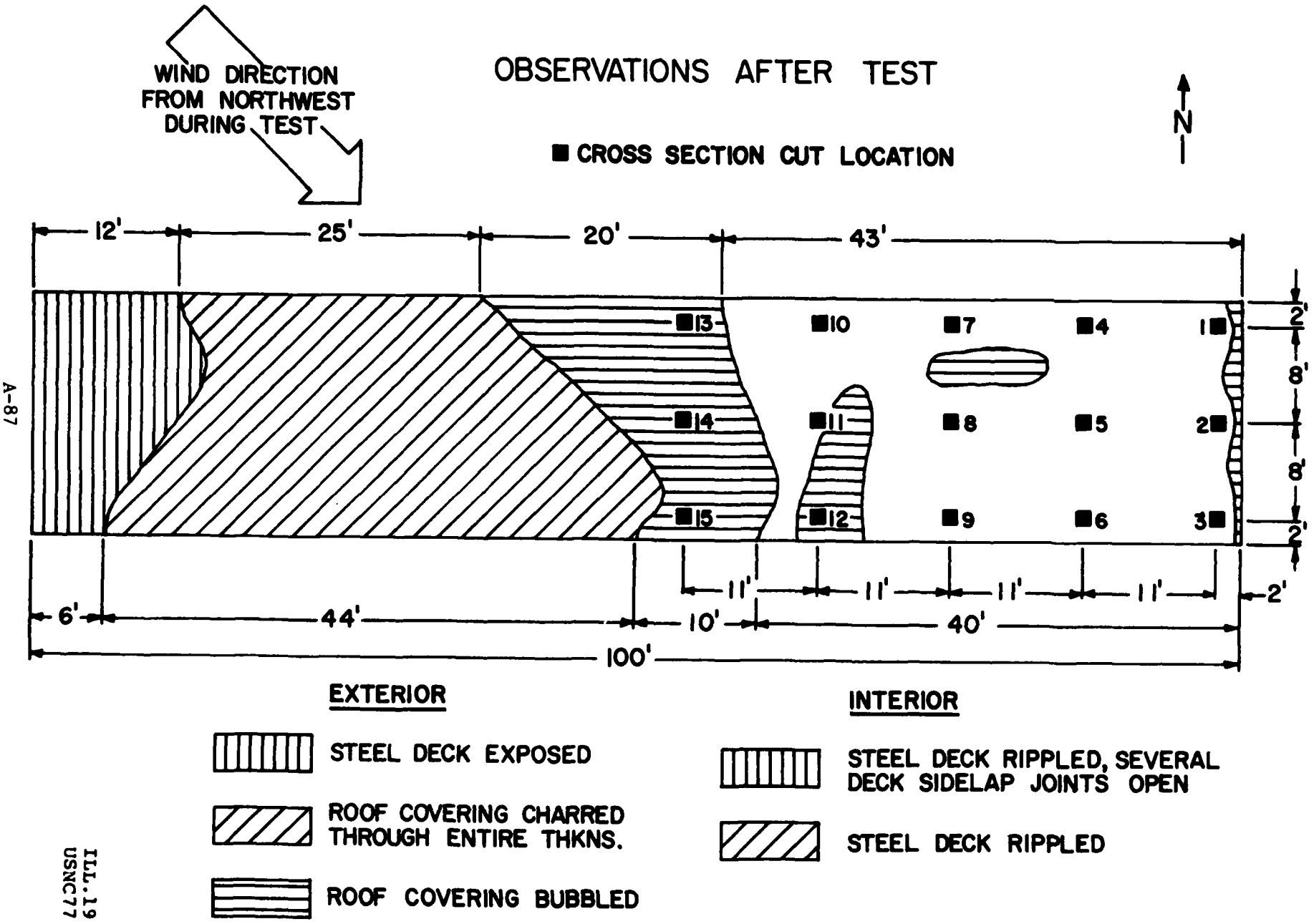


ILL.17
USNC77



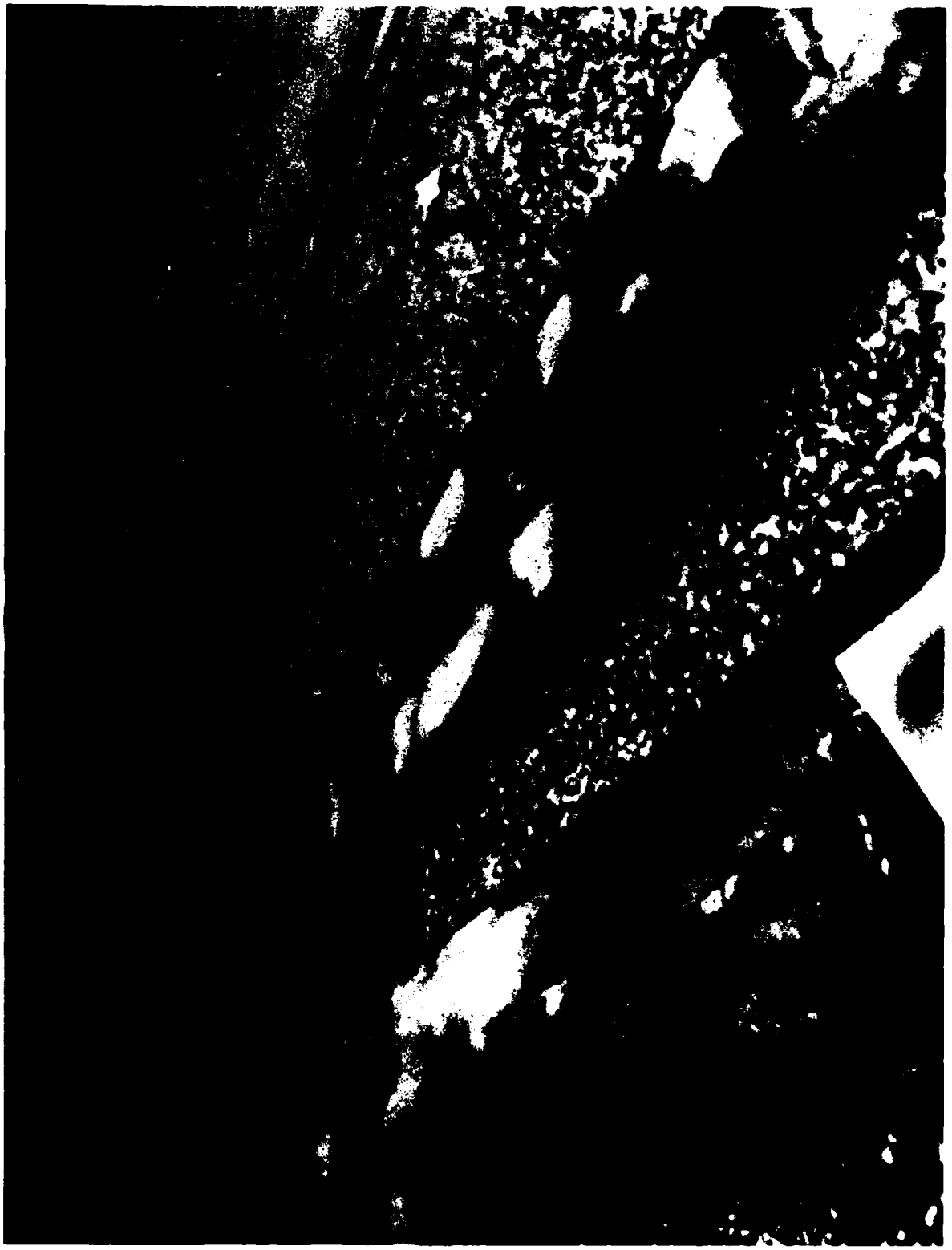
ILL.18
USNC77

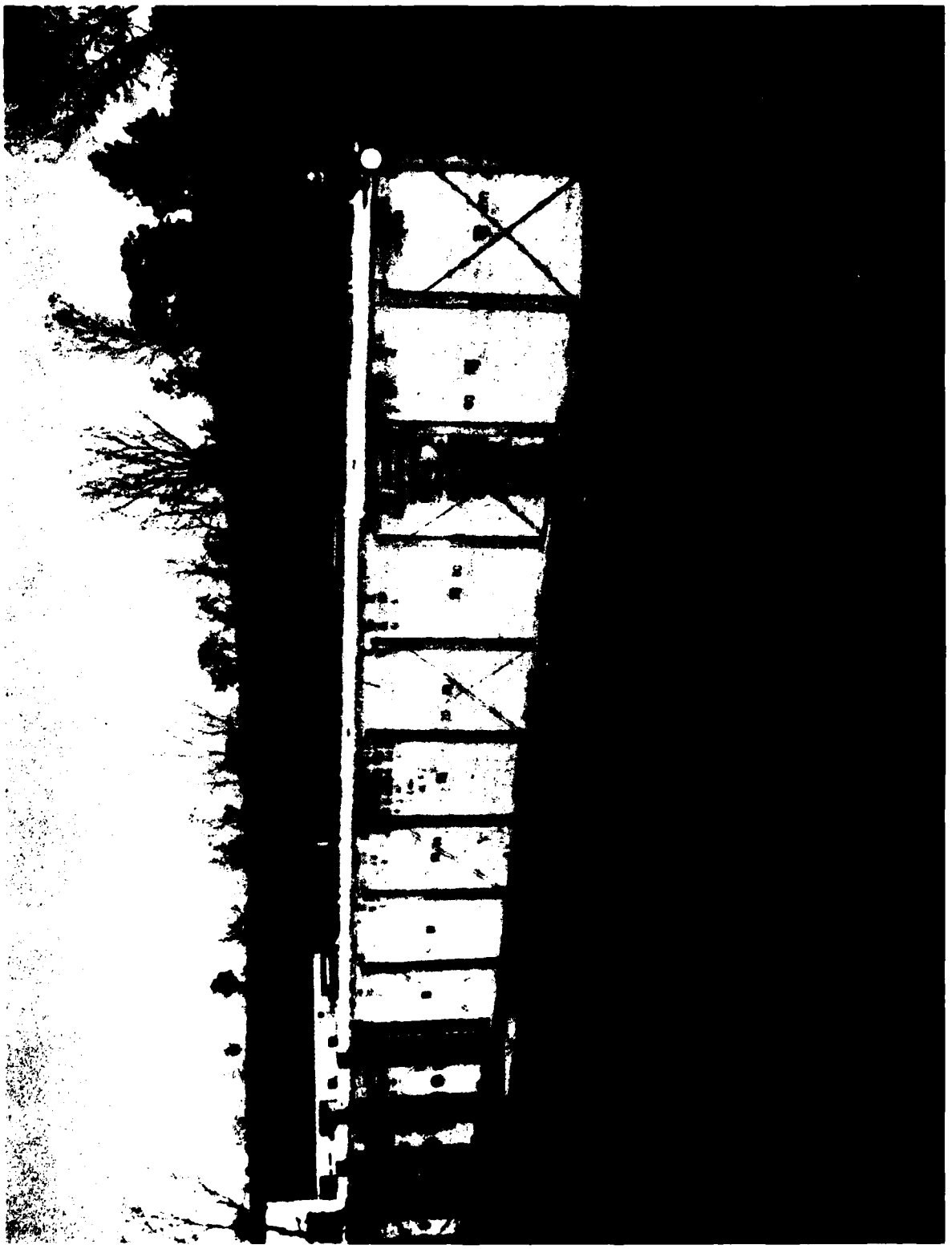


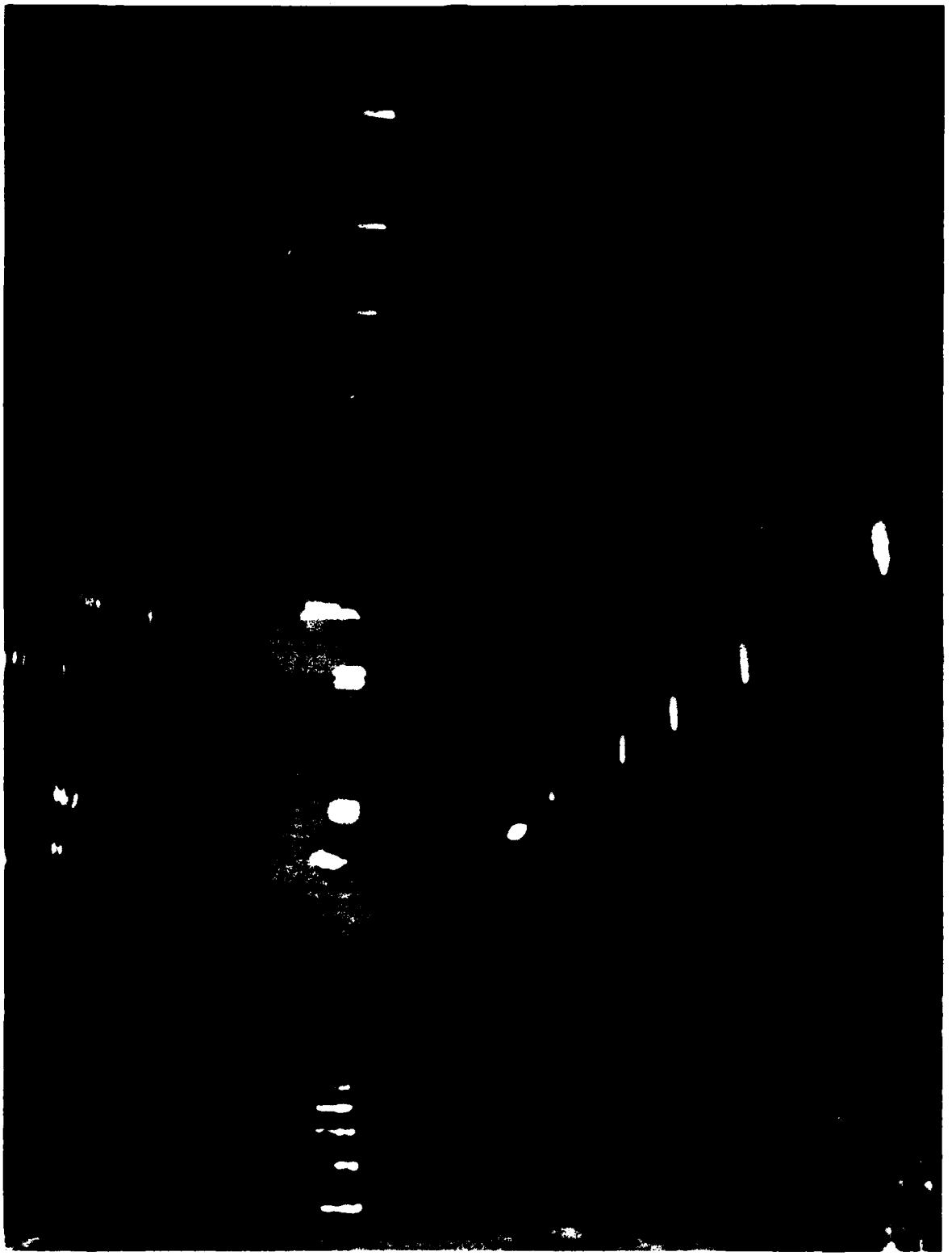
A-87

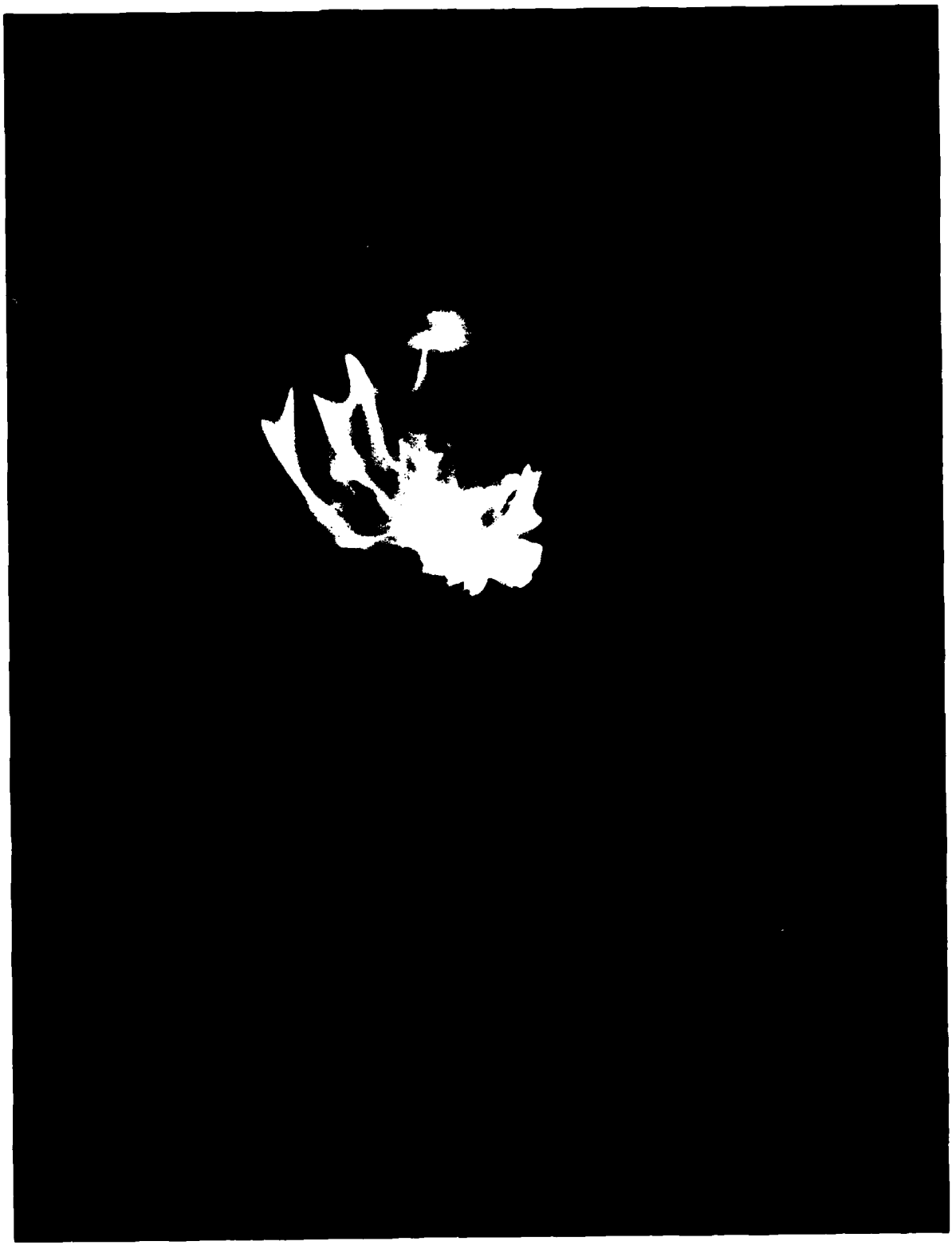
USNC77 III.19

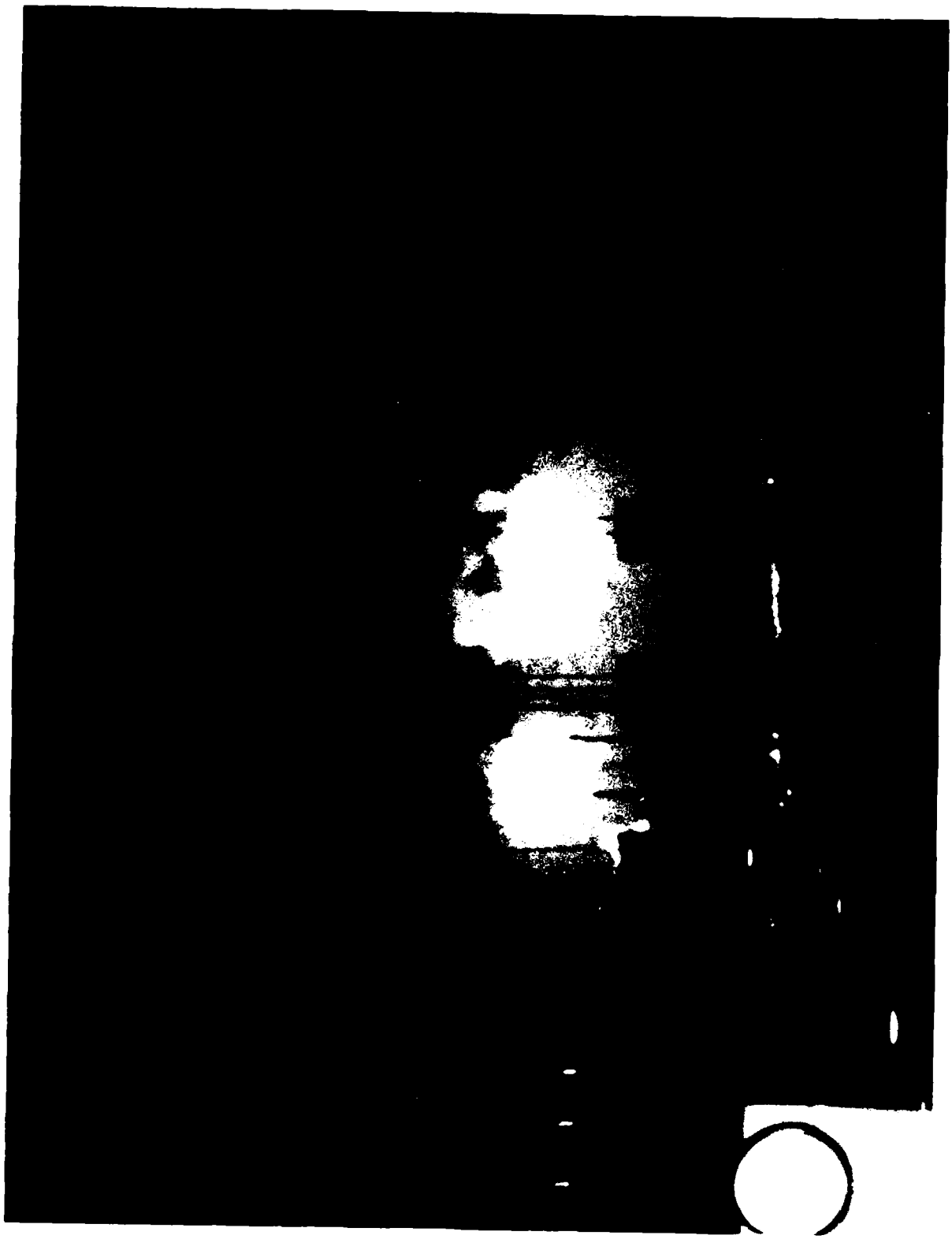
USNC 77
ILL. 20

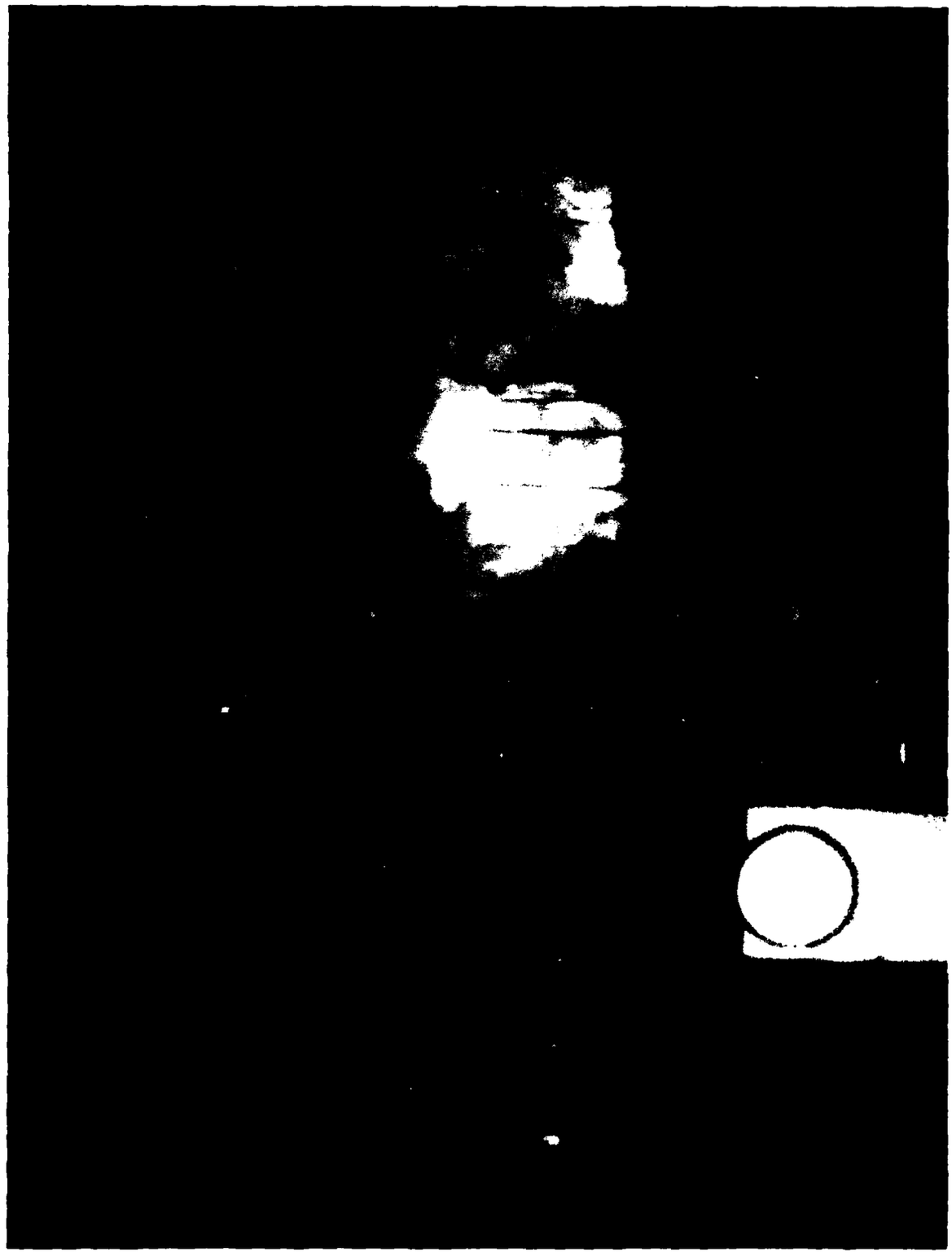












Appendix B

UL TEST REPORT
ON

FIRE TESTS OF POLYURETHANE FOAM ROOFING SYSTEMS
APPLIED DIRECTLY TO CORRUGATED METAL DECK

August 5, 1981

Note: PUF Roof System 1 in this appendix is the same as System 1 in the body of the report. However, PUF Roof System 2 in this appendix is designated as System 4 in the body of the report.

UNDERWRITERS LABORATORIES INC.
NORTHBROOK, IL · MELVILLE, NY · SANTA CLARA, CA · TAMPA, FL
an independent, not-for-profit organization testing for public safety

File USNC77
Project 81NK1849

August 5, 1981

REPORT

on

FIRE TESTS OF POLYURETHANE FOAM ROOFING SYSTEMS APPLIED DIRECTLY TO CORRUGATED METAL DECK

Department Of The Navy, Naval Civil Engineering Laboratory
Port Hueneme, CA

I N T R O D U C T I O N

The Naval Civil Engineering Laboratory (NCEL), Department of the NaVY, HAS AN INTEREST IN ROOF SYSTEMS FOR Navy installations throughout the world, including spray-applied polyurethane foam surfaced with fluid applied elastomeric coatings and No. 11 roofing granules. This type of assembly would be particularly advantageous when applied directly to steel roofs of buildings.

The NCEL previously sponsored investigations with Underwriters Laboratories Inc. (UL) of built-up roof covering systems consisting of spray-applied polyurethane foam surfaced with fluid-applied elastomeric coatings and No. 11 roofing granules under Project USNC77, 77NK11796, in accordance with Statement of Work 77-0054, which culminated in a Report dated December 29, 1978.

A portion of the previously referenced investigation included evaluations made with respect to the 25 ft tunnel furnace underdeck fire exposure determination using No. 26 gauge corrugated galvanized steel decking. The results of these fire exposure tests suggested that additional laboratory scale tests would be needed to establish a basis for the qualification of this type of decking for use in "Fire Classified" assemblies under the Roof Deck Construction Category of UL.

T H E I N V E S T I G A T I O N

OBJECTIVE:

The objective of this Investigation was to evaluate roof deck construction systems of polyurethane foam spray-applied directly to a corrugated steel deck and then covered with an elastomeric coating and ceramic roofing granules.

GENERAL:

Two of the four spray-applied foam built-up roof systems, which were included under the earlier investigation, were selected as representative of the four systems for evaluation with respect to the 25 ft tunnel furnace underdeck fire exposure tests. A maximum of three tests were anticipated on each system. The results of these tests would be reviewed for compliance with respect to requirements described under the Laboratories' Subject 1256 "Outline Of The Proposed Investigation For Roof Deck Construction" which are:

1. The flame propagation on the underside of each assembly tested shall not exceed the following limits within the designated time periods:

   A. 10 ft (14-1/2 ft from furnace burner) in 10 min.

   B. 14 ft (18-1/2 ft from furnace burner).

2. Examination of fire tested assemblies shall show the following with respect to the extent of damage of component materials of the construction:

   A. Thermal degradation (i.e., damage in the form of charring, loss of integrity, etc.) shall not extend throughout all components of the assembly at the extremity of the test deck.

   B. Fire exposure damage (i.e., burning, charring, etc., of the component materials shall diminish at increasing distances from the immediate fire exposure area.

MATERIALS:

Two polyurethane foam materials, intended for spray application, and two elastomeric coating systems were utilized to form the built-up roof covering systems. (One coating system used for one of the two foam systems). As such, two finished systems were evaluated as representative of the four spray-applied foam built-up roof systems. For purposes of this Report the foam materials will be referred to as "PUF1" (2-1/2 pcf density) and "PUF2" (3 pcf density). The coating systems will be referred to as "C1" (silicone) and "C2" (acrylic elastomer).

The coating and foam materials were produced under the Laboratories' Follow-Up Service Program as evidenced by the Classification Marking of Underwriters Laboratories for Classified Built-Up Roof Covering Materials.

BUILT-UP ROOF COVERING SYSTEMS:

The following is a description of the two built-up roof covering systems utilized for this investigation as referenced in the statement of work provided by NCEL entitled "Requirements for Fire Testing of Polyurethane Foam Roofing Systems Applied Directly to Corrugated Metal Decks."

System 1

A nominal 3 in. thick foamed plastic was formed by the simultaneous spraying of two liquid components (PUF1). The foamed plastic was coated with a two-coat system (C1). Both the base coat and the top coat were applied at the nominal rate of 1-1/2 gal per 100 sq ft. (Total 3 gal per 100 sq ft.) With the top coat still wet, No. 11 roofing granules were applied at a nominal rate of 50 lb per 100 sq ft.

System 2

A nominal 3 in. thick foamed plastic was formed by the simultaneous spraying of two liquid components (PUF2). The foamed plastic was coated with a two-coat system (C2). Both the base coat and the top coat were applied at the nominal rate of 1-1/2 gal per 100 sq ft. (Total 3 gal per 100 sq ft.) With the top coat still wet, No. 11 roofing granules were applied at a nominal rate of 50 lb per 100 sq ft.

CONSTRUCTION OF TEST SAMPLES:

The spray-applied foamed plastic and coating built-up roof covering systems were applied to nominal 2 by 24 ft sections of No. 26 gauge galvanized corrugated steel deck with longitudinal centerline and transverse joints. The steel deck substrate was fabricated with a two corrugation overlap centerline joint, a 6 in. overlap transverse joint, 3/16 in. by 1-1/2 in. self-drilling, self-tapping fasteners spaced a maximum of 10 in. OC at the supports which were placed 40 in. OC. The joint detail, support and fastener schedule are shown by ILL. 1. A vinyl-based "wash" primer was used to provide a bond coat for the foamed plastic material to the steel deck as recommended by the manufacturers.

The foamed plastic built-up roof assemblies were allowed to cure for 42 days prior to testing.

F I R E T E S T S

METHOD:

The fire tests were conducted in accordance with the methods described under the Laboratories' Subject 1256 "Outline Of The Proposed Investigation For Roof Deck Construction." The 25 ft tunnel furnace is shown by ILLS. 2 and 3.

Test Procedure

The test assemblies were subjected to a 30 min fire exposure. The distance of flame spread advance was recorded throughout the 30 min test period. After 10 min, the maximum distance of flame propagation was recorded. After 20 min more of exposure to flame, (30 min total), the maximum distance of flame propagation was again recorded.

Observations were made during the testing from the open fire end and side of the tunnel furnace with respect to flammability characteristics of the assemblies.

Following the exposure period the assemblies were removed for examination with respect to damage.

SPECIMEN:

The specimens evaluated in the fire tests were as previously described in this Report.

The test assemblies were positioned in the tunnel furnace with the transverse joint located 8 ft from the ignition flame source.

Nominal 1 in. thick mineral wool was positioned on the tunnel ledges to provide a positive seal with the corrugated deck.

RESULTS:

Underdeck Flame Spread

Test No.	Roof Covering System	Maximum Flame Spread (Ft) After 10 Min	Maximum Flame Spread (Ft) After 30 Min
1	System 1	2.0	2
2	System 1	8.5	8.5
3	System 2	0	0
4	System 2	4.5	4.5

Observations During Test

System 1 - The ignition of the roof deck sample occurred at the centerline joint after elapsed times of 2 min, 26 sec, and 1 min, 34 sec, respectively, for Test Nos. 1 and 2. The underdeck flaming progressed along the centerline joint to a distance of 2 ft at 6 min, 15 sec and 8.5 ft at 12 min, 4 sec, respectively. Flame progression receded for the duration of the test. No residual flaming was evident after termination of the tests.

System 2 - No ignition or underdeck flaming was observed in Test No. 3. The ignition of the roof deck sample occurred at the centerline joint of Test No. 4 after an elapsed time of 1 min, 49 sec. The underdeck flaming progressed along the centerline joint to a distance of 4.5 ft (9.0 ft from furnace burner) at 7 min, 35 sec. Flame progression receded for the duration of the test. No residual flaming was evident after termination of the test.

Damage

For purposes of this description, damage will be defined according to two damage levels.

1. Char - Change due to thermal exposure resulting in significant loss in structural integrity and significant change in material texture.

2. Discoloration - Color change due to thermal exposure with some loss in structural integrity and some change in material texture.

The following table summarizes the damage to the foamed plastic material as noted through visual observation at nominal distances of 8 ft, 16 ft and 24 ft from the fire end of the assemblies.

Test	Char, In.			Discoloration, In.		
No.	8 Ft	16 Ft	24 Ft	8 Ft	16 Ft	24 Ft
1	1-5/8	1/4	None	1/8	Surface	Surface
2	1-3/4	Surface	None	1/8	11/16	11/16
3	Surface	None	None	1/4	Surface	None
4	1-3/8	1/4	None	1/8	1	7/8

RSL/WAK:wj

S U M M A R Y

Based upon the data presented herein, the four foamed plastic built-up roof coverings identified in this Report are eligible for Classification and Follow-Up Services by Underwriters Laboratories Inc. through its promulgation procedure including Fire Council advisement, as Roof Deck Construction utilizing specified corrugated steel roof deck panels in accordance with support and fastener practices specified in this Report.

Report by:

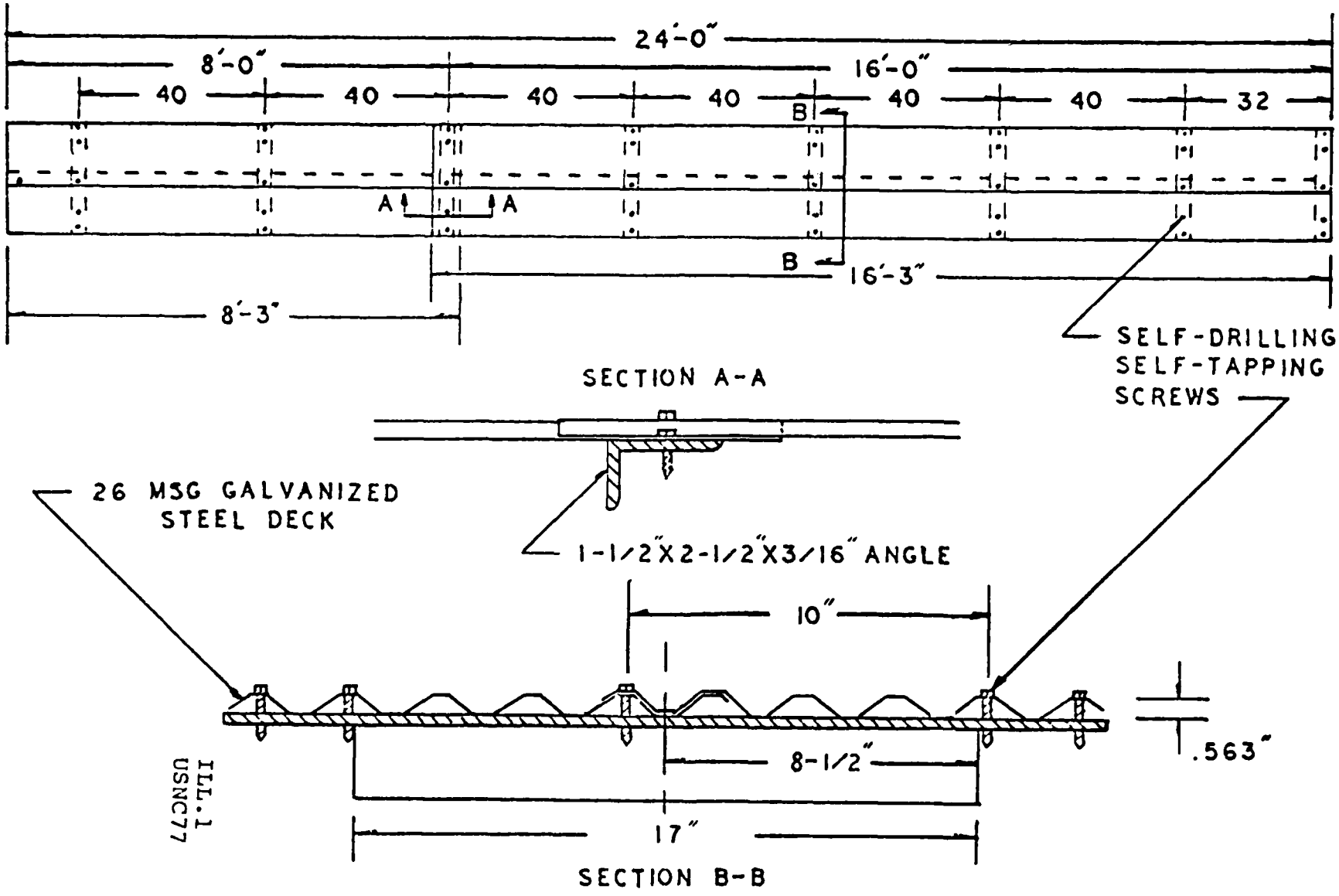
ROBERT S. LUKASZ
Engineering Associate
Fire Protection Department

Reviewed by:

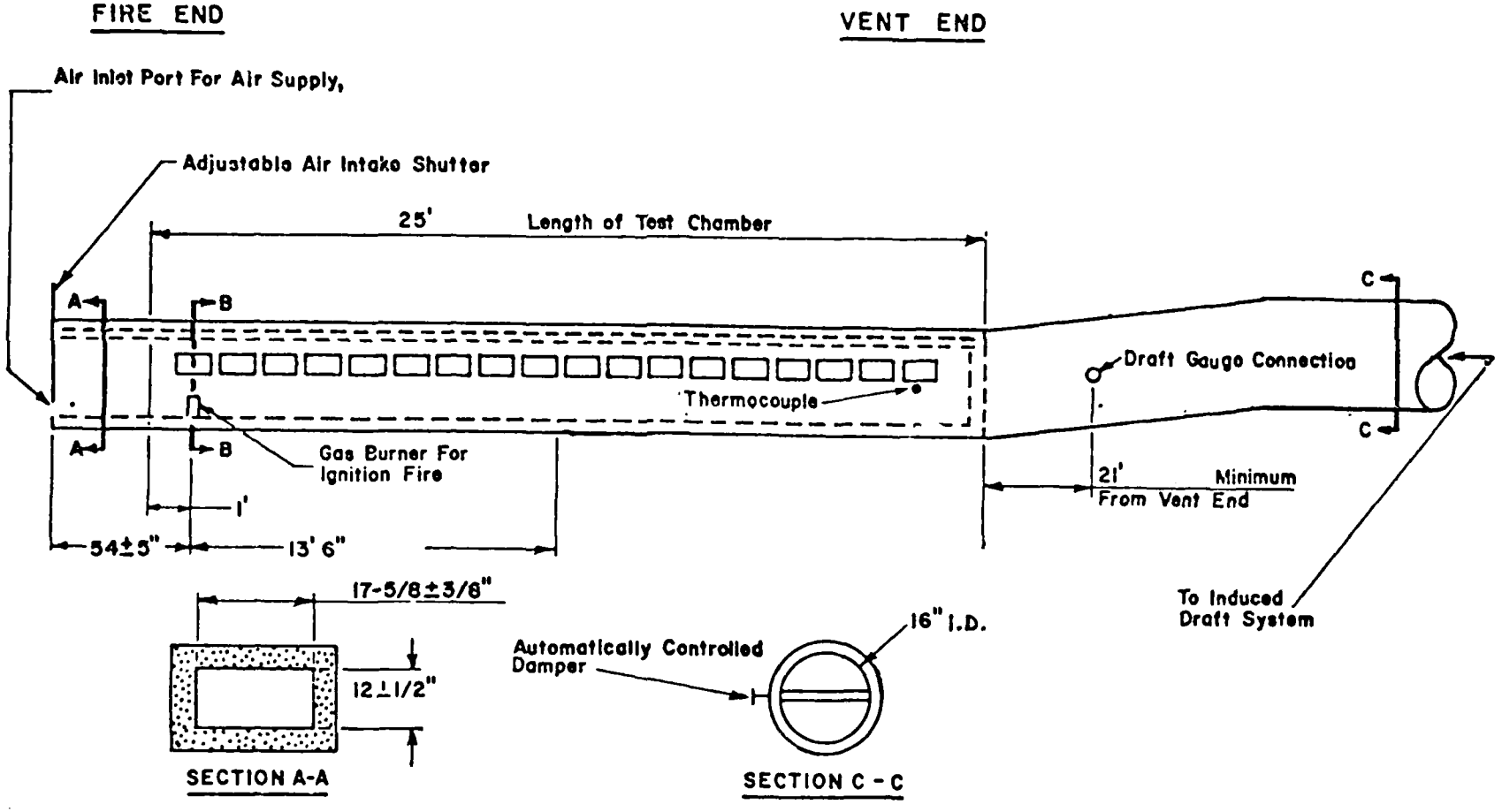
WILLIAM S. METES
Executive Staff Engineer
Fire Protection Department

JAMES R. BEYREIS
Managing Engineer
Fire Protection Department

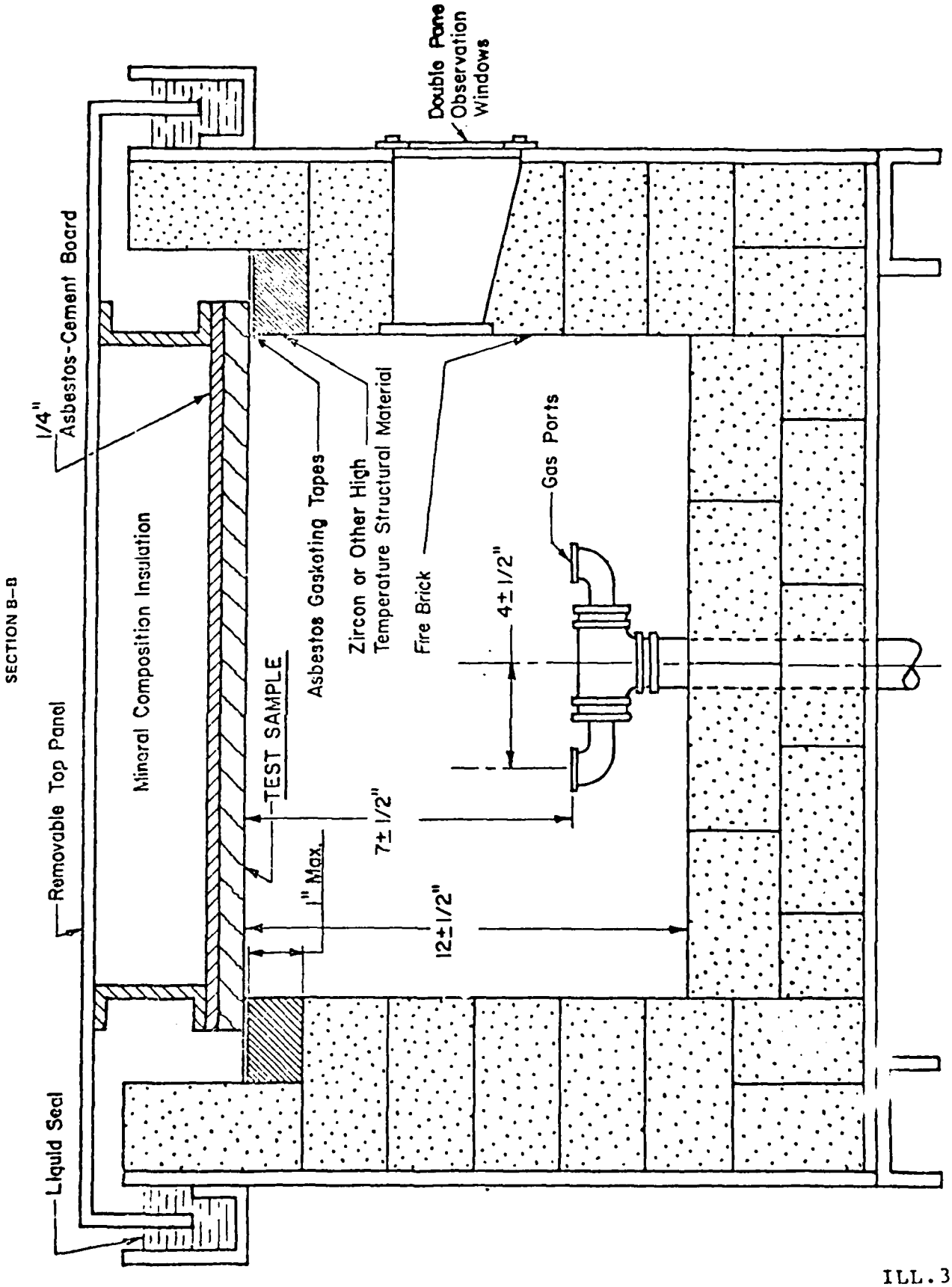
RSL/WSM/JRB:wj


24'-0"
8'-0"
16'-0"
40
40
40
40
40
40
32
A
A
B
B
16'-3"
8'-3"
SELF-DRILLING
SELF-TAPPING
SCREWS
SECTION A-A
26 MSG GALVANIZED
STEEL DECK
1-1/2"X2-1/2"X3/16" ANGLE
10"
8-1/2"
.563"
17"
SECTION B-B

DETAILS OF TEST FURNACE



ILL.2
USNC77


Double Pane Observation Windows
1/4" Asbestos-Cement Board
Asbestos Gasketing Tapes
Zircon or Other High Temperature Structural Material
Fire Brick
Gas Ports
4± 1/2"
Mineral Composition Insulation
TEST SAMPLE
7± 1/2"
1" Max.
12±1/2"
Removable Top Panel
Liquid Seal
SECTION B-B

ILL.3
US:IC77

Appendix C

UL TEST REPORT
ON

FIRE TESTS OF POLYURETHANE FOAM ROOFING SYSTEMS
APPLIED DIRECTLY TO FLUTED METAL DECK

April 14, 1982

Note: PUF Roof System 1 in this appendix is the same as System 1 in the body of the report. However, PUF Roof System 2 in this appendix is designated as System 4 and PUF Roof System 3 in this appendix is designated as System 5 in the body of the report.

UNDERWRITERS LABORATORIES INC.
333 PFINGSTEN ROAD · NORTHBROOK, ILLINOIS 60062
an independent, not-for-profit organization testing for public safety

File USNC117
Project 81NK19399

April 14, 1982

REPORT

on

FIRE TESTS OF POLYURETHANE FOAM ROOFING SYSTEMS APPLIED DIRECTLY TO FLUTED METAL DECK

Department of the Navy, Naval Civil Engineering Laboratory
Port Hueneme, California

I N T R O D U C T I O N

The Naval Civil Engineering Laboratory (NCEL), Department of the Navy, has an interest in insulated roof systems for Navy installations throughout the world, including spray-applied polyurethane foamed plastic surfaced with fluid applied elastomeric coatings with or without roofing granules.

The NCEL previously sponsored investigations with Underwriters Laboratories Inc. (UL) of built-up roof covering systems consisting of spray-applied polyurethane foamed plastic surfaced with fluid-applied elastomeric coatings and roofing granules under Projects USNC77, 77NK11796 and USNC77, 81NK1849, which culminated in Reports dated December 29, 1978 and August 5, 1981, respectively.

The previously referenced investigations included evaluations made with respect to the 25 ft tunnel furnace underdeck fire exposure using 26 gauge ribbed and corrugated galvanized steel decking. The results of these fire exposure tests suggested that further laboratory scale tests should be conducted to establish a basis for the qualification of additional standard roof decking for use in "Fire Classified" assemblies under the Roof Deck Construction Category of UL.

THE INVESTIGATION

OBJECTIVE:

The objective of this Investigation was to evaluate roof deck construction systems of polyurethane foamed plastic spray-applied directly to fluted factory primed steel deck, covered with an elastomeric coating, with or without roofing granules. The effect of three variations of flute pre-treatment on underdeck flame spread was also evaluated under this Investigation.

GENERAL:

Two tests were conducted on each of three polyurethane foamed plastic roof covering systems directly applied to the fluted steel deck. In addition, two tests each were conducted on a single polyurethane foamed plastic roof covering system, selected by NCEL from one of the three above, when applied to fluted steel deck utilizing three different flute pre-treatments.

The results of these tests were reviewed by UL for compliance with respect to requirements described under the Laboratories' Subject 1256 "Outline Of The Investigation For Roof Deck Construction" which are:

1. The flame propagation on the underside of each assembly tested shall not exceed the following limits within the designated time periods:

   A. 10 ft (14-1/2 ft from furnace burner) in 10 min.

   B. 14 ft (18-1/2 ft from furnace burner) in 30 min.

2. Examination of fire tested assemblies shall show the following with respect to the extent of damage of component materials of the construction:

   A. Thermal degradation (i.e., damage in the form of charring, loss of integrity, etc.) shall not extend throughout all components of the assembly at the extremity of the test deck.

B. Fire exposure damage (i.e., burning, charring, etc.) of the component materials shall diminish at increasing distances from the immediate fire exposure area.

MATERIALS:

Three polyurethane foamed plastic materials and three coating systems were selected by NCEL to form the Built-Up Roof Covering Systems. The three systems were evaluated when spray applied directly into the flutes and over the entire surface of 22 gauge intermediate rib factory primed steel deck. In addition, a single system was selected by NCEL to be evaluated over identical steel deck substrates with the following deck flute pre-treatments:

1. Four inch wide self-adhesive polyester tape placed longitudinally across the flutes to provide a flat deck surface.

2. Polyurethane board stock, cut to the flute configuration, friction fit into the flutes to provide a flat deck surface.

3. Lightweight cementitious fill placed in the flutes and screeded level with deck surface to provide a flat deck surface.

For purposes of this Report, the spray applied foam plastic materials will be referred to as "PUF1," "PUF2" and "PUF3." The coating material systems will be referred to as "C1" (silicone), "C2" (acrylic elastomer) and "C3" (urethane).

The foam materials, coatings, board stock fillers and cementitious mixture were produced under the Laboratories' Follow-Up Service Program as evidenced by the Classification Marking of Underwriters Laboratories for Classified Built-Up Roof Covering Materials.

BUILT-UP ROOF COVERING SYSTEMS:

The following is a description of the built-up roof covering systems utilized for this investigation as referenced in the statement of work provided by NCEL entitled "Fire Tests of Polyurethane Foam Roofing Systems Applied to Fluted Metal Decks." dated July 6, 1981.

System 1

A nominal 3 in. thick foamed plastic (PUF1) was formed by the simultaneous spraying of two liquid components in accordance with the manufacturer's recommended installation instructions. The foamed plastic, applied at a density of 2.3 lb/ft^3, was coated with a two-coat roof coating system (C1). Both the base coat and the top coat were applied at the nominal rate of 1-1/2 gal per 100 ft^2. (Total 3 gal per 100 ft^2.) With the top coat still wet, No. 11 roofing granules were applied at a nominal rate of 50 lb per 100 ft^2.

System 2

A nominal 3 in. thick foamed plastic (PUF2) was formed by the simultaneous spraying of two liquid components in accordance with the manufacturer's recommended installation instructions. The foamed plastic, applied at a density of 4.3 lb/ft^3 *, was coated with a two-coat roof coating system (C2). Both the base coat and the top coat were applied at the nominal rate of 1-1/2 gal per 100 ft^2. (Total 3 gal per 100 ft^2.) With the top coat still wet, No. 11 roofing granules were applied at a nominal rate of 50 lb per 100 ft^2.

* - The foamed plastic material did not rise during application as expected requiring more passes than anticipated to develop the design thickness.

System 3

A nominal 2 in. thick foamed plastic (PUF3) was formed by the simultaneous spraying of two liquid components in accordance with the manufacturer's recommended installation instructions. The foamed plastic, applied at a density of 4.3 lb/ft^3, was coated with a three-coat roof coating system (C3). Both base coats and the top coat were applied at the nominal rate of 1-1/2 gal per 100 ft^2 (total 4.5 gal per 100 ft^2).

CONSTRUCTION OF TEST SAMPLES:

The roof covering systems were applied to nominal 2 by 8 ft sections of 22 gauge fluted intermediate rib factory primed steel deck with longitudinal centerline and transverse joints. Three 8 ft sections were loosely assembled into a 24 ft long panel with 2 in. end overlaps. The foamed plastic was sprayed continuously to the full 24 ft length and allowed to cure. The foam plastic was then cut across the width of the panel, on an offset, so that each system was again divided into three easily handled 8 ft sections that overlapped. These three sections were later reassembled in the tunnel furnace with the cut foam edges butted together. The joint details, support, and fastener schedule are shown by ILLS. 1 and 1A.

The deck pre-treatments previously described were installed prior to the spray application of the System 1 foam material. Only the lightweight cementitious fill, mixed in accordance with the manufacturer's instructions, was allowed a seven day cure prior to application of the built-up roof covering.

The foamed plastic built-up roof assemblies were allowed to cure for 32 days prior to testing.

F I R E T E S T S

SPECIMEN:

The specimens evaluated in the fire tests were as previously described in this Report.

Test specimens were assembled by placing three 24 in. wide, 8 ft long deck sections in the tunnel furnace with the cut foam edges butted together. The overlapping steel deck sections were mechanically fastened through the support at the flutes on 6 in. centers with self-drilling, self-tapping screws. (See ILL. 1A.)

Nominal 1 in. thick mineral wool was positioned on the tunnel ledges to provide a positive seal with the fluted deck.

METHOD:

The fire tests were conducted in accordance with the methods described under the Laboratories' Subject 1256 "Outline Of The Proposed Investigation For Roof Deck Construction." The 25 ft tunnel furnace is shown by ILLS. 2 and 3.

Test Procedure

The test assemblies were subjected to a 30 min fire exposure. The distance of underdeck flame spread advance was recorded throughout the 30 min test period. After 10 min, the maximum distance of flame propagation was recorded. After an additional 20 min of flame exposure (30 min total), the maximum distance of flame propagation was again recorded.

Observations were made during the testing from the open fire end and side of the tunnel furnace with respect to flammability characteristics of the assemblies.

Following the exposure period, the assemblies were removed for examination with respect to damage.

RESULTS:

Underdeck Flame Spread

Test No.	Roof Covering System	Flute Treatment	Maximum Flame Spread (Ft) 10 Min	Maximum Flame Spread (Ft) 30 Min
1	System 1	None	8.0	8.0
2	System 1	None	9.0	9.0
3	System 1	Cementitious Fill	5.5	5.5
4	System 1	Cementitious Fill	4.0	4.0
5	System 2	None	15.0	*
6	System 1	Polyester Tape	9.0	9.0
7	System 2	None	19.5	*
8	System 1	Polyester Tape	8.0	8.0
9	System 1	Board Stock Fillers	4.5	4.5
10	System 1	Board Stock Fillers	4.5	4.5
11	System 3	None	8.0	8.0
12	System 3	None	6.0	6.0

* - Test terminated prior to 30 min

Observations During Test

System 1 - Standard Application, No Flute Pre-Treatment

The ignition of the roof deck samples occurred at the centerline joint after elapsed times of 1 min, 11 sec and 1 min, 16 sec, respectively for Test Nos. 1 and 2. The underdeck flaming progressed along the centerline joint to a distance of 8 ft at 5 min, 16 sec and 9 ft at 4 min, 54 sec, respectively. Flame progression receded for the duration of the tests. No residual flaming was evident after termination of the tests.

System 1 - Cementitious Filled Flutes

The ignition of the roof deck samples occurred at the centerline joint after elapsed times of 1 min, 22 sec and 1 min, 14 sec, respectively for Test Nos. 3 and 4. The underdeck flaming progressed along the centerline joint to a distance of 5.5 ft at 5 min, 28 sec and 4 ft at 3 min, 18 sec, respectively. Flame progression receded for the duration of the tests. No residual flaming was evident after termination of the tests.

System 1 - Taped Flutes

The ignition of the roof deck samples occurred at the centerline joint after elapsed times of 1 min, 39 sec and 1 min, 38 sec, respectively for Test Nos. 6 and 8. The underdeck flaming progressed along the centerline joint to a distance of 9 ft at 6 min, 25 sec and 8 ft at 4 min, 2 sec, respectively. Flame progression receded for the duration of the tests. No residual flaming was evident after termination of the tests.

System 1 - Board Stock Filled Flutes

The ignition of the roof deck samples occurred at the centerline joint after elapsed times of 1 min, 20 sec and 1 min, 10 sec, respectively for Test Nos. 9 and 10. The underdeck flaming progressed along the centerline joint to a distance of 4.5 ft at 5 min, 29 sec and 4 min, 38 sec, respectively. Flame progression receded for the duration of the tests. No residual flaming was evident after termination of the tests.

System 2 - Standard Application, No Flute Treatment

The ignition of the roof deck samples occurred at the centerline joint after elapsed times of 1 min, 37 sec and 1 min, 15 sec, respectively for Test Nos. 5 and 7. The underdeck flaming progressed along the centerline joint to a distance of 15 ft at 4 min, 19 sec and 19.5 ft (the full length of the tunnel furnace) at 4 min, 27 sec, respectively. Due to the extent of flame travel, both tests were terminated before completion of the entire 30 min exposure period.

System 3 - Standard Application, No Flute Treatment

The ignition of the roof deck samples occurred at the centerline joint after elapsed times of 1 min, 0 sec and 48 sec, respectively for Test Nos. 11 and 12. The underdeck flaming progressed along the centerline joint to a distance of 8 ft at 4 min, 30 sec and 6 ft at 5 min, 4 sec, respectively. Flame progression receded for the duration of the tests. No residual flaming was evident after termination of the tests.

Damage

For purposes of this description, damageability will be defined according to the two following cumulative levels:

1. Char - Physical change due to thermal exposure resulting in significant loss in structural integrity and significant change in material texture.

2. Discoloration - Color change due to thermal exposure with some loss in structural integrity and some change in material texture.

The following table summarizes the damage to the foamed plastic material as noted through visual observation at nominal distances of 8 ft, 16 ft and 24 ft from the fire end of the assemblies.

Test No.	Depth of Char, In. 8 Ft	16 Ft	24 Ft	Depth of Discoloration, In. 8 Ft	16 Ft	24 Ft
			System 1 - Standard Application			
1	Thru Char	Surface	None	-	1	1/2
2	Thru Char	Surface	None	-	3/4	1/2
			System 1 - Cementitious Filled Flutes			
3	2-9/16	Surface	None	1/8	3/8	3/8
4	2-1/4	Surface	None	1/4	1/2	3/8
			System 1 - Taped Flutes			
6	Thru Char	Surface	None	-	7/8	5/8
8	Thru Char	1/16	Surface	-	1/2	7/16
			System 1 - Board Stock Filled Flutes			
9	2-5/8	Surface	None	1/8	3/4	9/16
10	2-11/16	Surface		1/8	3/4	3/8
			System 3 - Standard Application			
11	1-1/4	Surface	None	3/4	1/2	1/2
12	1-5/8	Surface	None	3/8	3/8	1/4

Due to early termination, the damage to System 2, Tests 5 and 7, was not evaluated.

S U M M A R Y

Based upon the data presented herein, the following summarization statements can be made:

1. The specimens prepared with the polyurethane foam built-up roof covering identified as System 2 exceeded the underdeck flame propagation requirements of Subject 1256 "Outline Of The Investigation For Roof Deck Construction."

2. The samples containing the polyurethane foamed plastic built-up roof coverings identified as Systems 1 and 3 are judged to comply with the requirements of Subject 1256 "Outline Of The Investigation For Roof Deck Constructions."

3. The specimens prepared with System 1 over the three methods of flute pre-treatment, as described, exhibited flammability performance equal to or greater than those assemblies with the foamed plastic spray applied directly into the flutes. In addition, the thermal degradation of those samples prepared with flute pre-treatment was equal to or less than those assemblies with the foamed plastic spray applied directly into the flutes. Systems 1 and 3, applied over all three methods of flute pretreatment are judged to comply with the requirements of Subject 1256, "Outline Of The Investigation For Roof Deck Constructions."

Based on the data presented herein, the foamed plastic built-up roof coverings, identified as Systems 1 and 3, would be eligible for Classification by Underwriters Laboratories Inc. over all four types of deck preparation, if subjected to UL's Promulgation Procedure and Fire Council review, and if the respective manufacturers subscribe to UL's Follow-Up Services for factory inspection of the products. Classification would be as Roof Deck Construction utilizing the fluted steel roof deck panels and the support and fastener practices specified in this Report.

Report by:

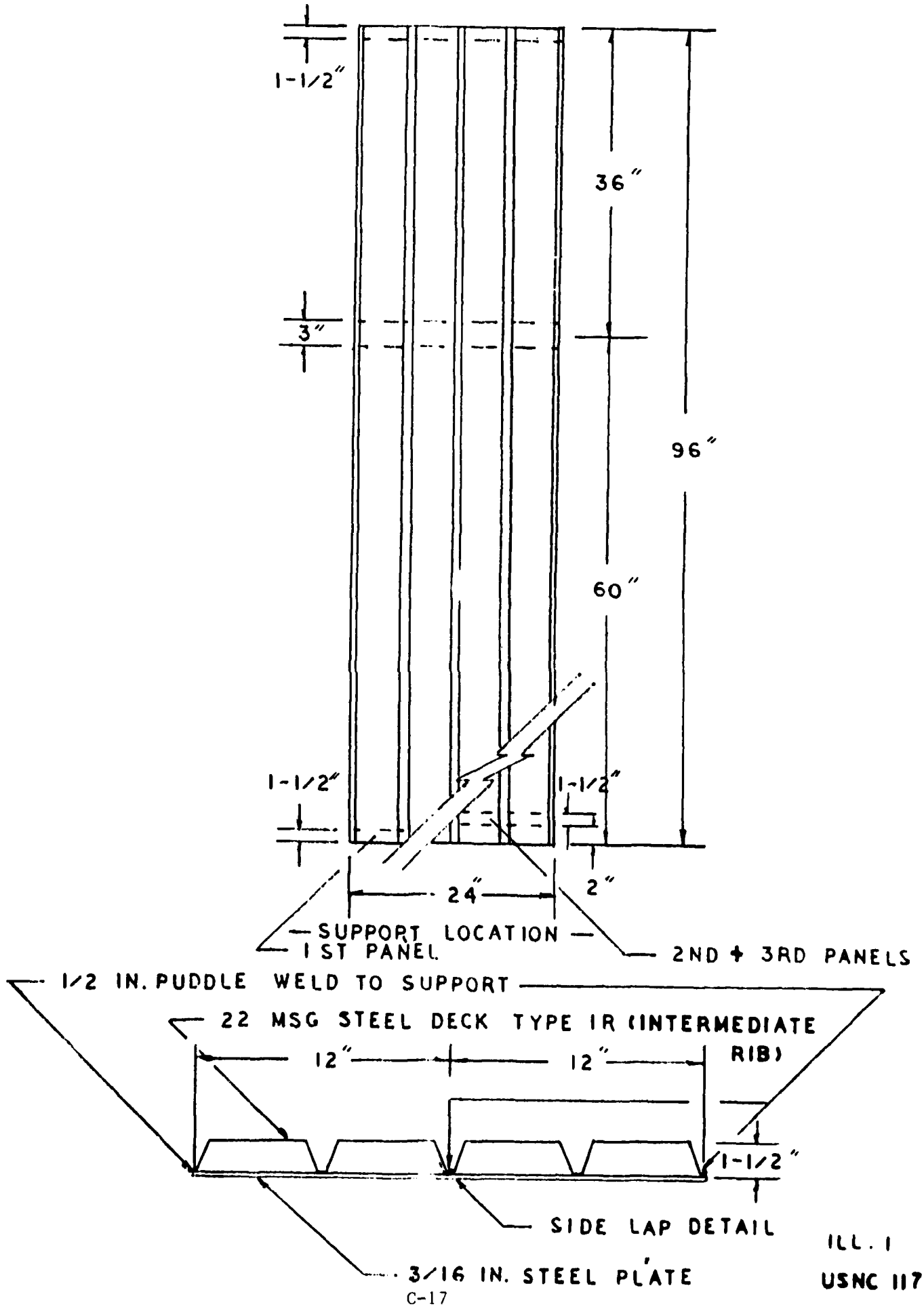
ROBERT S. LUKASZ
Engineering Associate
Fire Protection Department

RSL/KDR/JRB:pr

Reviewed by:

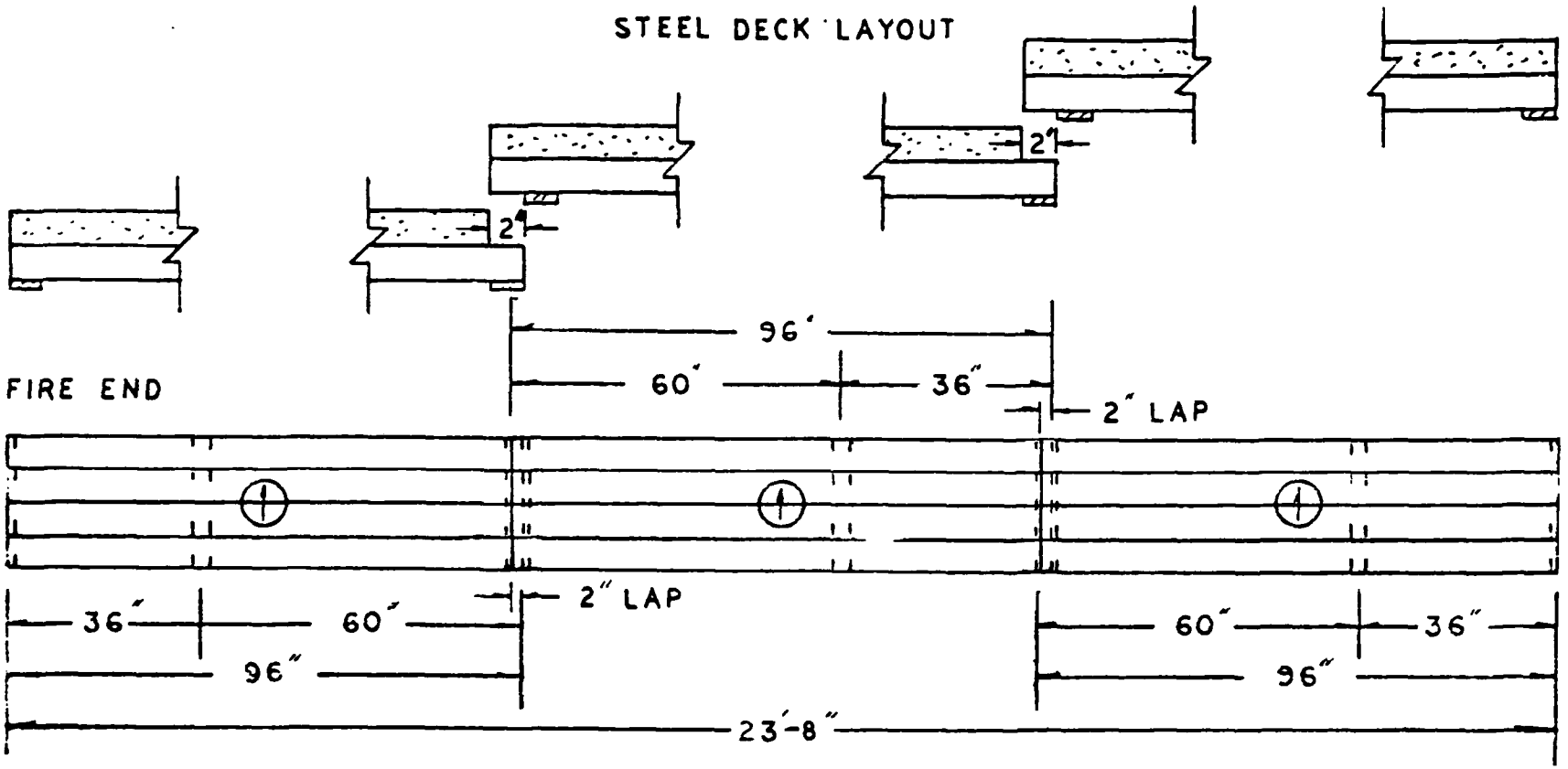
KENNETH D. RHODES
Engineering Group Leader
Fire Protection Department

JAMES R. BEYREIS
Managing Engineer
Fire Protection Department



ILL. 1

USNC 117



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ILL. IA
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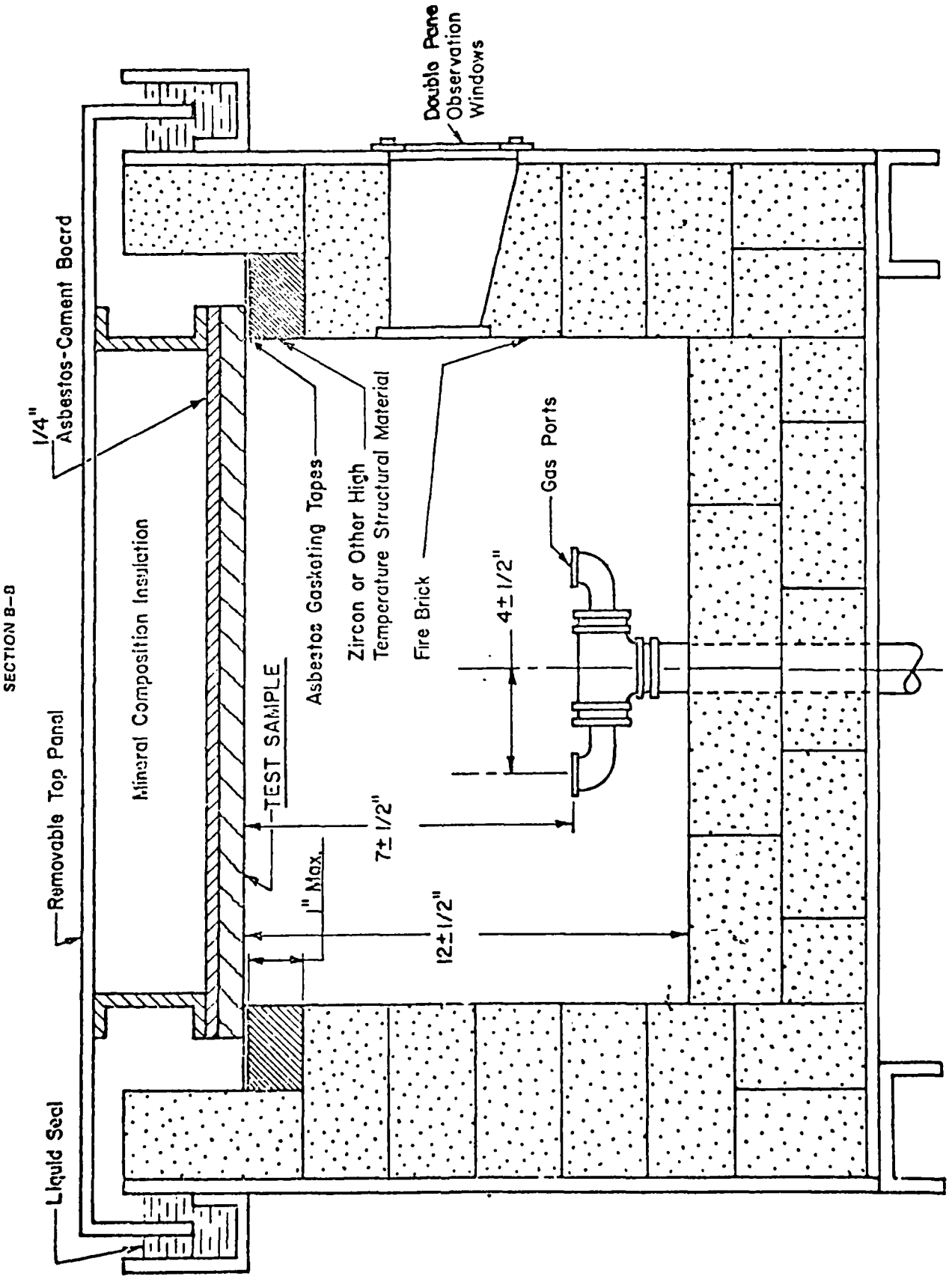
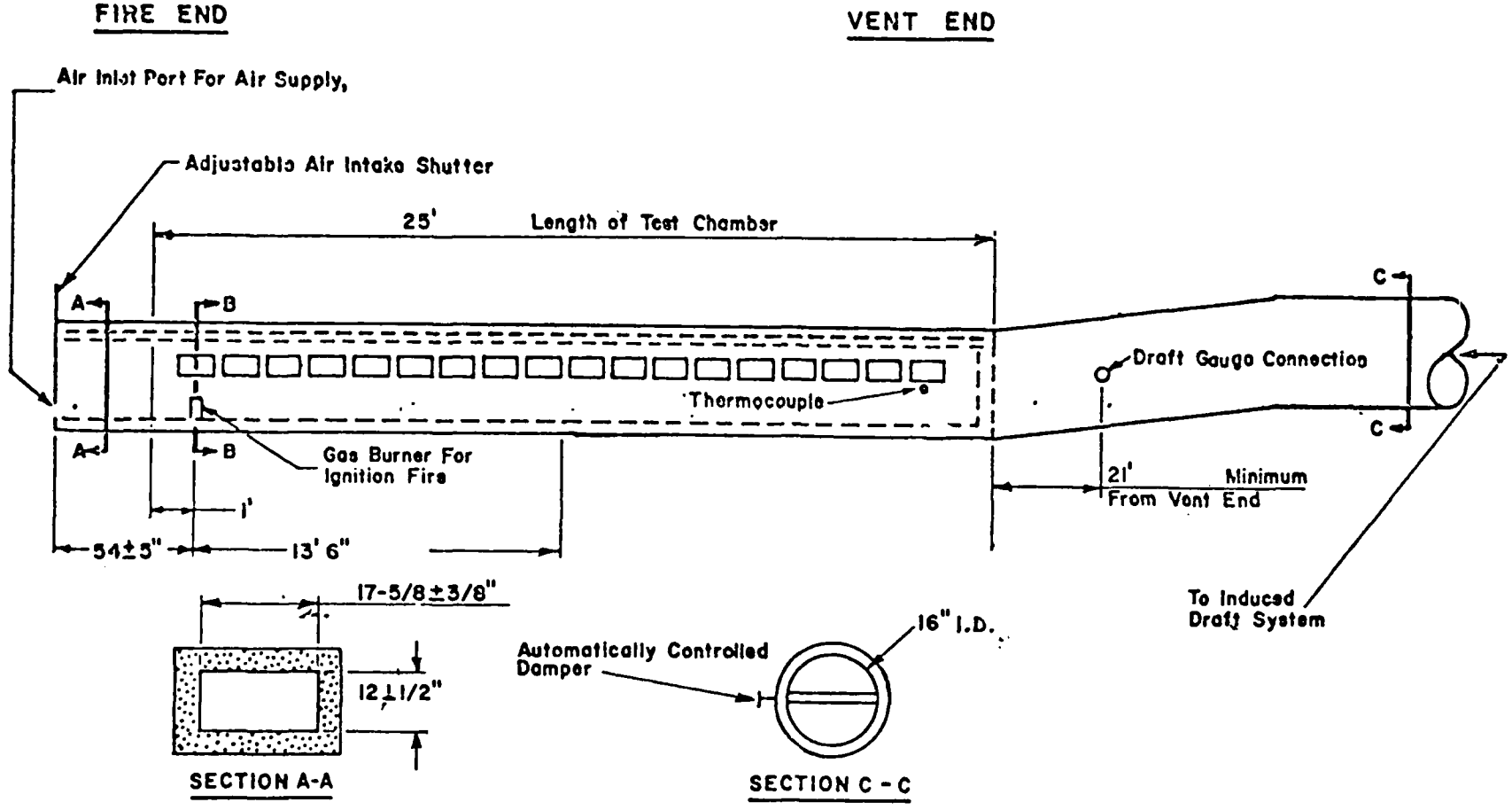


ILL.2
USNC 117

DETAILS OF TEST FURNACE



ILL. 3
USNC 111

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BUREAU OF RECLAMATION Code 1512 (C. Selander) Denver CO
CINCLANT CIV ENGR SUPP PLANS OFFR NORFOLK, VA
CINCPAC Fac Engrng Div (J44) Makalapa, HI
CNAVRES Code 13 (Dir. Facilities) New Orleans, LA
CNM Code MAT-04, Washington, DC; Code MAT-O8E, Washington, DC; NMAT - 044, Washington DC
CNO Code NOP-964, Washington DC; Code OP 987 Washington DC; Code OP-413 Wash, DC; Code OPNAV 09B24 (H); OP-098, Washington, DC; OP987J, Washington, DC
COMCBPAC Operations Off, Makalapa HI
COMFLEACT, OKINAWA PWD - Engr Div, Sasebo, Japan; PWO, Kadena, Okinawa; PWO, Sasebo, Japan
COMNAVAIRLANT NUC Wpns Sec Offr Norfolk, VA
COMNAVMARIANAS Code N4, Guam
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DTIC Defense Technical Info Ctr/Alexandria, VA
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- Remove my name from all your lists – check box on list.
- Change my address – line out incorrect line and write in correction (DO NOT REMOVE LABEL).
- Number of copies should be entered after the title of the subject categories you select.

Fold on line below and drop in the mail.

Note: Numbers on label but not listed on questionnaire are for NCEL use only, please ignore them.

Fold on line and staple.

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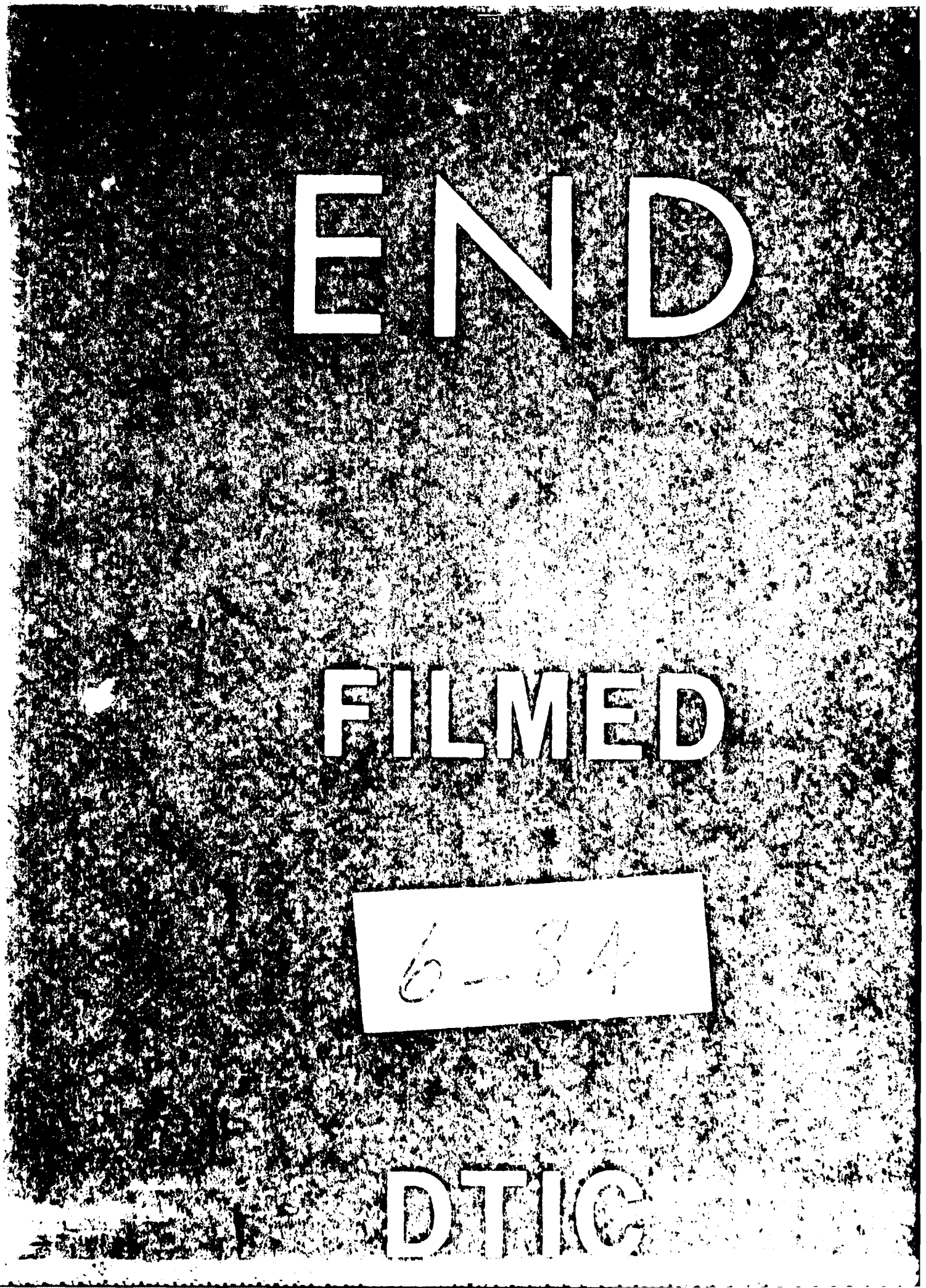
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