RUBIN FELDMAN, P.E.
President

4 October 1982

Nuclear Regulatory Commission
7920 Norfolk Avenue
Bethesda, Md. 20014

Attention: Mr. Dennis Kubicki
Division of Licensing, CMEB

Subject: I.T.L. Test Report No. 82-5-355A Entitled: One Hour ASTM E119 Fire Simulation Facility Fire Tests, Water Hose Stream Impact Tests and Electrical Circuitry Continuity Tests on Nuclear Facility Class 1E Cable Trays and Conduit Test Assemblies Protected With a One Hour Fire Rated Design of THERMO-LAG 330-1 Subliming Coating Envelope System

and

I.T.L. Test Report No. 82-5-355B Entitled: Three Hour Fire Endurance Tests on THERMO-LAG 330-1 Subliming Coating Envelope System for Washington Public Power Supply System Nuclear Projects

Re: NRC Docket No. 50-397

Dear Mr. Kubicki:

All entries and exits of test articles, utilized in the above subject test programs, were sealed air tight with THERMO-LAG 330-70 Conformable Ceramic Blanket in order to prevent air from circulating within each test article.

All test articles were instrumented with chromel/alumel thermocouples. The thermocouples were uniformly distributed within each test article. They were placed on the surface of the cable jacket at approximately twelve inch (12") intervals, in most instances, in the immediate proximity of the metal enclosure comprising the shelf, ladder rungs, or wall of the tray or, in the case of the conduit, its walls and on the surface of the bottom or side row of the cables being tested. The primary objective of these engineering thermocouples was to identify and characterize the "worst case" - or the

X003

8210070009 KA

1/16

locations most apt to experience the highest temperature reading of the internal thermal environment - that could exist through the entire length and cross-section of the test article. For details of thermocouple placement, please refer to the above reports.

If you have any further questions, please feel free to contact us directly.

Very truly yours,
TSI, Inc.

Rubin Feldman, P.E.
President

Industrial Testing Laboratories, Inc.

Allan Siegel, P.E.
President

RF/ig

cc: Dave Evans, WPPSS
Jim Freer, Burns & Roe, Inc.

INDUSTRIAL TESTING LABORATORIES inc.

Chemists
Engineers
Metallurgists

2350 Seventh Blvd. • St. Louis, Missouri 63104 | 314/771-7111

I.T.L. REPORT NO. 82-11-80

ONE-HOUR FIRE ENDURANCE TESTS CONDUCTED ON

TEST ARTICLES CONTAINING "GENERIC" CABLES

PROTECTED WITH

THERMO-LAG 330-1 SUBLIMING COATING ENVELOPE SYSTEM

CLIENT:

TSI, INC.
3260 BRANNON AVENUE
ST. LOUIS, MISSOURI 63139

NOVEMBER 1982

I.T.L. REPORT NO. 82-11-80

TEST DATE: SEPTEMBER 9 THROUGH SEPTEMBER 28, 1982

TESTS: ONE-HOUR FIRE ENDURANCE TESTS CONDUCTED ON TEST ARTICLES CONTAINING "GENERIC" CABLES PROTECTED WITH THERMO-LAG 330-1 SUBLIMING COATING ENVELOPE SYSTEM

LOCATION OF TESTS:
TSI, INC.
3260 BRANNON AVENUE
ST. LOUIS, MISSOURI 63139

WITNESSED BY
I.T.L. REPRESENTATIVE:

Donald Storment

DONALD STORMENT, P.E.

APPROVED:
INDUSTRIAL TESTING LABORATORIES, INC.
2350 SOUTH SEVENTH BOULEVARD
ST. LOUIS, MISSOURI 63104

Allan M. Siegel

ALLAN M. SIEGEL, P.E.
DIRECTOR

NOVEMBER 1982

TEST ATTENDEES

Witnessing all five tests for Industrial Testing Laboratories, Inc:

Mr. D. Storment

Witnessing one test for American Nuclear Insurers:

Mr. W. Bornhoeft

Witnessing all five tests for TSI, Inc:

Mr. R. Feldman
Mr. B. Evans

Conducting the tests:

Mr. W. Paddock

Operating TSI's ASTM E119 Furnace:

Mr. A. Thorpe

TSI

PROPRIETARY RIGHTS STATEMENT

I.T.L. REPORT NO 82-11-80

ONE-HOUR FIRE ENDURANCE TESTS CONDUCTED ON TEST ARTICLES CONTAINING "GENERIC" CABLES PROTECTED WITH THERMO-LAG 330-1 SUBLIMING COATING ENVELOPE SYSTEM

PREPARED BY

INDUSTRIAL TESTING LABORATORIES, INC.
ST. LOUIS, MISSOURI

NOVEMBER 1982

TSI, INC. • 3260 BRANNON AVE. • ST. LOUIS, MO. 63139 • (314) 352-8422 • Telex: 44-2384

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

ONE-HOUR FIRE ENDURANCE TESTS CONDUCTED ON TEST ARTICLES CONTAINING "GENERIC" CABLES PROTECTED WITH THERMO-LAG 330-1 SUBLIMING COATING ENVELOPE SYSTEM

1.0 INTRODUCTION AND SUMMARY

1.1 Introduction

This report presents and discusses the experimental test results obtained from performing one-hour ASTM E119 fire endurance tests, followed by water hose stream tests, on test assemblies protected with a one-hour fire rated design of the THERMO-LAG 330-1 Subliming Coating Envelope System. The test assemblies consisted of various arrangements of generic power, control and instrumentation cabling in a ladder and solid bottom cable tray and conduit, as well as pullbox, a condulet and air drop. A protective envelope repair procedure was also tested.

This test program was conducted in accordance with all applicable sections of TSI's Engineering Test Plan, second revision dated March 8, 1982, and as supplemented by Minutes of the Meeting dated 2 June 1982 and TSI's letters to ANI dated August 2 and September 3, 1982. This test plan and supplements thereto were reviewed and approved by the American Nuclear Insurers prior to the commencement of the test program as indicated by letters dated March 16 and August 6, 1982.

All of the materials comprising the THERMO-LAG 330-1 Subliming Coating Envelope System used in this test program were manufactured in accordance with the procedures set forth in TSI's Nuclear Quality Assurance Program Manual and Quality Control Operating Procedures Manual, which were also previously accepted by the American Nuclear Insurers.

The THERMO-LAG 330-1 Subliming Coating Envelope System materials were applied in accordance with the procedures set forth in TSI's Nuclear Quality Assurance Program Manual and Quality Control Operating Procedures Manual. The envelope configuration is described in Section 7.0 and 8.0 of this report, and the Product Application and Repair Procedures are shown in Section 4 of Appendix I to this report.

1.2 Summary

Based on the results and observations of this test program, the THERMO-LAG 330-1 Subliming Coating Envelope System meets all the requirements and performance criteria of ANI's Bulletin #5(79) entitled: "ANI/MAERP Standard Fire Endurance Test Method to Qualify A Protective Envelope For Class 1E Electrical Circuits", which is shown in Appendix II of this report. This conclusion is supported by the following test results and observations:

1. The test articles were exposed to the standard time/temperature curve of ASTM E119 for a minimum of one hour, followed by a 2½ minute, minimum, water hose stream test, with no loss of circuit integrity in the test circuits. The THERMO-LAG 330-1 Subliming Coating Envelope System met all the one-hour ASTM E119 fire endurance and water hose stream test requirements in all aspects.

2. The water hose stream test did not adversely affect the virgin THERMO-LAG 330-1 Subliming Coating Envelope System remaining on the test articles following the fire endurance test.

3. Examination of the cables within the test articles, following both the fire endurance and water hose stream tests, indicated that they were all intact, functional and free of heat or fire damage.

4. The recorded cable surface temperatures in all test articles after exposure to the ASTM E119 time/temperature environment for a minimum of 60 minutes never exceeded:

   A) Average - 210° F

   B) Maximum Singular Thermocouple - 288° F

2.0 PURPOSE

The purpose of this test program was to provide engineering information required to qualify the THERMO-LAG 330-1 Subliming Coating Envelope System for use as a one-hour protective fire rated barrier for cable trays, conduits, air drops, instrumentation and equipment which contain "generic" cables.

This test program was performed to verify the capability of THERMO-LAG 330-1 Subliming Coating Envelope System to meet all the applicable acceptance criteria specified by the American Nuclear Insurers in their Bulletin #5(79).

3.0 TEST LOCATION

The test were performed during the period of September 9 through September 28, 1982. The tests were conducted at the laboratory facilities of TSI, Inc. in St. Louis, Missouri by its personnel, and under the supervision and total control of Industrial Testing Laboratories of St. Louis, Missouri, an independent testing laboratory.

4.0 TEST METHODS

The test methods and standards utilized in this test program were:

1. TSI's Engineering Test Plan, second revision dated March 8, 1982 and supplemented by Minutes of the Meeting dated June 2, 1982 and TSI's letters to ANI dated August 2 and September 3, 1982. This test plan and supplements thereto were reviewed and approved by the American Nuclear Insurers prior to the commencement of the test program as indicated by letters dated March 16 and August 6, 1982.

2. American Nuclear Insurer's Bulletin #5(79) entitled: "ANI/MAERP Standard Fire Endurance Test Method To Qualify A Protective Envelope for Class 1E Electrical Circuits", presented herein as Appendix II.

3. American Society for Testing Materials Standard entitled: "ASTM E119 Standard Method of Fire Tests of Building Construction and Materials".

4.1 ASTM E119 Fire Endurance Tests

Paragraph 3.4.1 of ANI's Bulletin #5(79) states that the protective envelope shall be exposed to the standard time/temperature curve found in ASTM E119-76 (revised to E119-81) for a minimum of one hour. In this test, test articles were exposed to the standard time/temperature curve presented in ASTM E119-76 (ANSI A2.1) for a minimum period of one (1) hour. The standard time/temperature curve is presented herein as Figure 1.

The required accuracy of the temperature control requirement under this test program is that the area under the test time/temperature curve shall be within ten percent (10%) of the corresponding area under the standard time/temperature curve.

4.2 Water Hose Stream Tests

In accordance with Paragraph 3.4.2(1) of ANI's Bulletin #5(79), each of the test articles was exposed to a 2½ minute minimum water hose stream test, applied to the exposed surfaces of the test articles, within three (3) minutes after the completion of the fire endurance test.

A Mack 800 gpm water pumper fire truck was used to provide the water hose stream during these tests. The hose stream was delivered through a 2½-inch national standard playpipe, equipped with a 1 1/8-inch tip at a nozzle pressure of 30 psi. The tip of the nozzle was held at a distance of 20 feet from the test assembly. The length of the hose was 50 feet.

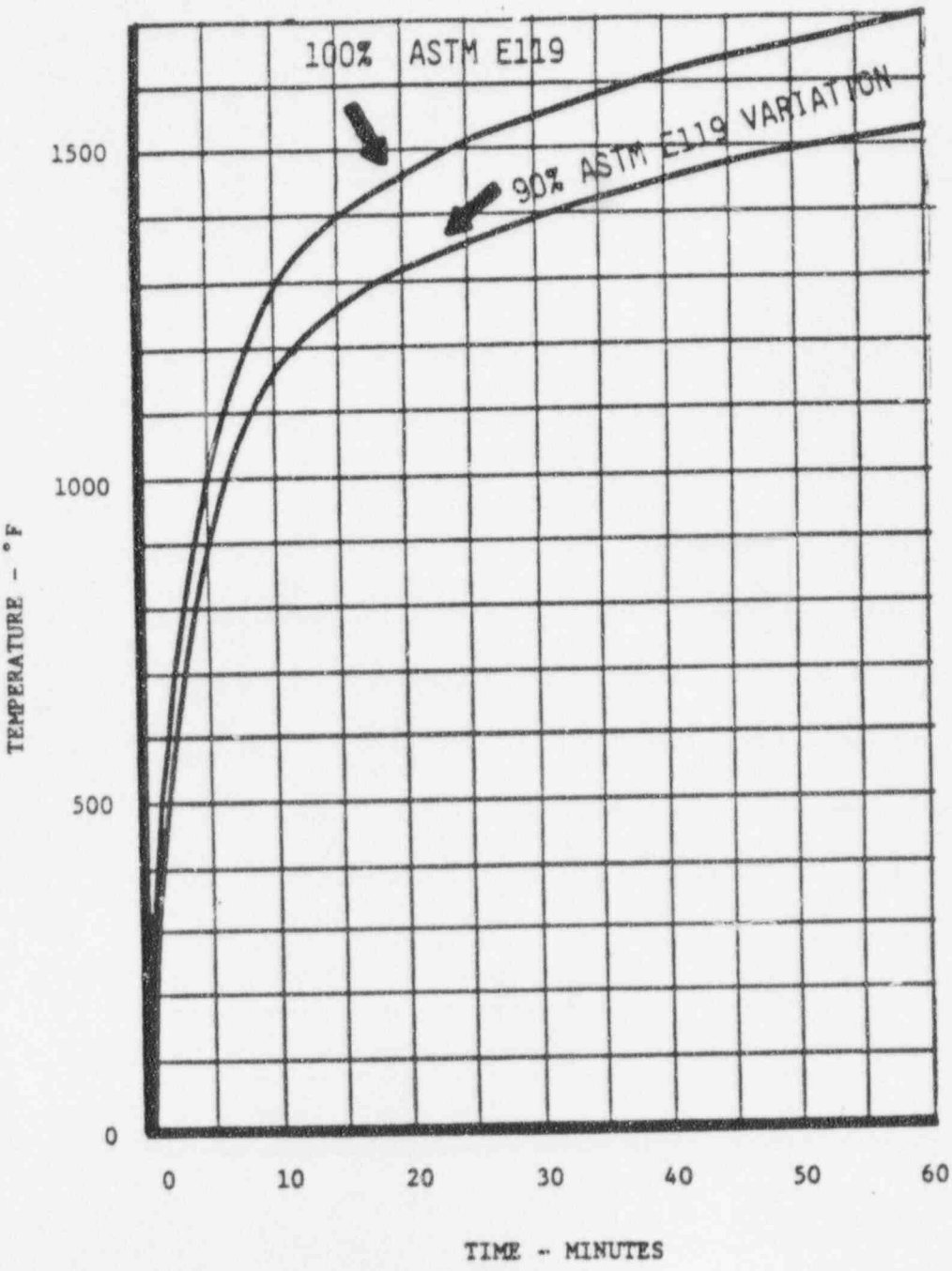
4.3 Electrical Circuit Integrity Monitoring

Paragraph 3.5 of ANI's Bulletin #5(79) requires that circuits contained in a test article do not de-energize during exposure to the fire endurance and water hose stream tests. A required test condition is to continuously monitor a sufficent number of electrical circuits in each test specimen to detect failure; circuit to circuit (conductor to conductor short circuits), circuit to system (conductor continuity), and circuit to ground (conductor to ground). Schematic diagrams of the three monitoring channels utilitized in this test program are shown in Figure 2.

FIGURE 1

TSI'S ASTM E119 FIRE SIMULATION TEST FACILITY

PERFORMANCE PARAMETERS



Since monitoring all of the conditions in each test assembly would be impractical, eight cables in each of the test assemblies were to be continuously monitored during the fire endurance and water hose stream tests using both a Multi-light Display Panel and an Eight-Channel Event Recorder as follows: (Specific cables instrumented in each of these monitoring channels are shown in Table 1)

1. Power, control and/or instrumentation cables in each assembly were connected as a short circuit detection circuit as shown in Figure 2A;

2. Power, control and/or instrumentation cables in each assembly were connected as a continuity monitoring circuit as shown in Figure 2B;

3. Power, control and/or instrumentation cables in each assembly were connected as a ground detection circuit as shown in Figure 2C.

The cables selected for continuous monitoring were immediately adjacent to a wall or to ladder rungs of the assembly to insure that the most heat critical locations were being monitored.

The Multi-light Display Panel and Event Recorder were wired in such a manner that the monitored circuits were energized, and in the event of a test article cable failure:

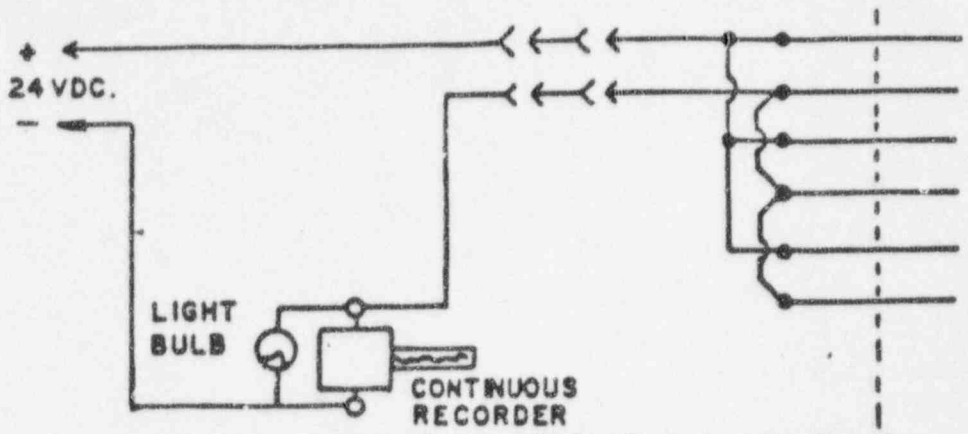
1. Circuit-to-Circuit: Light would come on and event recorder indicate the condition.

2. Circuit-to-System: Light would go out and event recorder indicate the condition.

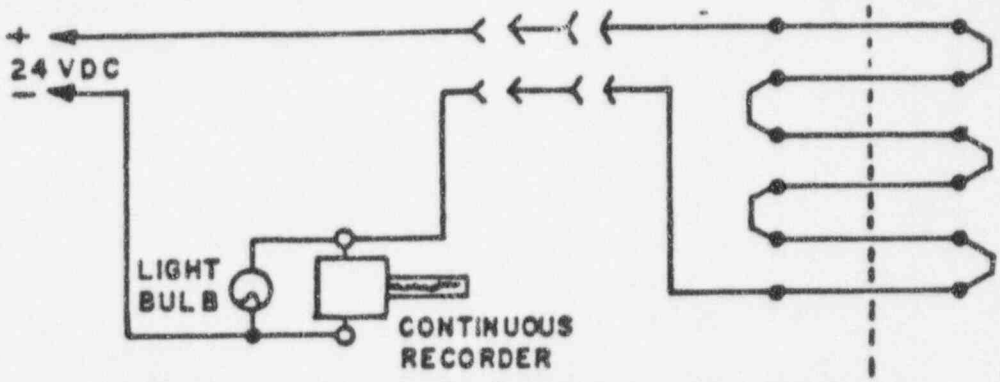
3. Circuit-to-Ground: Light would come on and event recorder indicate the condition.

4. Following the water hose stream test, the circuit to circuit and circuit to ground circuits were manually checked with a test lead to assure the monitoring circuits had been functioning during the fire and water hose stream tests.

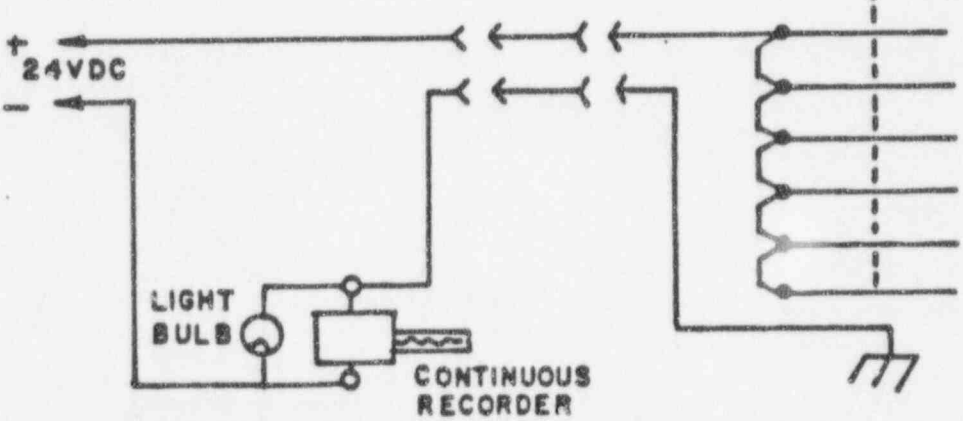
Figure 3 shows the Multi-light Display Panel and the Eight-Channel Event Recorder.



A-TYPICAL CIRCUIT TO CIRCUIT MONITORING CHANNEL



B-TYPICAL CIRCUIT TO SYSTEM MONITORING CHANNEL



C-TYPICAL CIRCUIT TO GROUND MONITORING CHANNEL

FIGURE 2: CABLE INTEGRITY MONITORING CIRCUITS

TOLERANCES (UNLESS OTHERWISE SPECIFIED)
DECIMAL ±
FRACTIONAL ±
ANGULAR ±

REVISIONS

NO	DATE	BY
1		
2		
3		
4		
5		

TSI, INC. 3260 BRANNON AVE. ST. LOUIS, MO. 63139.

CABLE INTEGRITY MONITORING CIRCUITS.

J. DUMAIS

CHK'D [illegible]
TRACED

SCALE NONE

DATE 7-17-1982
APP'D

MATERIAL

DRAWING NO.

TABLE 1

THERMOCOUPLE CHANNEL ASSIGNMENT

FOR MONITORING CIRCUIT INTEGRITY WITHIN

THE TEST ARTICLES

FUNCTION LEGEND:

P = POWER
C = CONTROL
I = INSTRUMENTATION

TEST NO	CHANNEL ASSIGNMENT	MONITORING CIRCUIT	CABLE TYPE	DESCRIPTION
1	1	Circuit to Circuit	C	12/7, 600V
	2	Circuit to Circuit	P	300MCM, 600V
	3	Circuit to System	I	16/2, 600V
	4	Circuit to System	C	12/7, 600V
	5	Circuit to System	C	12/7, 600V (No light)
	6	Circuit to Ground	C	12/7, 600V
	7	Circuit to Ground	P	300MCM, 600V
	8	Circuit to Ground	I	16/2, 600V
2	1	Circuit to System	C	12/7, 600V
	2	Circuit to System	I	16/2, 600V
	3	Circuit to System	P	300MCM, 600V
	4	Circuit to Circuit	C	12/7, 600V
	5	Circuit to Circuit	I	16/2, 600V
	6	Circuit to Ground	P	300MCM, 600V
	7	Circuit to Ground	C	12/7, 600V
	8	Circuit to Ground	I	16/2, 600V
3&5 Combined	1	Circuit to Circuit	I	16/2, 600V
	2	Circuit to Circuit	C	12/7, 600V
	3	Circuit to System	P	300MCM, 600V
	4	Circuit to System	I	16/2, 600V
	5	Circuit to System	C	12/7, 600V (No light)
	6	Circuit to Ground	C	12/7, 600V
	7	Circuit to Ground	P	300MCM, 600V
	8	Circuit to Ground	I	16/2, 600V

TABLE 1

THERMOCOUPLE CHANNEL ASSIGNMENT

FOR MONITORING CIRCUIT INTEGRITY WITHIN

THE TEST ARTICLES

(CONTINUED)

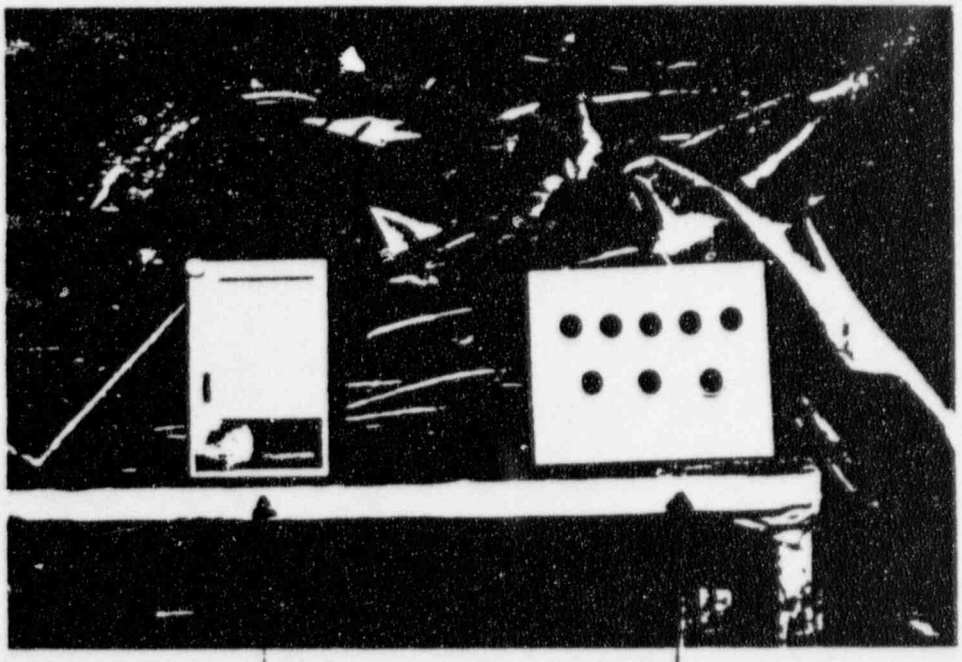
TEST NO	CHANNEL ASSIGNMENT	MONITORING CIRCUIT	CABLE TYPE	DESCRIPTION
4	1	Circuit to Circuit	I	16/2, 600V
	2	Circuit to Circuit	C	12/7, 600V
	3	Circuit to System	P	300MC, 600V
	4	Circuit to System	I	16/2, 600V
	5	Circuit to System	C	12/7, 600V (No Light)
	6	Circuit to Ground	I	16/2, 600V
	7	Circuit to Ground	C	12/7, 600V
	8	Circuit to Ground	P	300MCM, 600V
6	1	Circuit to Circuit	P	300MCM, 600V
	2	Circuit to Circuit	C	12/7, 600V
	3	Circuit to System	P	300MCM, 600V
	4	Circuit to System	I	16/2, 600V
	5	Circuit to System	C	12/7, 600V
	6	Circuit to Ground	P	300MCM, 600V
	7	Circuit to Ground	C	12/7, 600V
	8	Circuit to Ground	I	16/2, 600V

FIGURE 3

PHOTOGRAPH OF THE EIGHT-CHANNEL EVENT RECORDER

AND

THE MULTI-LIGHT DISPLAY PANEL



5.0 DESCRIPTION OF TSI'S TEST FACILITY

TSI's ASTM E119 Fire Simulation Facility consists of a high temperature test furnace, a water hose spray booth, equipped with a multi-positioning table, and a transfer cart with connecting rail system. The facility is a self contained test unit with the ASTM E119 fire endurance tests being conducted in the high temperature test furnace. Upon completion of the fire test, the test article is moved on the transfer cart to the water spray booth where it is transferred using an electric hoist to the multi-positioning table. This table rotates 180° and moves both vertically and horizontally during the water hose stream test, permitting the hose stream to be applied over all accessible surfaces of the test article. The water hose stream is provided by a Mack 800 gpm water pumper fire truck which is located outside the building. A schematic of TSI's ASTM E119 Fire Simulation Facility is shown in Figure 4.

5.1 High Temperature Test Furnace

The test furnace is constructed of steel plate lined with high temperature insulative material and has exterior dimensions of 49½-inches in width, 77-inches in depth and 66 3/4-inches in height. The bottom section of the furnace is made of 1/4-inch steel plate and is lined with a 5-inch layer of three different types of Fiberfrax Durablanket.

The furnace interior is 36-inches wide by 71-inches deep by 50½-inches high. The bottom section is further insulated with approximately 5-inches of Monocast 50 in order to protect the test assembly from lower end temperature effects. The entire furnace is mounted on 4-inch "H" beam supports.

A total of eleven burners (9 natural gas and 2 propane) are arranged in the furnace as follows:

One Group of three (3)	Back Wall
One Group of three (3)	East Wall
One Group of five (5)	West Wall

The burners are staggered to provide more uniform flamming in the proximity of the test article.

A general arrangement of a test article in the test furnace is shown in Figure 5, and a schematic of the High Temperature Test Furnace is shown in Figure 6.

5.2 Transfer Cart

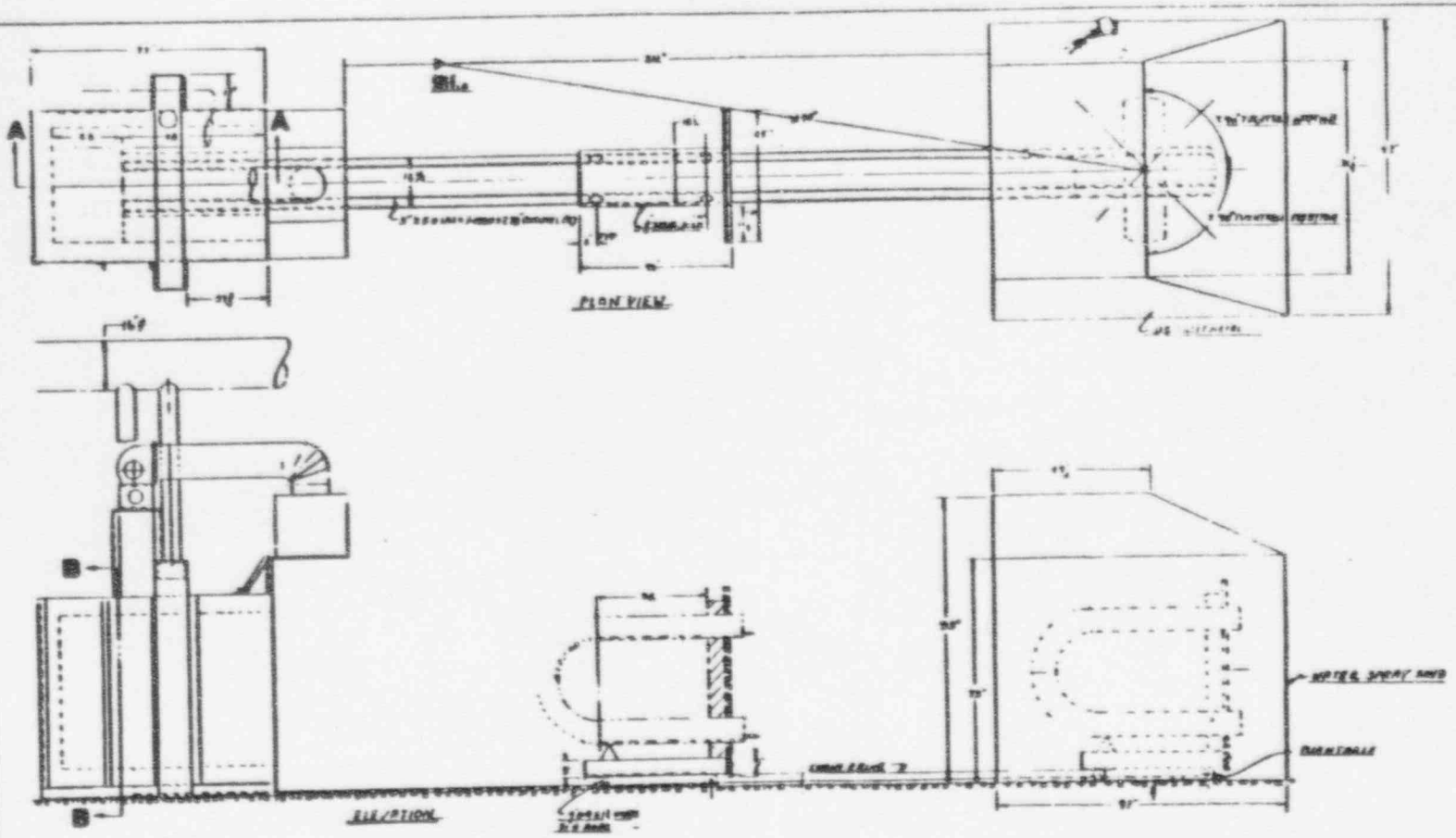
The transfer cart is used to move the test articles into the test furnace and then remove them upon completion of the fire test. It is also used to transport the test articles from the test furnace to the water hose spray booth. The transfer cart is approximately 50 inches long by 18 inches wide and has 4 inch diameter wheels. The transfer cart is attached to the access door which comprises one side of the test furnace. The door and transfer cart unit is rolled to the water hose spray booth on rails.

5.3 Water Hose Spray Booth

The water hose spray booth is constructed of 1/8-inch steel plate and has exterior dimensions of 97 inches in width, 97 inches in depth and 93 inches in height, at the front of the spray booth. The roof of the spray booth tapers to 73 inches at the back of the enclosure.

5.4 Multi-positioning Table

The multi-positioning table is hydraulically operated by control valves located on the exterior of the spray booth and is constructed of two forks from a fork lift truck and the necessary supporting structure. The test article on the transfer cart is pulled on the multi-positioning table using a 1/2 ton electric hoist. During the water hose stream test, the multi-positioning table is rotated and raised and lowered such that the water hose stream can be applied to the exposed surfaces of the test article.



See Figure 6 for Sections.

DES	DATE	DESCRIPTION
TSI		INC. 3260 BRANNON ST. LOUIS, MO 63139
SCALE 1/16 = 1'		APPROVED BY: Richard A. Schwartz
DATE 7-10 1982		DRAWING BY: pumpis

FIGURE 41 TSI'S ASTM E119 FIRE SIMULATION FACILITY

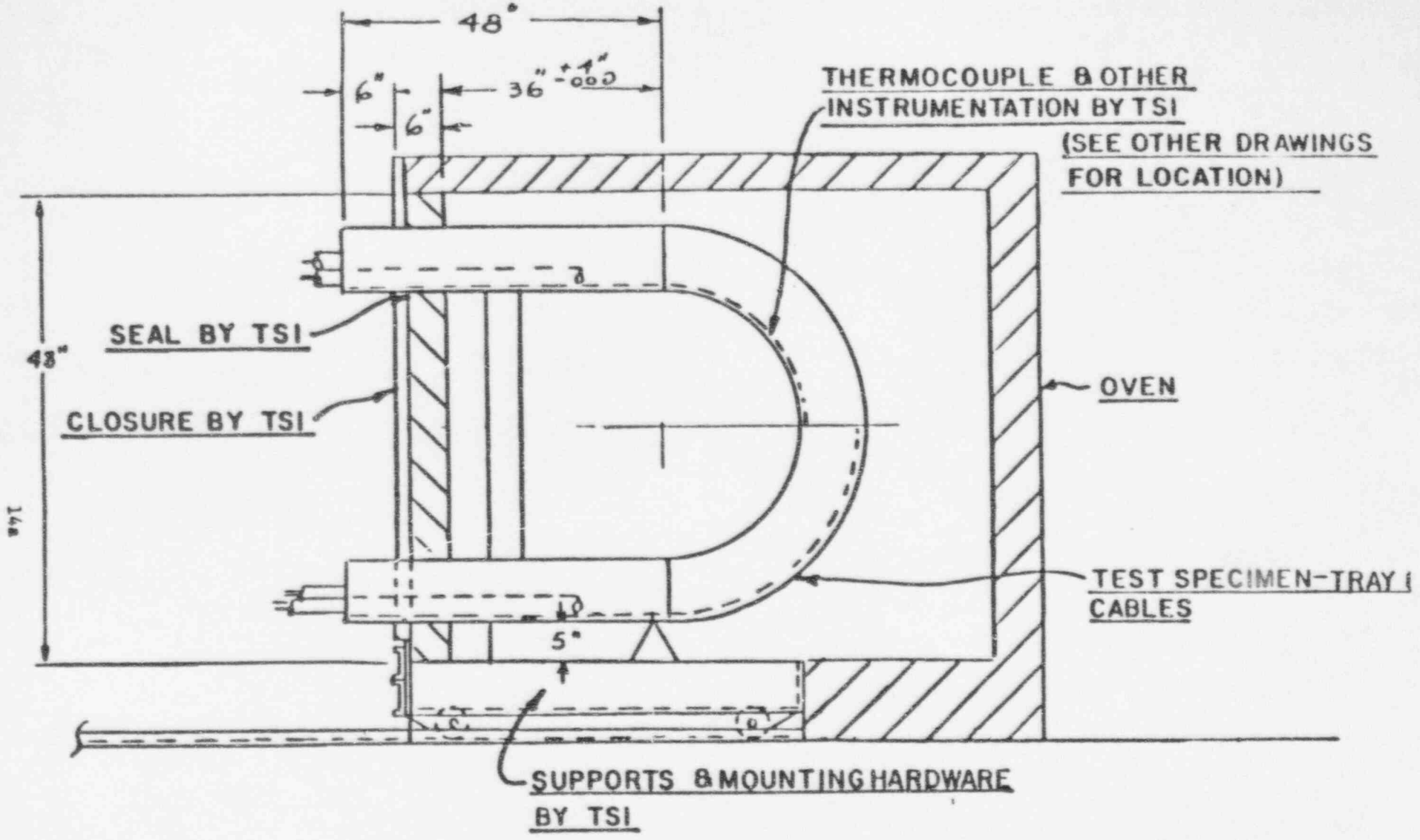


FIGURE 5A: TEST ARTICLE NO. 2 IN TSI'S TEST FURNACE

TSI, INC. 3260 BRANNON. ST. LOUIS. MO. 63139

SCALE: NONE	APPROVED BY: B. Elwood	DRAWN BY J. DUMI
DATE: 10-8-1982		REVISED

GENERAL ARRANGEMENT - FIRE ENDURANCE TESTS

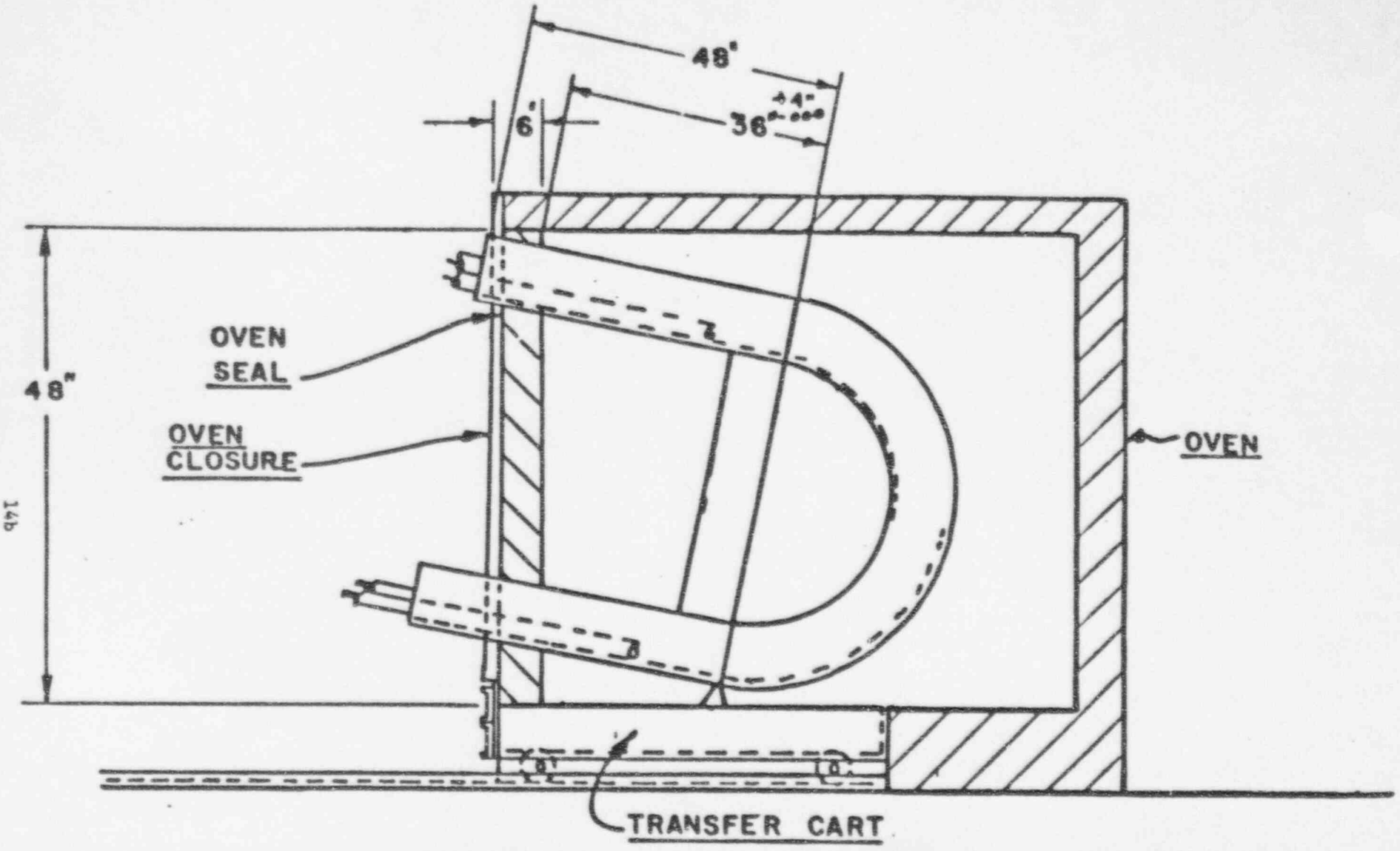


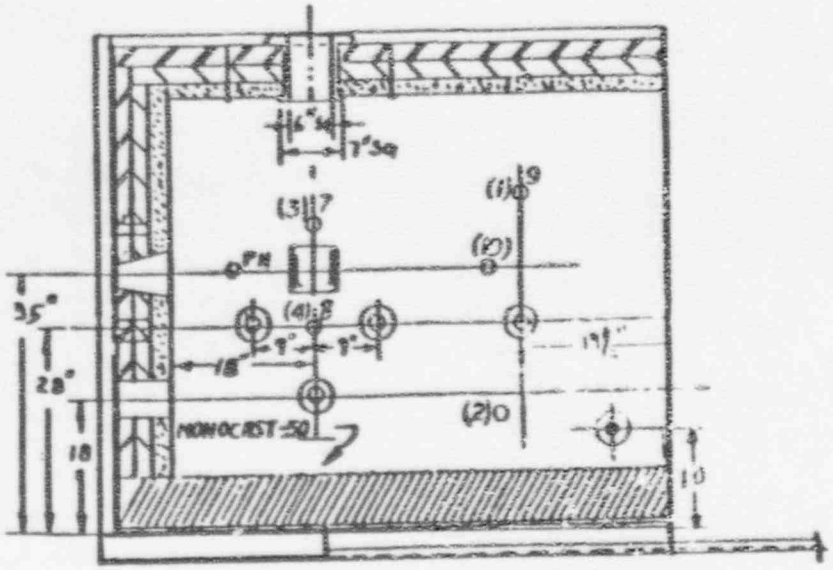
FIGURE 5B: TYPICAL ARRANGEMENT OF TEST ARTICLE IN TSI'S TEST FURNACE FOR TEST ARTICLES 1, 3&5 COMBINED, 4 AND 6

TSI, INC. 3260 BRANNON. ST. LOUIS. MO. 63139.

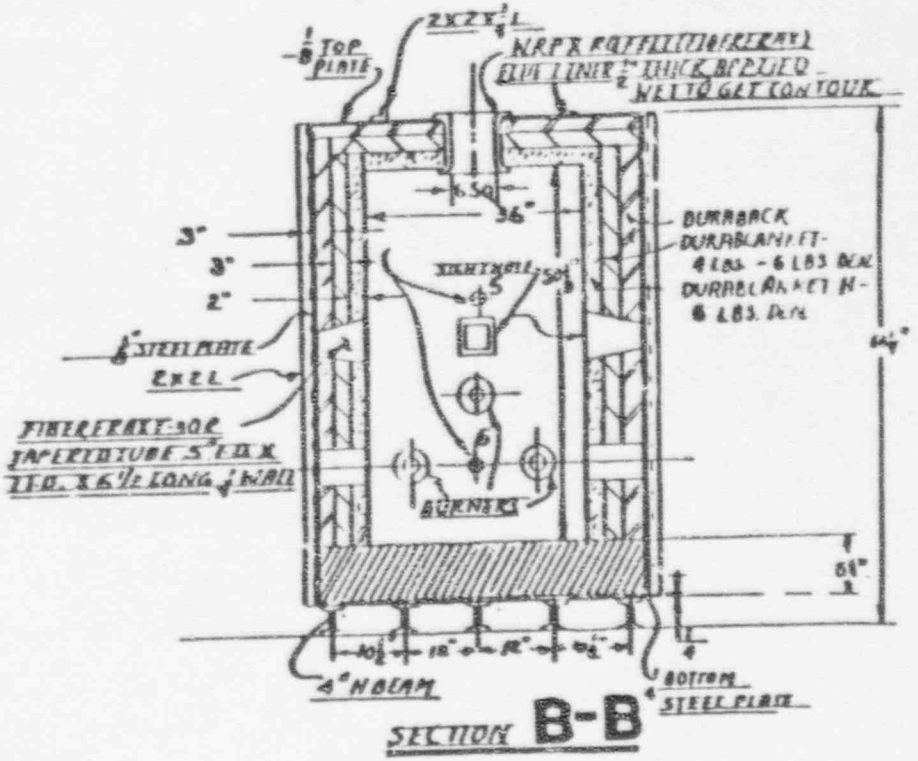
SCALE: NONE | APPROVED BY: B. Evans | DRAWN BY J. DUMP

DATE: 10-8-1982 | REVISED

GENERAL ARRANGEMENT - FIRE ENDURANCE TESTS



SECTION A-A



SECTION B-B

LOCATION OF FURNACE THERMOCOUPLES:

T/C #	LOCATION
(1)	Section A/ - East
(2)	Section AA - East
(3)	Section AA - East
(4)	Section AA - East
5	Section BB - South
6	Section BB - South
7	Section AA - West
8	Section AA - West
9	Section AA - West
(10)	Section AA - East

See Figure 4 for location of Sections.

DWT	QTY	DESCRIPTION
TSI, INC. 3260 BRANNON ST. LOUIS, MO 63139		
SCALE: None	APPROVED BY: Richard A. Johnson	DRAWING NO. DUMP15
DATE: 7-19-1982		REVISION
FIGURE 6: HIGH TEMPERATURE TEST FURNACE		
		FIGURE 6

6.0 TEST MATERIALS

The THERMO-LAG 330-1 Subliming Coating Envelope System used in this test program is described in the following paragraphs. Product data sheets for each of these materials are shown in Section 2 of Appendix I.

6.1 THERMO-LAG STRESS SKIN TYPE 330-69

This material provides strong mechanical base for the THERMO-LAG 330-1 Subliming Coating. It is an open weave, "V" stiffened steel mesh having a 0.017 inch minimum strand diameter, 56 minimum mesh size and a weight per square yard of 1.75 pounds minimum.

6.2 THERMO-LAG 330-1 SUBLIMING COATING

This material provides the required level of fire resistance. It is a water based, subliming, thermally activated fire resistive coating which volatilizes at fixed temperatures - exhibits a volume increase through the formation of a multi-cellular matrix, and blocks heat to protect the substrate material to which it is applied.

6.3 THERMO-LAG 330-70 CONFORMABLE CERAMIC BLANKET (Used on Air Drop Only)

This material is used for insulation enhancement of temperature sensitive components and is designed to provide equal compatibility, efficiency and greater heat resistance when used in concert with THERMO-LAG 330-1 Subliming Coating. It is a lightweight, flexible ceramic blanket manufactured from long ceramic fibers.

As specified in Paragraph 3.3 of ANI's Bulletin #5(79), the above materials are rated as non-combustible with a Flame Spread, Fuel Contributed and Smoke Developed of 25 or less. Section 3 of Appendix I is comprised of ASTM E84 Test Documentation for the above materials.

6.4 THERMO-LAG CURE ACCELERATOR (OPTIONAL)

This is a non-combustible material which when mixed with the THERMO-LAG 330-1 Subliming Coating will accelerate the set-up time without adversely affecting the fire resistive properties of the material. The mixture was applied to the test articles, by means of caulking and troweling, to seal and cover the edges, butt joints, flanges and other surfaces, and to effect the simulated repair patch area, thus, demonstrating the feasibility of accelerated set-up time.

7.0 TEST ARTICLES

The test articles used in this test program were comprised of two (2) 6-inch by 6-inch industry standard solid bottom cable tray sections, two (2) 12-inch by 4-inch industry standard ladder cable tray sections, and one (1) 4-inch diameter industry standard electrical conduit.

An air drop was incorporated into one of the 12-inch by 4-inch ladder cable trays. A condulet and pullbox were incorporated into the conduit test article. A repair procedure was incorporated into one of the 12-inch by 4-inch ladder cable tray test articles.

The following test article generic cables, utilized in this test program, were purchased by TSI, Inc. from Ranger Wire and Cable Company (Texas) and were manufactured by Manhattan Cable Co. (New York):

GENERIC CABLE FUNCTION	DESCRIPTION			REEL
Power Cable	300 MCM	XLP/PVC	.8125 OD	#ELM 503411A
Control Cable	12/7	XLP/PVC	.625 OD	#ELM 503431A
Instrumentation Cable	16/2	XLP/PVC	.250 OD	#ELM 503421A

The configuration of all test articles was that of a block letter "U". These test articles are described in terms of their configuration and the location of each generic cable within each of the test articles in the following paragraphs.

7.1 Test Articles 1 & 2 - Solid Bottom Cable Trays Test Numbers 1 & 2

A. Design and Construction

Two solid bottom cable tray sections were used to construct Test Articles 1 and 2. These trays were constructed of 11 gauge galvanized steel side and bottom sections. The cross-sectional configuration of each tray was 6-inches wide by 6-inches high. The approximate length and height of each test article was 5 feet and 3 feet in a "U" configuration, for a combined total fire exposed length of 10 feet minimum. A 5-inch square steel tube was attached to the tray in Test Article No. 1.

B. "Generic" Cables

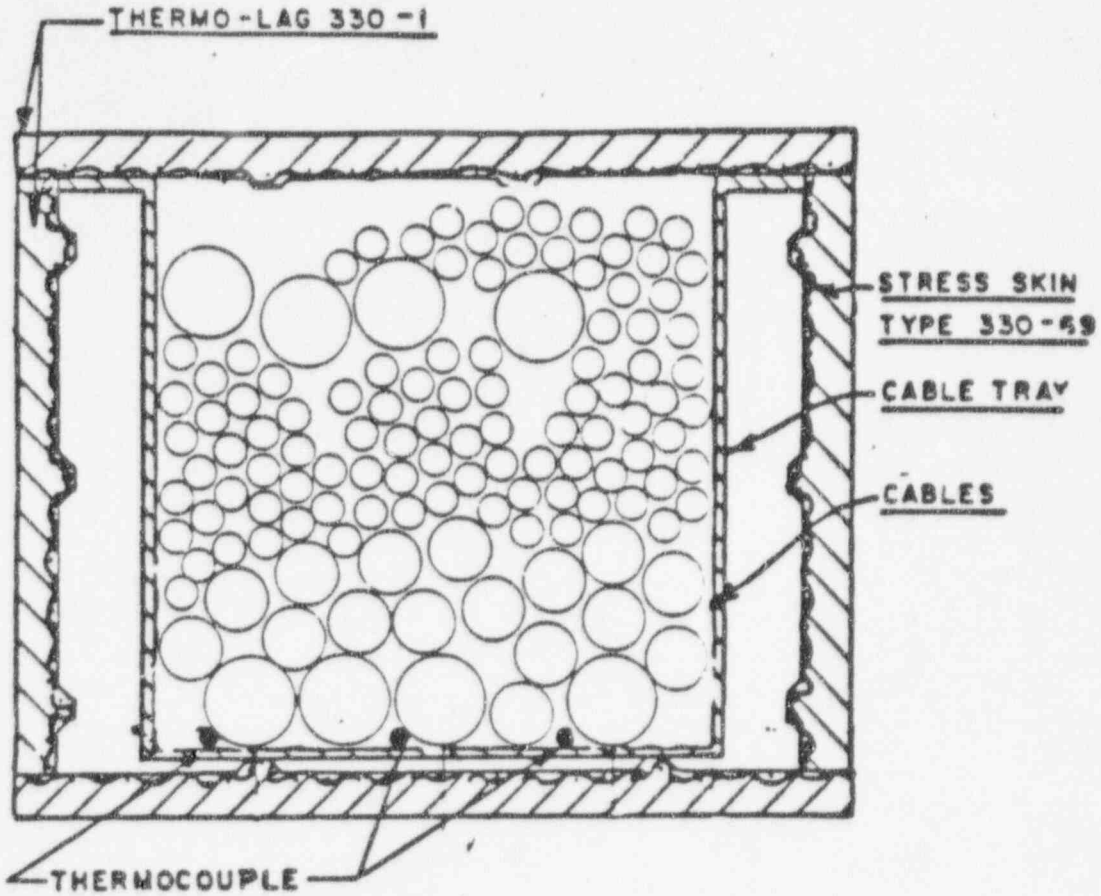
A total of 122 generic power, control and instrumentation cables were installed in Test Article No. 1 and 15 generic power, control and instrumentation cables were installed in Test Article No. 2. These generic cables are described as follows:

Cable Type	Test Article No. 1	Test Article No. 2
300MCM Power	8	2
12/7 Control	98	9
16/2 Instrumentation	16	4

The location of each of these cables, identified by cable item number within each of the test articles, is shown in Figure 7A and 7B.

C. Applicability

Test Article No. 1 was representative of a typical instrumentation or control tray filled to 100% of capacity (40% of cross-sectional area). Test Article No. 2 was representative of a typical instrumentation or control tray filled with a single layer of cables. The steel tube attached to Test Article No. 1 was representative of tray support steel utilized with cable trays.



1/2

3/8

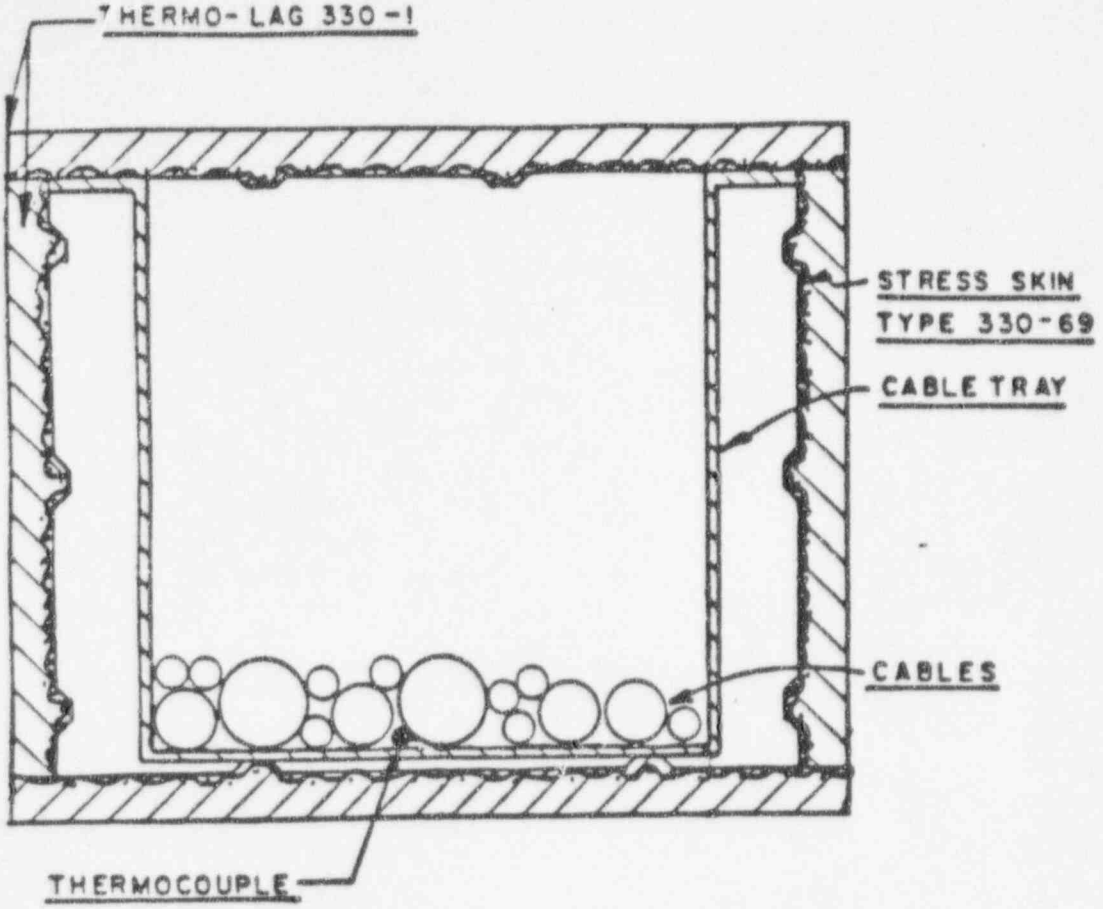
3/16

TSI. INC. 3260 BRANNON. ST. LOUIS, MO. 63139.

SCALE: NONE	APPROVED BY: B Elrod	DRAWN BY J. DUMPIS
DATE: 10-9-1982		REVISED

CROSS-SECTIONAL VIEW OF TEST ARTICLE NO. 1
6"x6" TRAY - 40% FILL

DRAWING NUMBER 7A



TSI, INC. 3260 BRANNON. ST. LOUIS, MO. 63139.

SCALE: NONE	APPROVED BY: B E Evans	DRAWN BY J. DUMPIS
DATE 10-9-1982		REVISED

CROSS-SECTIONAL VIEW OF TEST ARTICLE NO. 2
6" X 6" TRAY - 1 LAYER

20	DRAWING NUMBER 7B

7.2 Test Articles 3&5 Combined & 4 - Ladder Cable Trays
Test Numbers 3&5 Combined & 4

A. Design and Construction

Two ladder cable tray sections were used to construct Test Articles 3&5 combined and 4. These trays were constructed of 11 gauge galvanized steel. The bottom ladder section of each test article was constructed of 3/4-inch galvanized steel tubing. The cross-sectional configuration of each tray was 12-inches wide by 4-inches high. The approximate length and height of each test article was 5 feet and 3 feet in a "U" configuration, for a combined total fire exposed length of 10 feet, minimum. An air drop, which was originally identified as Test Article No. 5, was subsequently installed as an integral part of Test Article No. 3, thus, the designation of the combined ladder cable tray test section was changed to Test Article 3&5 Combined.

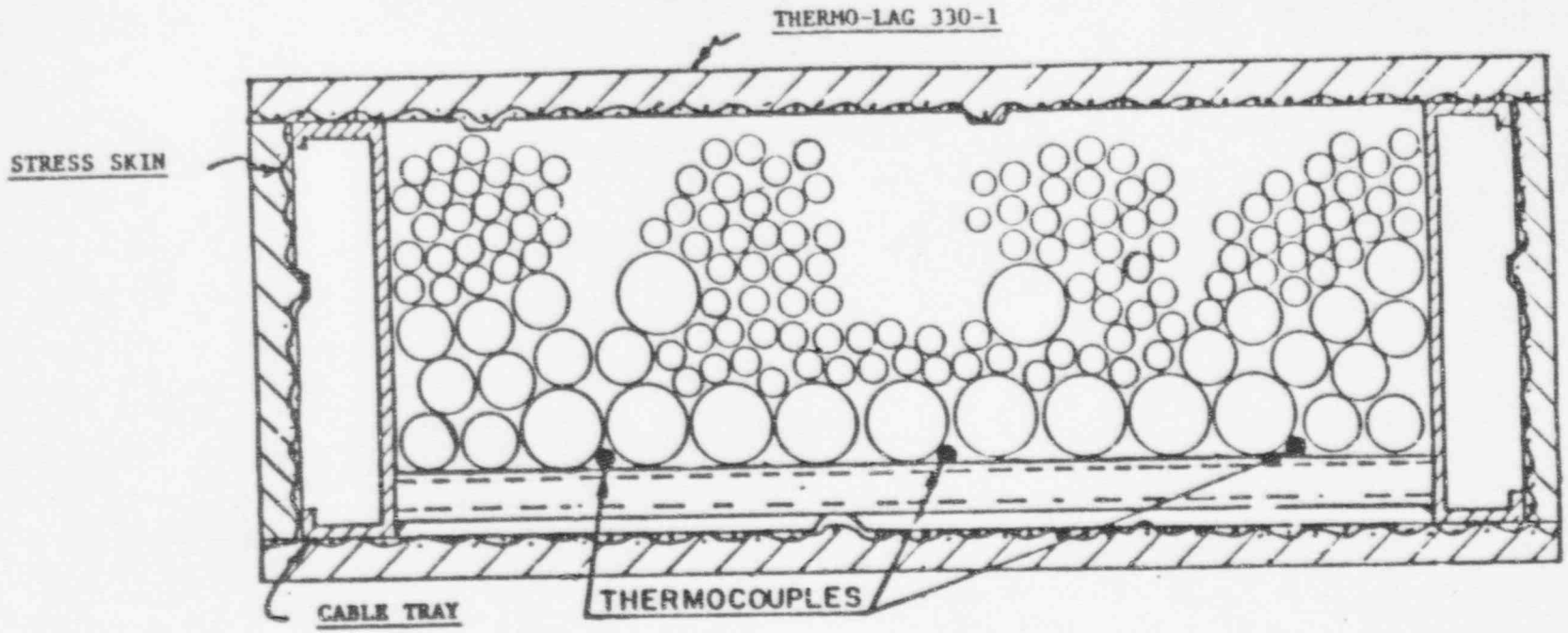
A repair procedure was also incorporated into the envelope of Test Article No. 3&5 Combined (see Section 8.0).

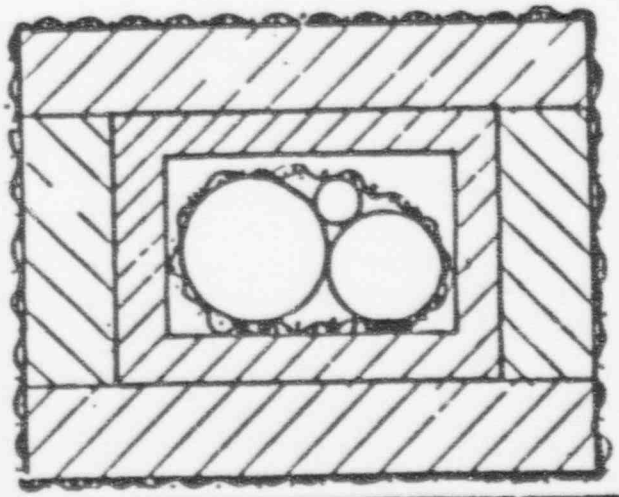
B. "Generic" Cables

A total of 161 generic power, control and instrumentation cables were installed in Test Article No. 3&5 Combined and 33 generic power, control and instrumentation cables were installed in Test Article No. 4. These generic cables are described as follows:

Cable Type	Test Article No. 3&5	Test Article No. 4
300MCM Power	12	5
12/7 Control	19	14
16/2 Instrumentation	130	14

The location of each of these cables, identified by cable item number within each of the test articles, is shown in Figure 7C and 7D.



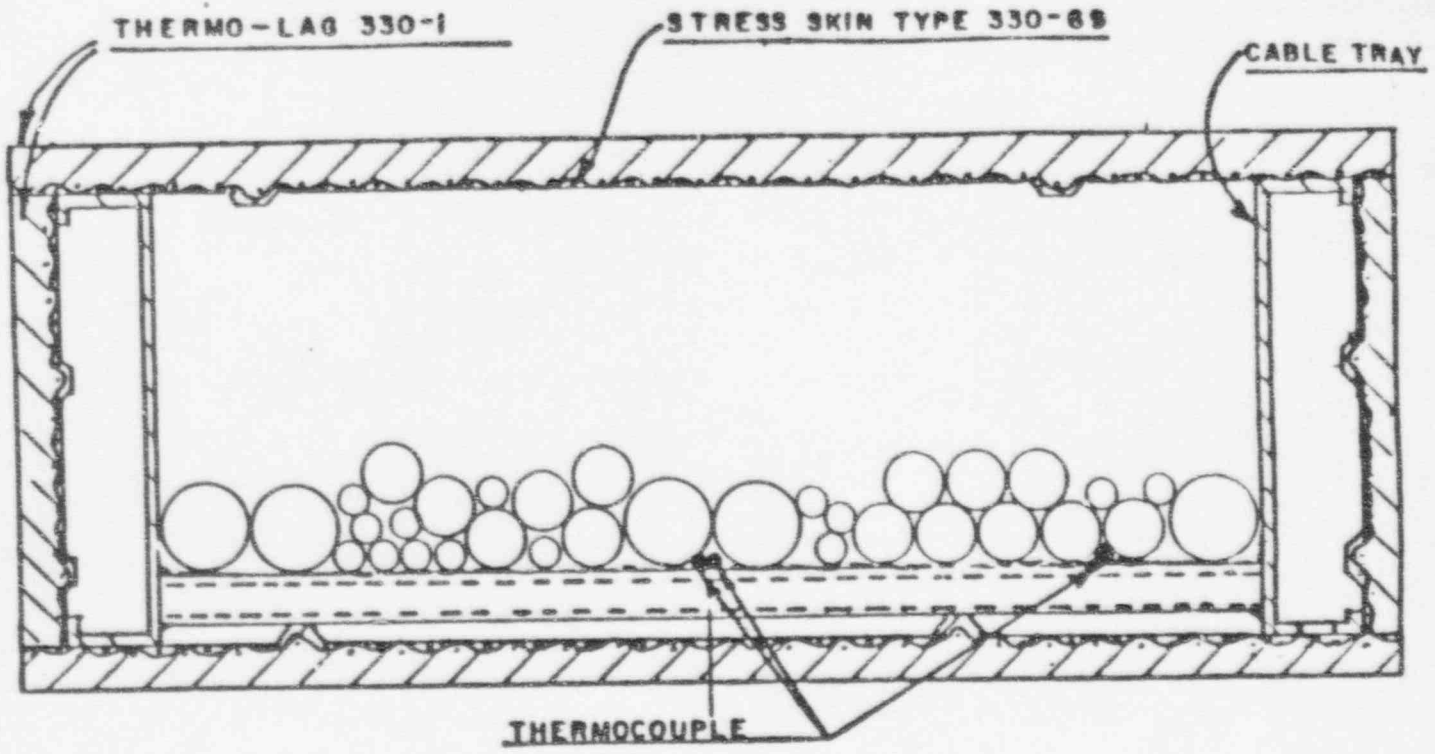


TSI, INC. 3260 BRANNON. ST. LOUIS. MO. 63139.

SCALE: NONE	APPROVED BY: B.E. Evans	DRAWN BY J. DUMPS
DATE: 10-15-1982		REVISED

CROSS-SECTIONAL VIEW OF TEST ARTICLE NO. 3&5 COMBINED
12"x4" TRAY - 40% FILL WITH AIR DROP

DRAWING NUMBER
7C



TSI, INC. 3260 BRANNON. ST. LOUIS. MO. 63139.

SCALE: NONE	APPROVED BY: B. Evans	DRAWN BY J. DUMPIS
DATE: 10-10-1982		REVISED

CROSS-SECTIONAL VIEW OF TEST ARTICLE NO. 4
12" X 4" TRAY - ONE LAYER

DRAWING NUMBER
7D

C. Applicability

Test Article No. 3 was representative of a typical power or control tray filled to 100% of capacity (40% of cross-sectional area). The repair patch incorporated into Test Article No. 3 was typical of a repair patch that might be made after initial installation (see Section 8.0).

Test Article No. 5, which was an integral part of Test Article No. 3, was representative of a typical air drop. The method utilized to seal the air drop opening is identical to that which might be used to create a new air drop following installation, and also qualified as a repair procedure.

Test Article No. 4 was representative of a typical power or control tray filled with a single layer of cables.

7.3 Test Article No. 6 - 4 Inch Diameter Standard Electrical Conduit Test No. 6

A. Design and Construction

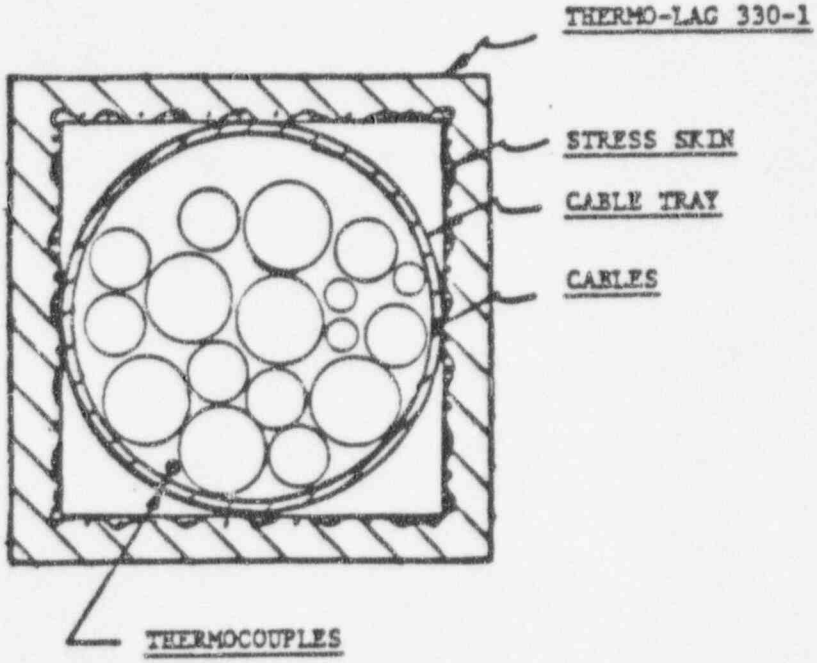
Test Article No. 6 was used to conduct Test No. 6. It was constructed of a 4-inch diameter standard electrical conduit section. A pullbox and a condulet were also installed in this test assembly. The approximate length and height of the test article was 5 feet and 3 feet in a "U" configuration, for a combined total fire exposed length of 10 feet, minimum.

B. "Generic" Cables

A total of 17 generic power, control and instrumentation cables were installed in Test Article No. 6. These generic cables are describe as follows:

Cable Type	Test Article No. 6
300MCM Power	6
12/7 Control	8
16/2 Instrumentation	3

The location of each of these cables, identified by cable item number within the test article, is shown in Figure 7E.



TEST, INC. 3260 BRANNON.ST.LOUIS,MO.63139.

SCALE: NONE	APPROVED BY: B Elsom	DRAWN BY: J DUMPS
DATE: 10-15-1982		DEVICE

CROSS-SECTIONAL VIEW OF TEST ARTICLE NO. 6
4 INCH DIAMETER STANDARD ELECTRICAL CONDUIT

25	DRAWING NUMBER 7E

C. Applicability

Test Article No. 6 was representative of a bulk power conduit (4-inch) filled to 100% capacity (40% cross-sectional area). Inclusion of the conduiet and the pullbox was designed to demonstrate that the envelope system can be used to protect equipment and hardware other than raceways.

7.5 All test article entries and exits were sealed air tight with THERMO-LAG 370 Conformable Ceramic Blanket in order to prevent air from circulating within each test articles. Typical photographs of this installation are shown in Figures 7F and 7G.

TYPICAL PHOTOGRAPHS OF

TEST ARTICLE ENTRIES AND EXITS SEALED

WITH THERMO-LAG 330-70 CONFORMABLE CERAMIC BLANKET

TO PREVENT AIR FROM CIRCULATING WITHIN EACH TEST ARTICLE

DURING EXPOSURE TO THE ASTM E119 FIRE ENDURANCE TEST

FIGURE 7F

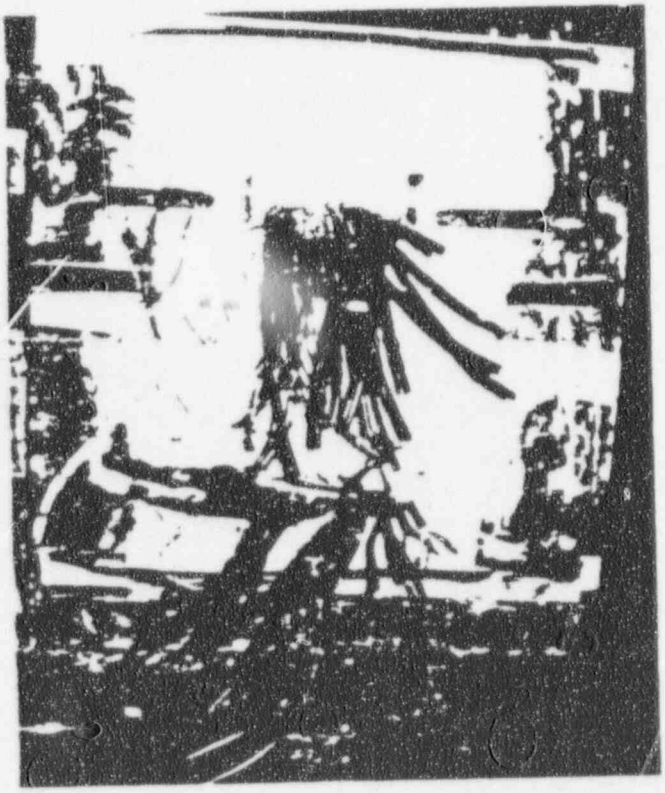
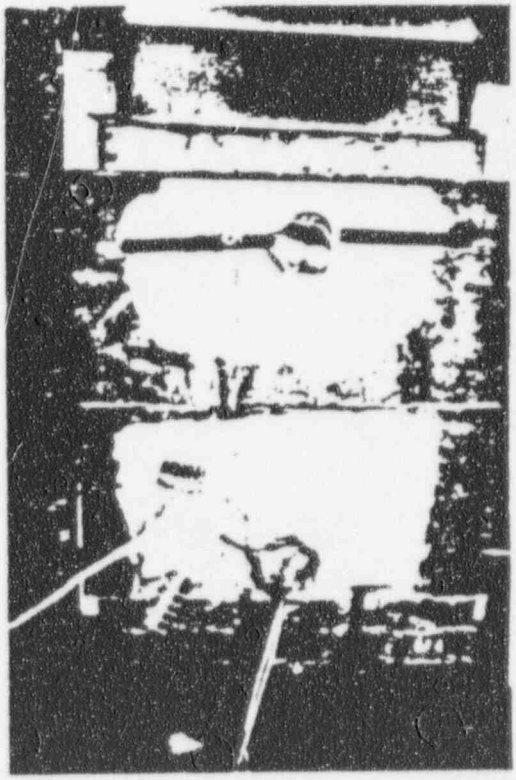


FIGURE 7G



8.0 PROTECTIVE ENVELOPE SYSTEM

A one-hour fire rated design of the THERMO-LAG 330-1 Subliming Coating Envelope System was applied to all test articles in accordance with TSI's Nuclear Quality Assurance Program Manual and Quality Control Operating Procedures Manual. The envelope configuration, as described in the following paragraphs, was also previously described in Section 7.0 of this report. Product Application and Repair Procedures are shown in Section 4 of Appendix I.

The Protective Envelope consisted of:

A) A layer of THERMO-LAG Stress Skin Type 330-69

B) A 0.500 inch minimum (-0.00, +0.125 inches) dry film thickness of THERMO-LAG 330-1 Subliming Coating

C) Butt joints, edges, flanges and the simulated repair patched area on Test Article No. 3&5 Combined were filled in with the THERMO-LAG 330-1/Cure Accelerator Mixture to demonstrate the ability of the material to accelerate the otherwise normally required set up time.

D) In addition to the above, the air drop utilized a layer of THERMO-LAG 330-70 Conformable Ceramic Blanket and an additional layer of THERMO-LAG Stress Skin Type 330-69.

A cross-sectional view of the one-hour fire rated design of the THERMO-LAG 330-1 Subliming Coating Envelope System, as applied to each test article, is shown in Figures 7A through 7E.

Several alternate application methods were used to install the THERMO-LAG 330-1 Subliming Coating Envelope System to the test articles. These methods included direct spray, brushing, rolling, troweling, caulking, and THERMO-LAG Prefabricated Panels, which were cut to the required size and shape and affixed to each test article by means of fasteners.

The application methods are delineated in considerable detail in Section 7 "Daily Work Sheets" and Section 8 "Applied Chronological Log Sheets" contained in Appendix III. Photographs of the coated test articles are shown in Figures 8 through 12.

FIGURE 8

PHOTOGRAPH OF TEST ARTICLE NO. 1

PRIOR TO BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS

FIGURE 9

PHOTOGRAPH OF TEST ARTICLE NO. 2

PRIOR TO BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS

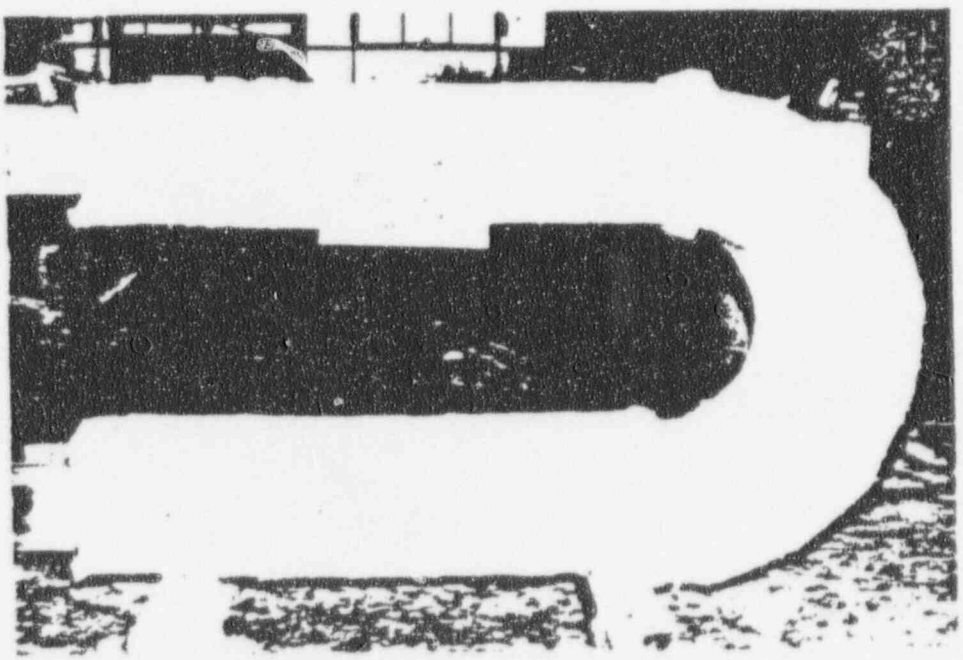


FIGURE 10

PHOTOGRAH OF TEST ARTICLE NO. 3&5 COMBINED

PRIOR TO BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS

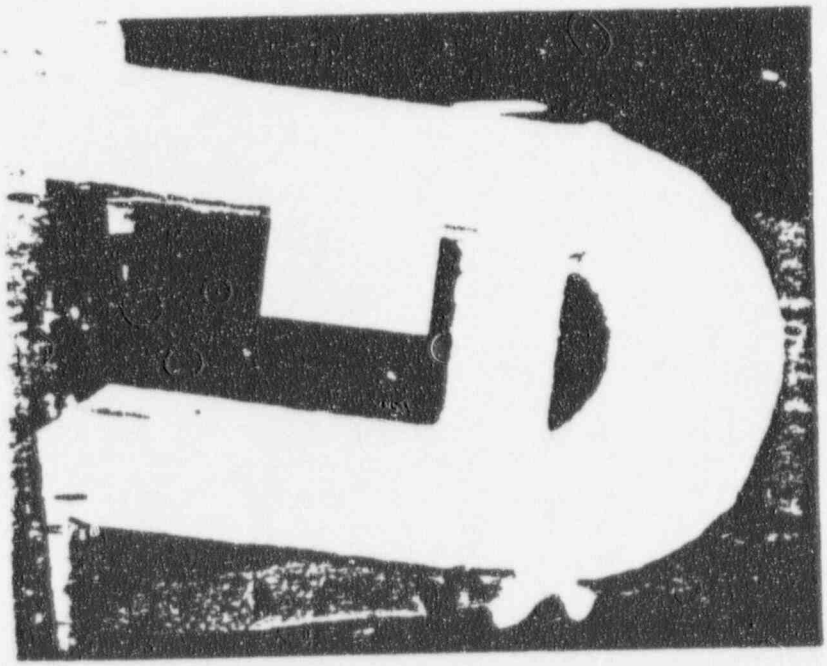


FIGURE 11

PHOTOGRAPH OF TEST ARTICLE NO. 4

PRIOR TO BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS

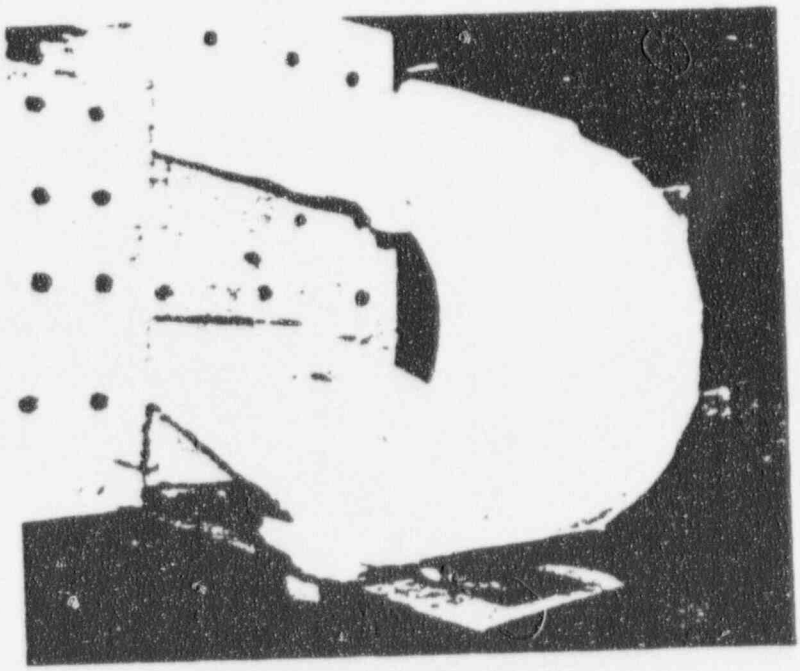


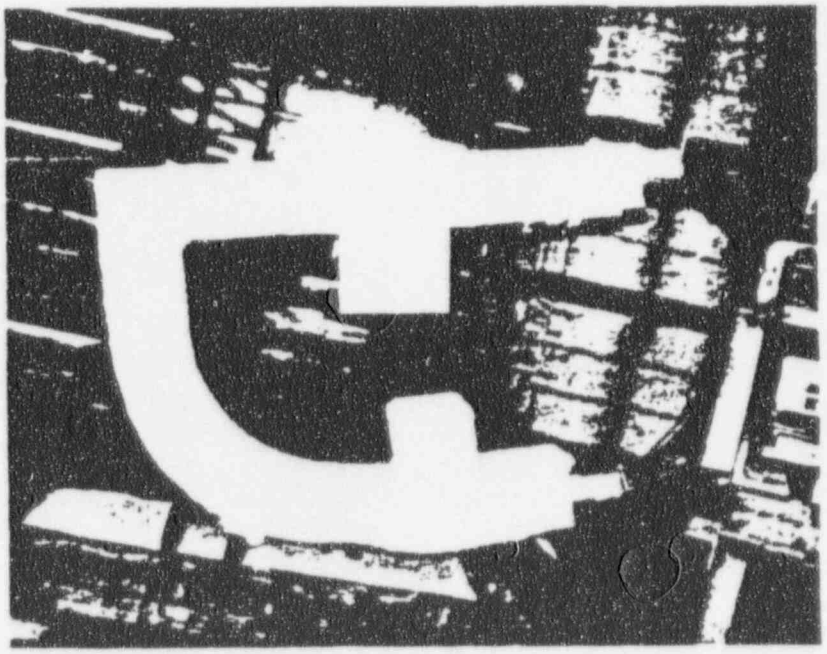
FIGURE 12

PHOTOGRAPH OF TEST ARTICLE NO. 6

PRIOR TO BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS



8.1 Simulated Repair Patch to Test Article No. 4

A tapered circular section, approximately 4-inches in diameter, was cut through the fully cured protective envelope of Test Article No. 4, to effect a "simulated" repair. This patch was then removed and installed in the cut out section by attaching it to the test article with wire fasteners. The open areas around the repair patch were filled in with the THERMO-LAG 330-1/Cure Accelerator mixture using troweling and caulking methods.

Photographs illustrating the simulated repair process are shown in Figures 13A through 13E.

9.0 TEST INSTRUMENTATION

The test instrumentation used to conduct this test program consisted of:

A) A Twenty-four (24) Point Chart Type Thermocouple Temperature Recorder

B) A Twelve (12) Point Chart Type Thermocouple Temperature Recorder

C) An Eight (8) Channel Event Record

D) A Multi-light Display Panel

All instrumentation used in this test program was calibrated in accordance with TSI's Nuclear Quality Assurance Program Manual and Quality Control Operating Procedures Manual. Calibration records for this test instrumentation are on file at TSI, Inc.

SIMULATING AN "INSTIU" REPAIR PROCEDURE

TEST ARTICLE NO. 3&5 COMBINED

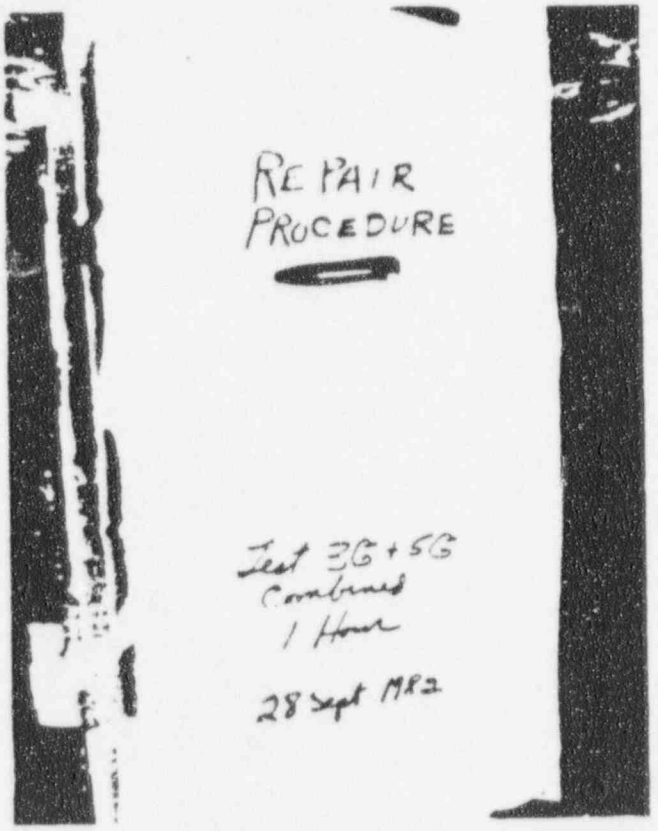


Figure 13A: "Repair" Patch Area Being Scored For Cutting

SIMULATING AN "INSTIC" REPAIR PROCEDURE

TEST ARTICLE NO. 365 COMBINED

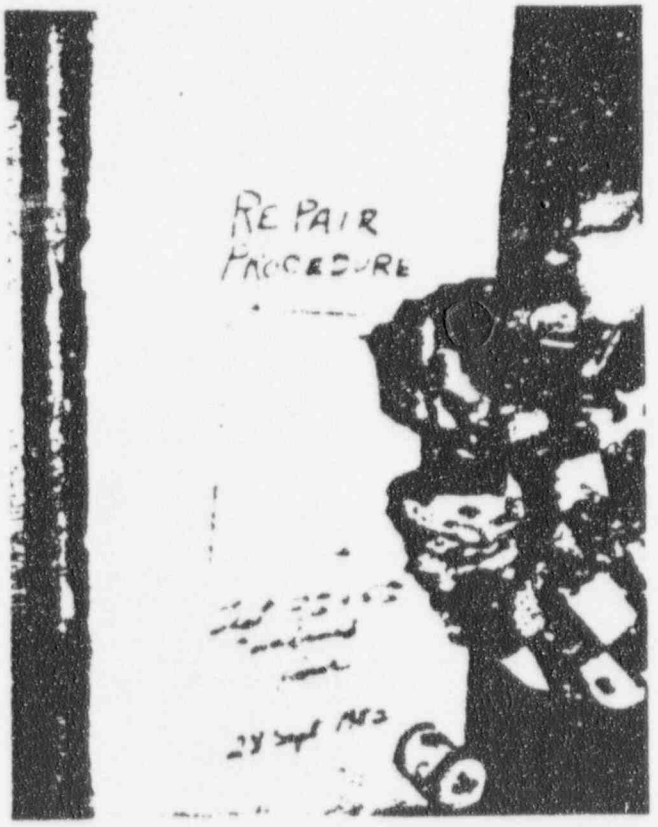


Figure 13B: Drilling Holes For
Fastening "Repair" Patch

SIMULATING AN "INSTIU" REPAIR PROCEDURE

TEST ARTICLE NO. 365 COMBINED

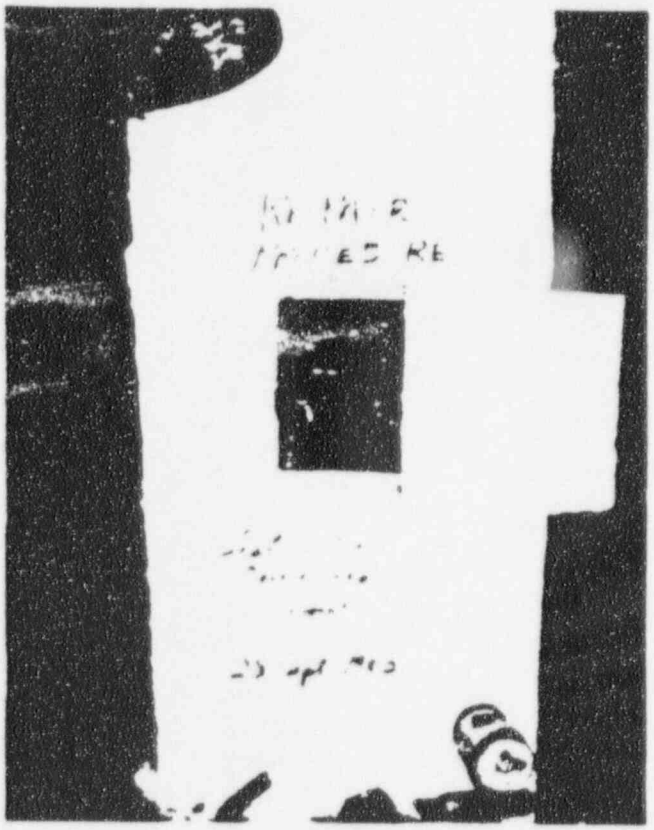


Figure 13C: "Repair" Patch Area Cut Out, Holes Drilled And Ready for Fastening

SIMULATING AN "INSTIU" REPAIR PROCEDURE

TEST ARTICLE NO. 3&5 COMBINED

Figure 13D: A "Patch" of THERMO-LAG Stress Skin Type 330-69 Coated With The THERMO-LAG 330-1/Cure Accelerator Mixture Being Affixed To The Test Article

SIMULATING AN "INSTIU" REPAIR PROCEDURE

TEST ARTICLE NO. 3&5 COMBINED

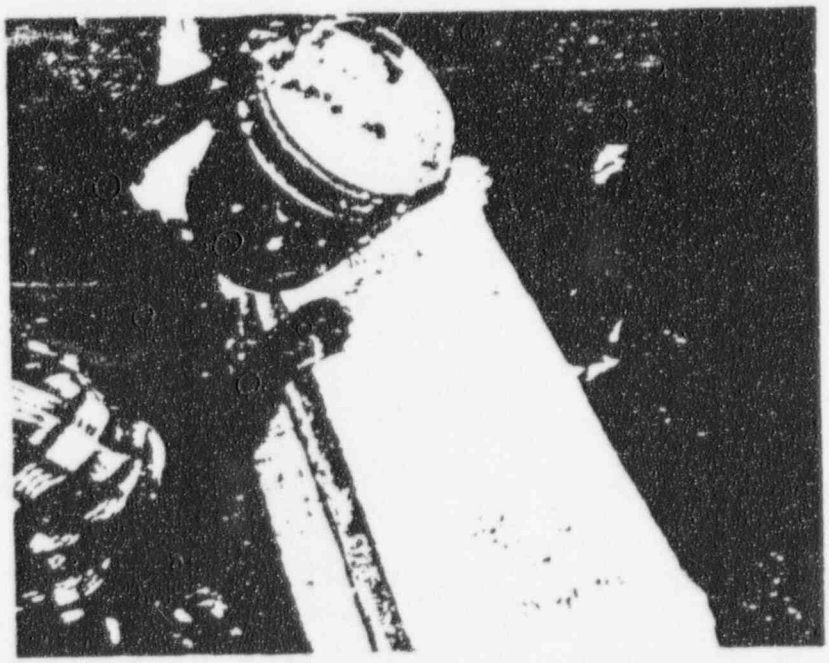


Figure 13E: Simulated "Insitu Repair Procedure" Completed

10.0 THERMOCOUPLES

Thermocouples used in this test program consisted of Shielded and Unshielded 24 ga. Chromel/Alumel Thermocouples. Shielded thermocouples were used to record the air temperature inside the ASTM E119 High Temperature Test Furnace. Unshielded thermocouples were used to record the cable surface temperature of each test article during the tests.

The total number of thermocouples and their location are described in the following paragraphs.

10.1 High Temperature Test Furnace Thermocouples

A total of ten (10) shielded chromel/alumel thermocouples were used to monitor the furnace air temperature in this test program. These thermocouples were located in the High Temperature Test Furnace as follows:

Three (3) thermocouples were located at the East Wall

Three (3) thermocouples were located at the West Wall

Two (2) thermocouples were located at the South Wall adjoining the two walls

One (1) thermocouple was located at the center of the plenum provided by the "U" cross-section of the test article

One (1) thermocouple was located approximately midway underneath the lower run of the test article.

These furnace thermocouples are shown in Figure 6 contained in Section 5.0 of this report.

10.2 Test Article Thermocouples

The cable surface temperatures within each test article were measured by unshielded 24 ga. chromel/alumel thermocouples. The location of each of these thermcouples within each test article is shown in Figures 14A through 14E, and in Section 4 of Appendix III.

A. Test Article No. 1

Twenty-three (23) thermocouples were used to measure the cable and structural steel support surface temperatures in Test Article No. 1. These thermocouples were located in twenty (20) cross-sectional areas along the cable tray section and at three (3) cross-sectional areas of the structural steel support.

Twelve (12) of these thermocouples were installed in direct contact with the steel surface of the cable tray and the cables.

B. Test Article No. 2

Ten (10) thermocouples were used to measure the cable surface temperature in Test Article No. 2. The thermocouples were located in ten (10) cross-sectional areas along the cable tray.

Five (5) of these thermocouples were installed in direct contact with the steel surface of the cable tray and the cables.

C. Test Article No. 3&5 Combined

Twenty-four (24) thermocouples were used to measure the cable surface temperature in Test Article No. 3&5 Combined. Seven (7) groups of three (3) thermocouples each were installed within the cable tray section, and three (3) others were placed at three (3) points within the air drop of Test Article No. 3&5 Combined.

Fifteen (15) of these thermocouples were installed in direct contact with the steel rungs of the ladder cable tray and the cables.

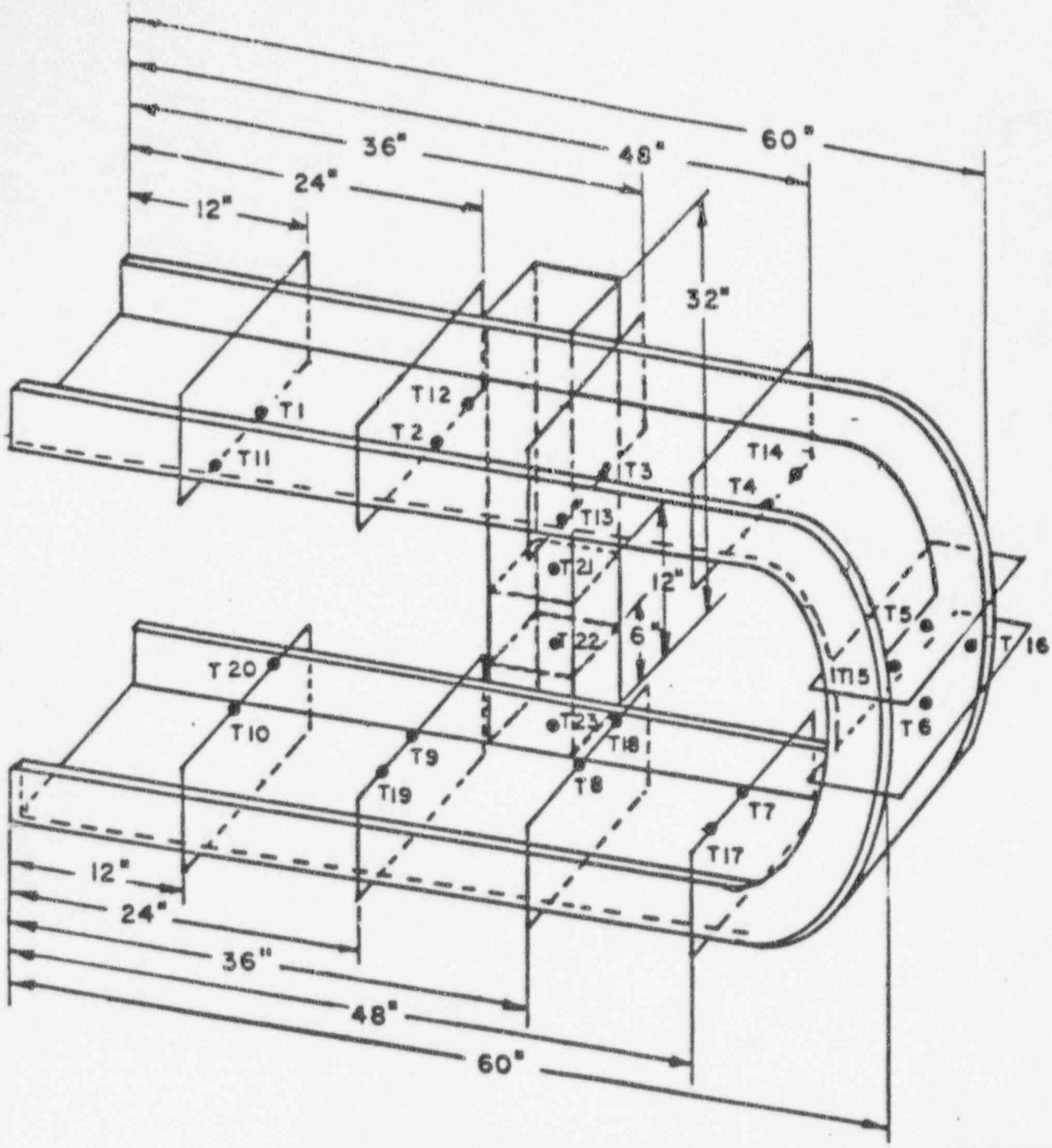
D. Test Article No. 4

Twenty-four (24) thermcouples were used to measure cable surface temperatures in Test Article No. 4. These thermocouples were located in eight (8) groups of three (3) thermocouples each on the cross-sectional areas of the cable tray section.

Fifteen (15) of these thermocouples were installed in direct contact with the steel rungs of the ladder cable tray and the cables.

E. Test Article No. 6

Eleven (11) thermocouples were used to measure cable surface temperatures in Test Article No. 6. All eleven (11) thermocouples were installed in direct contact with the inside of the 4-inch diameter standard electrical conduit section.

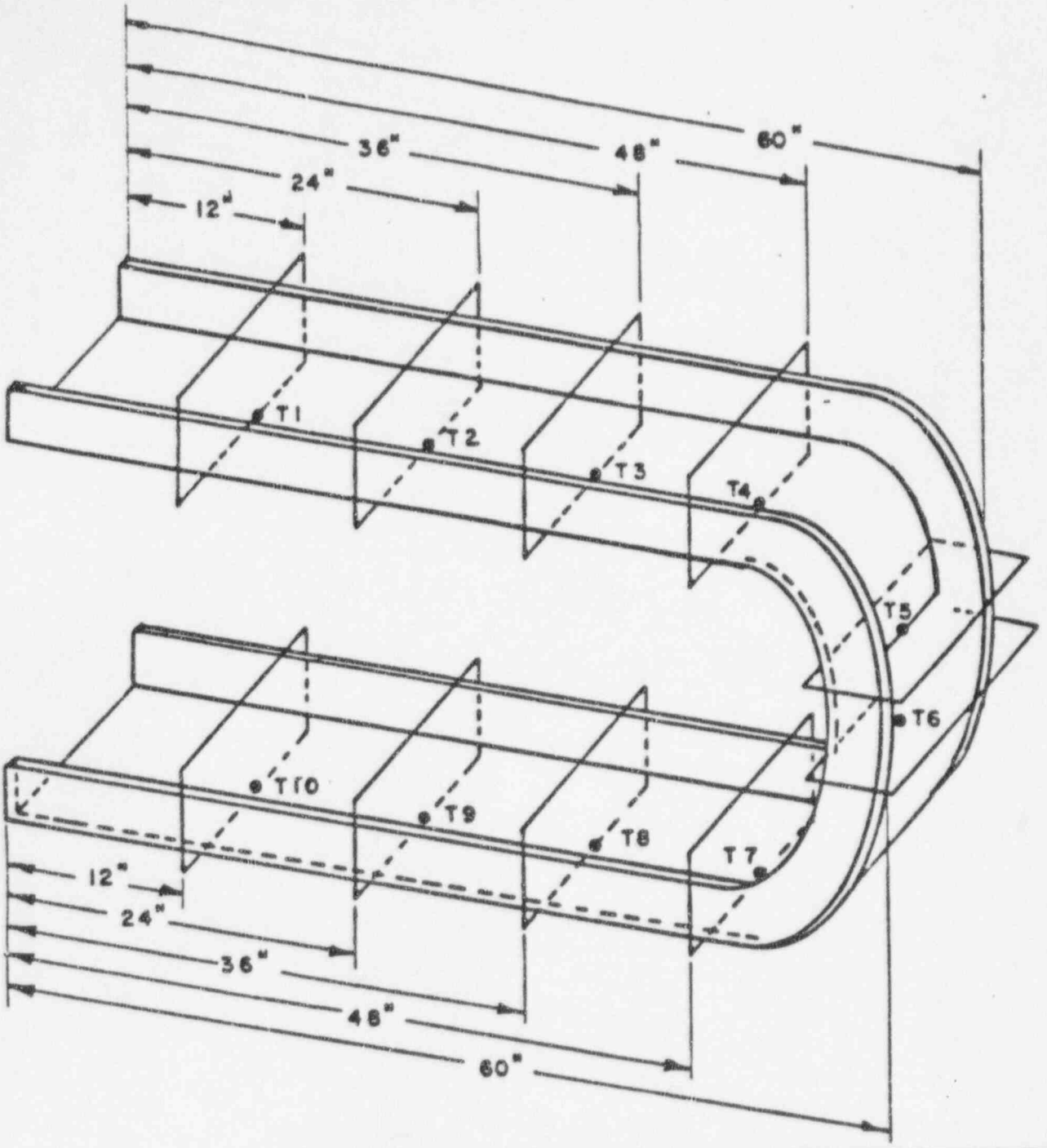


TSI, INC. 3260 BRANNON. ST. LOUIS, MO. 63139.

SCALE: NONE	APPROVED BY: B. E. Evans	DRAWN BY J. DUMPIS
DATE: 10-9-1982		REVISED

LOCATION OF THERMOCOUPLES WITHIN TEST ARTICLE NO. 1

FIGURE 14A

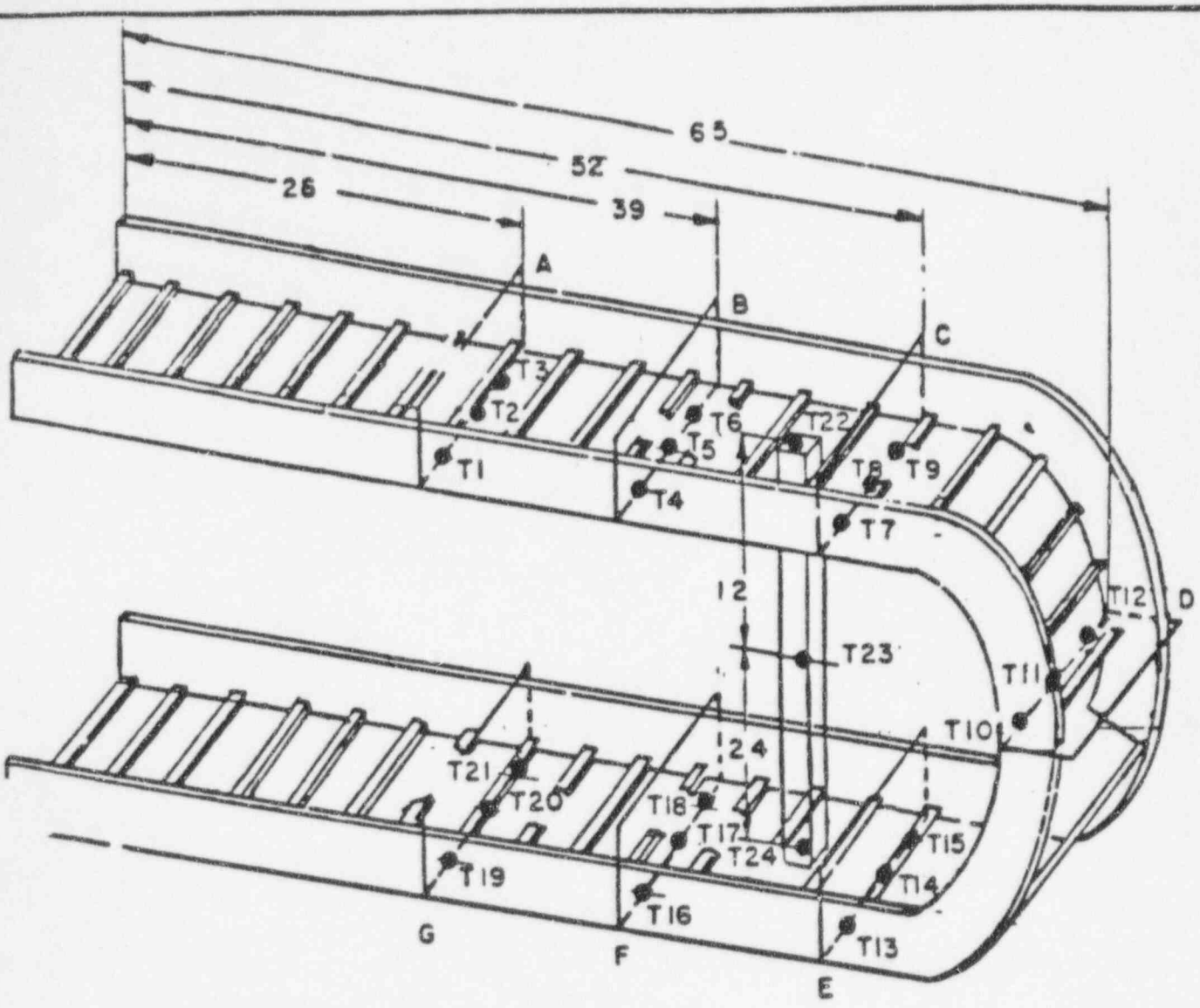


TEII, INC. 3260 BRANNON. ST. LOUIS, MO. 63139.

SCALE: NONE	APPROVED BY: B. E. Evans	DRAWN BY J. DUMPIS
DATE: 10-9-1982		REVISED

LOCATION OF THERMOCOUPLES WITHIN TEST ARTICLE NO. 2

FIGURE 14B



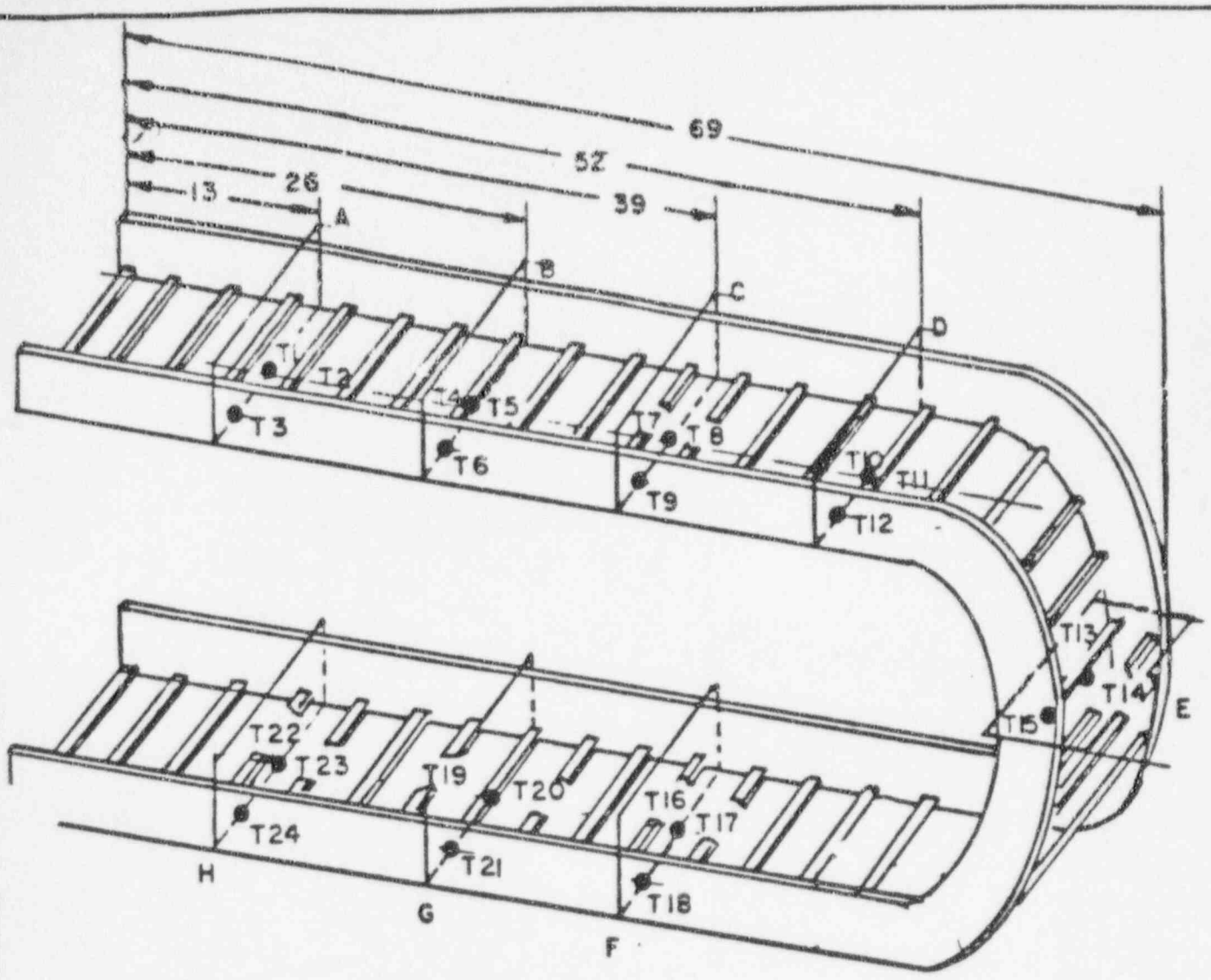
TSI, INC. 3260 BRANNON. ST. LOUIS. MO. 63139.

SCALE: NONE	APPROVED BY: B. Evans	DRAWN BY J. DUMAS
DATE: 10-16-1982		REVISED

LOCATION OF THERMOCOUPLES WITHIN
TEST ARTICLE NO. 3&5 COMBINED

45

DRAWING NUMBER
14C

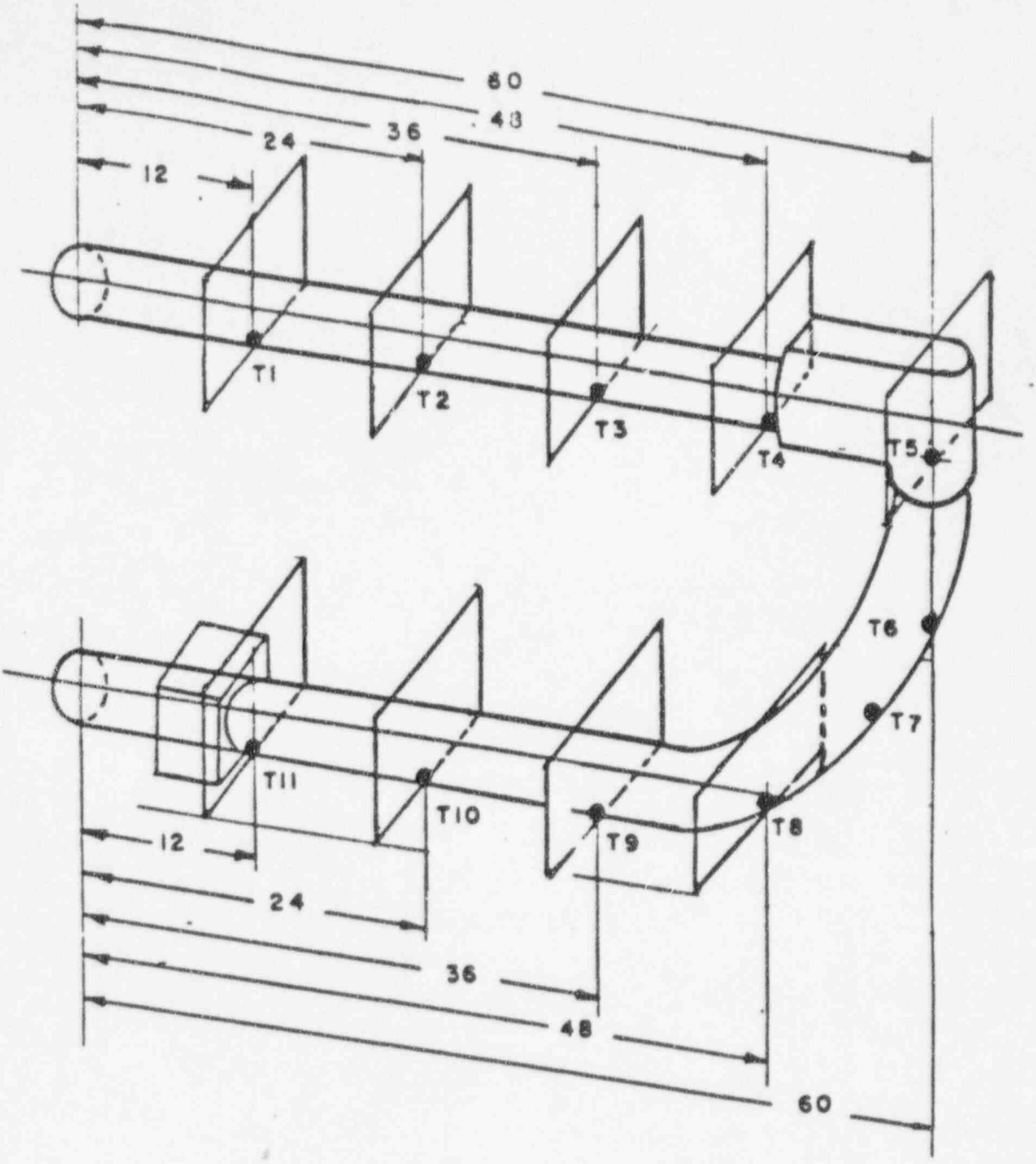


TSI, INC. 3260 BRANNON. ST. LOUIS. MO. 63139.

SCALE: NONE	APPROVED BY: B. Evans	DRAWN BY: J. DUMPIS
DATE: 10-21-1982		REVISED

LOCATION OF THERMOCOUPLES WITHIN TEST ARTICLE NO. 4

FIGURE 14D



TSI, INC. 3260 BRANNON. ST. LOUIS, MO. 63139.

SCALE: NONE	APPROVED BY: B E Evans	DRAWN BY J. DUMPIS
DATE: 10-10-1982		REVISED

LOCATION OF THERMOCOUPLES WITHIN TEST ARTICLE NO. 6

FIGURE 14E

11.0 TEST OBSERVATIONS

A. Details of the One-Hour ASTM E119 Fire Endurance Tests

The total exposure to the ASTM E119 time/temperature environment for each of the one-hour fire endurance tests was as follows:

TEST NUMBER	TIME IN MINUTES
1	61
2	65
3&5 Combined	61
4	60
6	61

Electrical cable surface temperature measurements were recorded once every six (6) minutes (5 seconds between individual thermocouple readings) using the 24 Point Chart Type Thermocouple Temperature Recorder.

B. Visual Observations Made During the Fire Tests

1. Only light volatiles were observed to come from within the test articles at any time during the one-hour fire exposure period.

2. After a period of approximately 50 minutes into the fire exposure, a "slight" cracking was observed to have occurred in the outer layer of the THERMO-LAG 330-1 Subliming Coating as it begins to expand and form the char layer.

3. During the remainder of the fire endurance tests, the subliming coating continued to expand and form progressively greater char areas.

4. Photographs of the test articles after being exposed to the one-hour ASTM E119 fire endurance tests and the water hose stream tests are shown in Figures 15A through 15E.

5. Examination of the test articles after exposure to the fire endurance and water hose stream tests showed evidence that a considerable amount of virgin material (white areas) were present. The "dark areas" shown in Figures 15A through 15E represent the char formation of the consumed product.

6. After the fire exposure, examination of the edges, butt joints, flanges and simulated repair patched area, which had been applied with the THERMO-LAG 330-1/Cure Accelerator mixture, indicated that this material mixture will provide the same degree of fire resistive enhancement as the THERMO-LAG 330-1 Subliming Coating when the Cure Accelerator has not been added.

C. Details of the Water Hose Stream Tests

As required by Paragraph 3.4.2(1) of ANI's Bulletin #5(79), water hose stream tests were conducted following each of the fire endurance tests. The time span between removal of the test article from the furnace and the start of the water hose stream test, in all cases, was within three (3) minutes.

The following test conditions were used:

1. A Mack 800 gpm water pumper fire truck was used for conducting the required water hose stream tests.

2. A 2½-inch diameter national standard playpipe equipped with a 1 1/8-inch tip was used to conduct the water hose stream tests.

3. The nozzle discharge pressure ranged between 30 and 45 psi which meets or exceeds the minimum of 30 psi required in ANI's Bulletin #5(79) for water hose stream tests.

4. The nozzle distance from the test article was maintained at a maximum of 20 feet.

5. The length of the water hose was 50 feet.

FIGURE 15A

PHOTOGRAPH OF TEST ARTICLE NO. 1

AFTER BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS

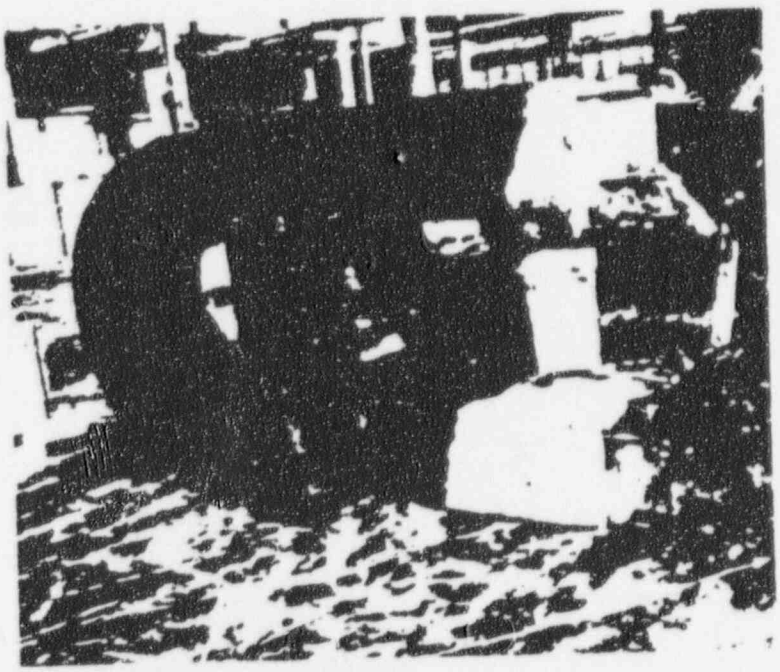


FIGURE 13B

PHOTOGRAPH OF TEST ARTICLE NO. 2

AFTER BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS

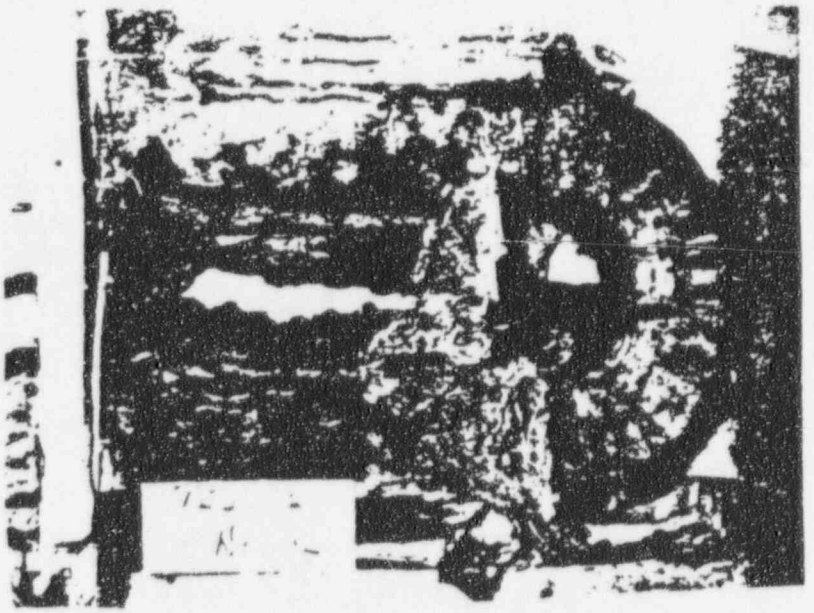


FIGURE 13c

[illegible] TEST ARTICLE NO. 3c3 COMBINED

AFTER BEING EXPOSED TO THE

[illegible] ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS

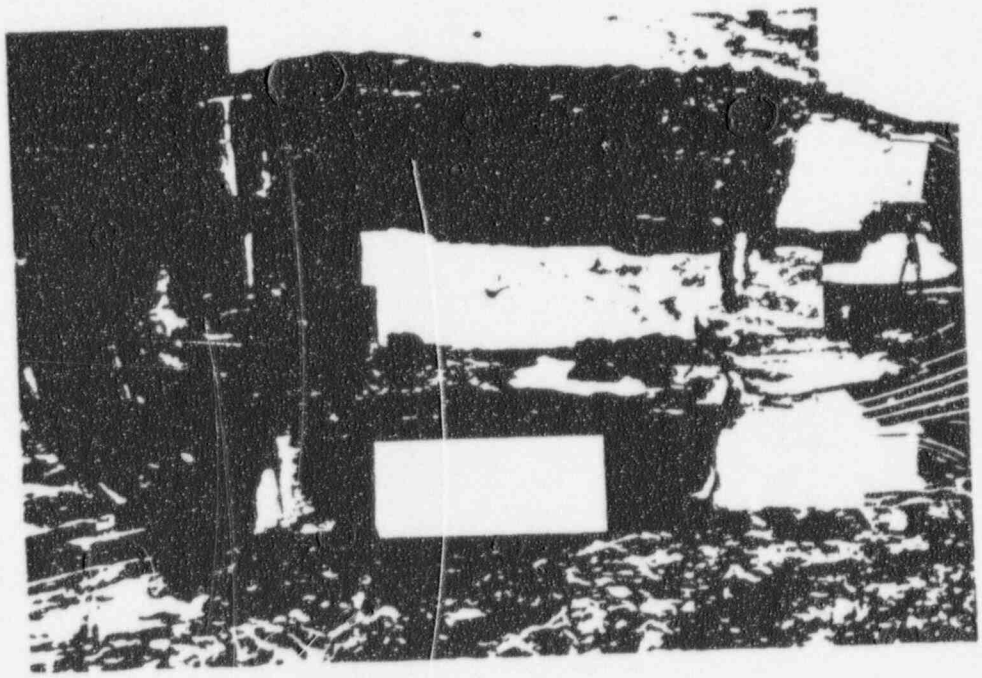


FIGURE 15D

PHOTOGRAPH OF TEST ARTICLE NO. 4

AFTER BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS

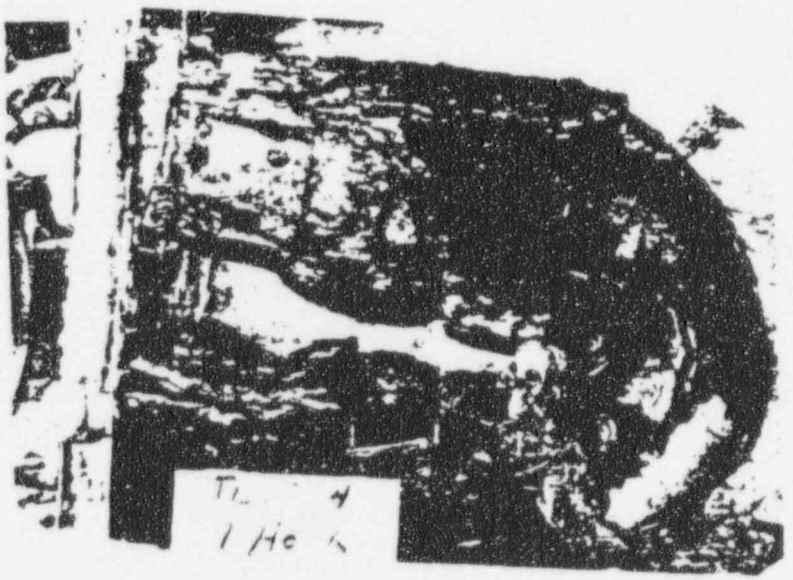


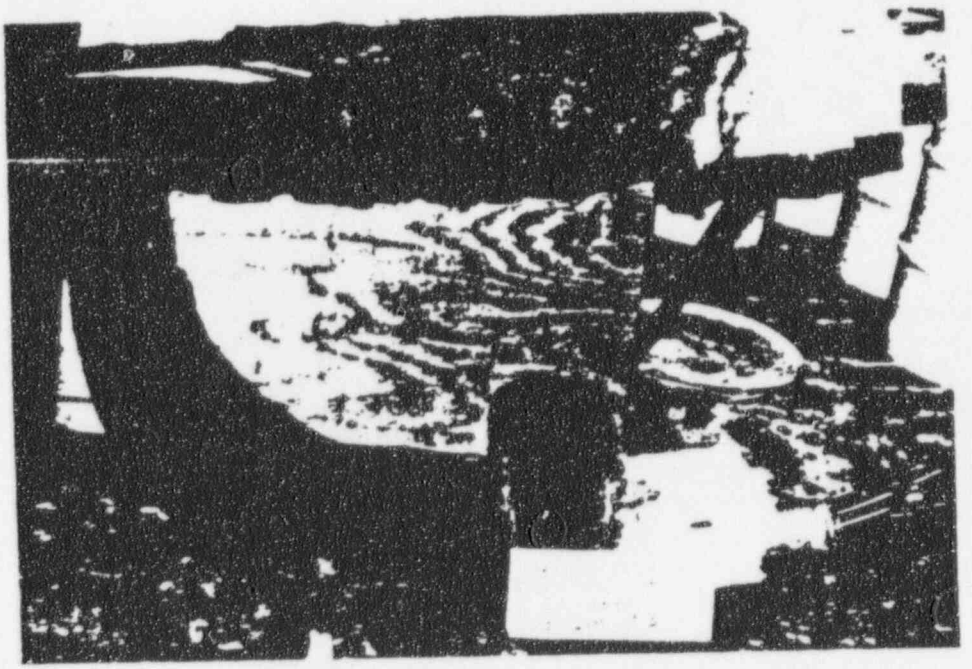
FIGURE 15E

PHOTOGRAPH OF TEST ARTICLE NO. 6

AFTER BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS



D. Visual Observations Made During the Water Hose Stream Tests

1. The duration of the water hose stream tests ranged between 2½ and 3½ minutes for each test article, as compared to ANI's water hose stream exposure requirement of 2½ minutes, minimum.

2. The virgin phase of the THERMO-LAG 330-1 Subliming Coating Envelope System remaining after the ASTM E119 fire endurance tests did not separate from the test articles during the water hose stream tests.

3. Examination of the cables after the completion of the tests, as shown in Figures 16A through 16E indicated that none of the electrical insulation of the cables were damaged. Further examination of the nylon tie wires used in retaining the cables within each test article showed no evidence of damage.

4. The "repair" patch on Test Article No. 365 Combined showed no evidence of damage after the fire exposure and water hose stream tests. This indicates that the THERMO-LAG 330-1 Subliming Coating Envelope System will provide the same degree of fire resistance with no adverse effects to a repaired area when compared to an unrepaired area.

5. Examination of all joints and surface areas where the THERMO-LAG 330-1/Cure Accelerator mixture was used showed no distinguishable difference in appearance after exposure to both the fire endurance and water hose stream tests.

E. Details of the Electrical Circuit Integrity Monitoring

As required by Paragraph 3.5 of ANI's Bulletin #5(79), a sufficient number of electrical circuits were monitored in each test article throughout the ASTM E119 fire endurance and subsequent water hose stream tests to detect failure on a circuit to circuit, circuit to system and circuit to ground basis. All electric cables which were selected for electrical circuit integrity monitoring were located in thermally critical areas immediately adjacent to the walls or steel rungs of the test article.

F. Visual Observations Made During the Electrical Circuit Integrity Monitoring

1. An Eight (8) Channel Event Recorder and a Multi-light Display Panel were used in parallel to conduct the electrical circuit integrity monitoring.

2. Power, control and/or instrumentation cables in the test circuit of each test assembly were connected as a short circuit detection circuit. No failures were observed during either the fire endurance or water hose stream tests.

3. Power control and/or instrumentation cables in the test circuit of each test assembly were connected as a continuity monitoring circuit. No failures were observed during either the fire endurance or water hose stream tests.

4. Power, control and/or instrumentation cables in the test circuit of each test assembly were connected as a ground short circuit detection circuit. No failures were observed during either the fire endurance or water hose stream tests.

Specific cables in each of the test articles, instrumented for monitoring the cable integrity during the fire endurance and water hose stream tests, are shown in Table 1, with the original test data presented in Appendix IV.

FIGURE 16A

VIEW OF THE CABLES WITHIN TEST ARTICLE NO. 1

AFTER BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS

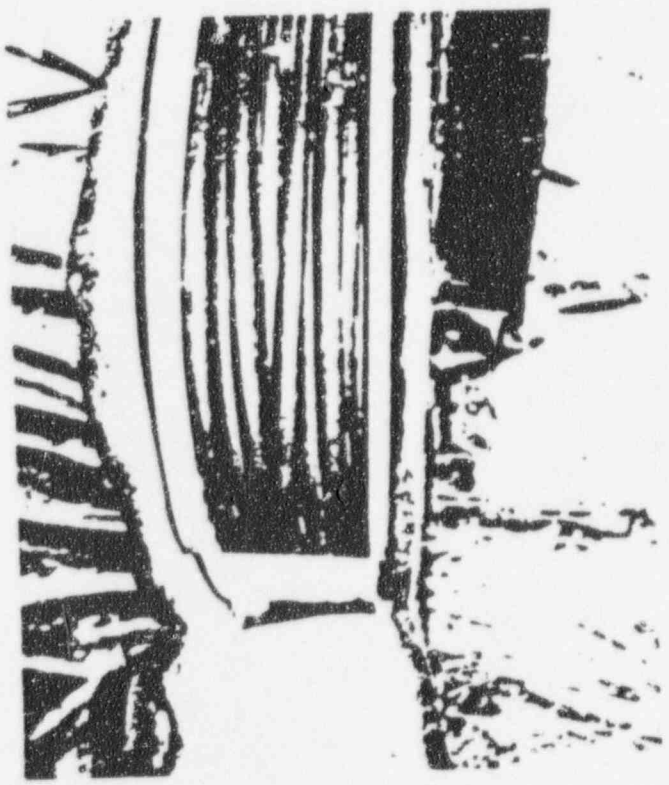


FIGURE 16B

VIEW OF THE CABLES WITHIN TEST ARTICLE NO. 2

AFTER BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS

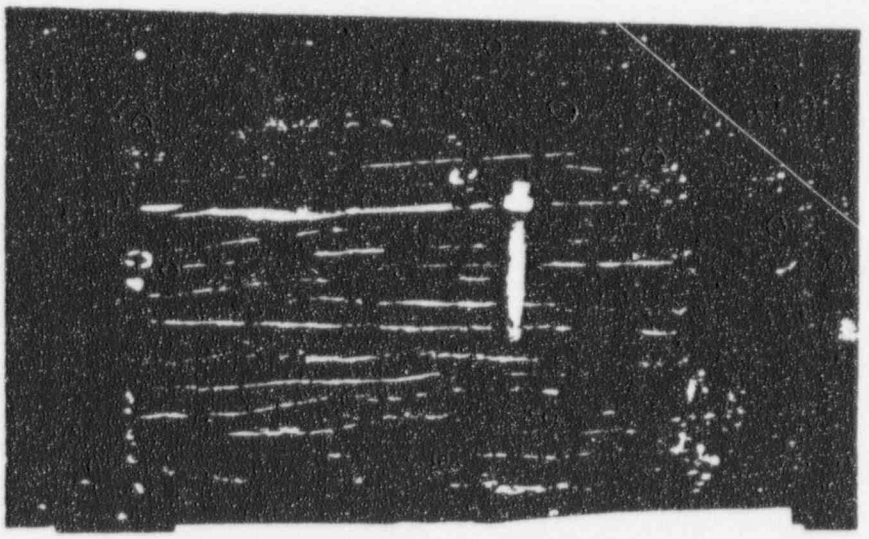


FIGURE 16

VIEW OF THE CABLES WITHIN

TEST ARTICLE NO. 163 COMBINED

AFTER BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE INSURANCE AND

WATER HOSE STREAM TESTS

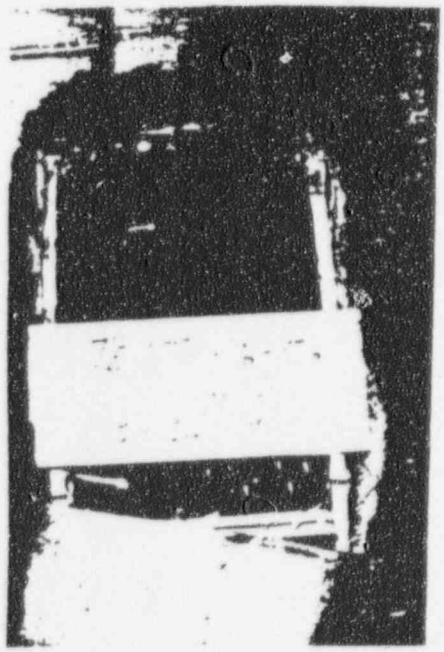


FIGURE 16D

VIEW OF THE CABLES WITHIN TEST ARTICLE NO. 4

AFTER BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS

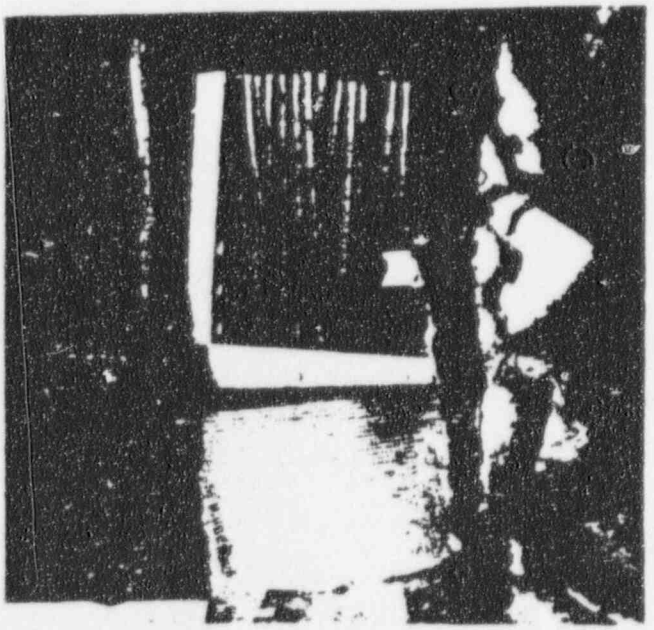


FIGURE 16E

VIEW OF THE CABLES WITHIN TEST ARTICLE NO. 6

AFTER BEING EXPOSED TO THE

ONE-HOUR ASTM E119 FIRE ENDURANCE AND

WATER HOSE STREAM TESTS

12.0 TEST RESULTS

The fire endurance and water hose stream tests conducted on the test articles protected with a one-hour fire rated design of the THERMO-LAG 330-1 Subliming Coating Envelope System clearly demonstrated the capability of the envelope system to meet the test criteria specified in ANI's Bulletin #5(79) for cable trays, conduit , air drops, instrumentation and equipment which contain "generic" cables for a period of at least one hour. These test results are discussed in the following paragraphs:

1. All of the test articles contained "generic" cables.

2. All of the test articles were exposed to the standard ASTM E119 time/temperature curve for a minimum of one hour, followed by a 2½ minute minimum exposure to a water hose stream test. Circuit integrity was continuously monitored during both the fire endurance and water hose stream tests, with no loss of circuit integrity in any of the test circuits.

3. Cable surface temperatures during the one-hour ASTM E119 fire endurance tests did not exceed:

   A) An average of 210° F
   B) A maximum for a singular thermocouple of 288° F

4. Cable surface temperatures recorded for each of the test assemblies at the end of the fire endurance tests are shown in Table 2.

5. The average and maximum cable surface temperatures recorded at six minute intervals during the required 60 minute test period are shown for each of the tests in Figures 17 through 21.

6. The average of all cable surface temperatures recorded at six minute intervals are shown in Table 3.

7. A comparison of the ASTM E119 test method time/temperature curve with the actual range of temperatures obtained during each test is shown in Figures 22 through 26.

   For each comparison, the area under the test time/temperature was calculated by integrating the time/temperature intervals under the curve. All integrated test areas were within 90% and 100% of the integrated standard area.

8. Throughout the fire endurance and water hose stream tests, the Multi-light Display Panel remained in its prescribed lighted and non-lighted positions. The lights were energized in the circuit to system monitoring system, while the lights in the circuit to ground/circuit to circuit monitoring system were not.

9. The Eight (8) Channel Event Recorder also indicated no circuit failures or faults during any of the fire endurance and water hose stream tests.

10. This indicates that the test articles containing generic cables, protected with the one-hour fire rated design of the THERMO-LAG 330-1 Subliming Coating Envelope System, meets all of the prerequisites specified for electrical cable integrity in the ANI/MAERP Standards.

TABLE 2

CABLE SURFACE TEMPERATURE RESULTS

AT THE CONCLUSION OF THE

ONE-HOUR ASTM E119 FIRE ENDURANCE TESTS

TEST NO.	DESCRIPTION OF TEST ARTICLE	CABLE SURFACE TEMPERATURE HIGHEST	CABLE SURFACE TEMPERATURE RANGE AT END OF TEST
1	Solid Bottom Cable Tray 6" x 6" - 40% Fill	232°F	70°F to 232°F
2	Solid Bottom Cable Tray 6" x 6" - 1 Layer	288°F	106°F to 288°F (306°F after 104 minutes of exposure)
3&5 Combined	Ladder Tray with Air Drop 12" x 4" - 40% Fill	180°F	100°F to 180°F
4	Ladder Tray 12" x 4" - 1 Layer	282°F	104°F to 282°F
6	4 Inch Diameter Standard Electrical Conduit	148°F	70°F to 148°F

TABLE 3

AVERAGE OF ALL CABLE SURFACE TEMPERATURES

TIME (Minutes)	1	2	365	4	6
0	66	82	70	78	70
6	69	82	70	81	70
12	73	88	71	89	70
18	78	102	74	105	71
24	83	120	88	121	73
30	91	132	96	132	76
36	98	142	104	147	80
42	105	152	112	162	83
48	113	165	118	178	87
54	122	186	124	192	88
60	127	210	131	202	96
64		225			

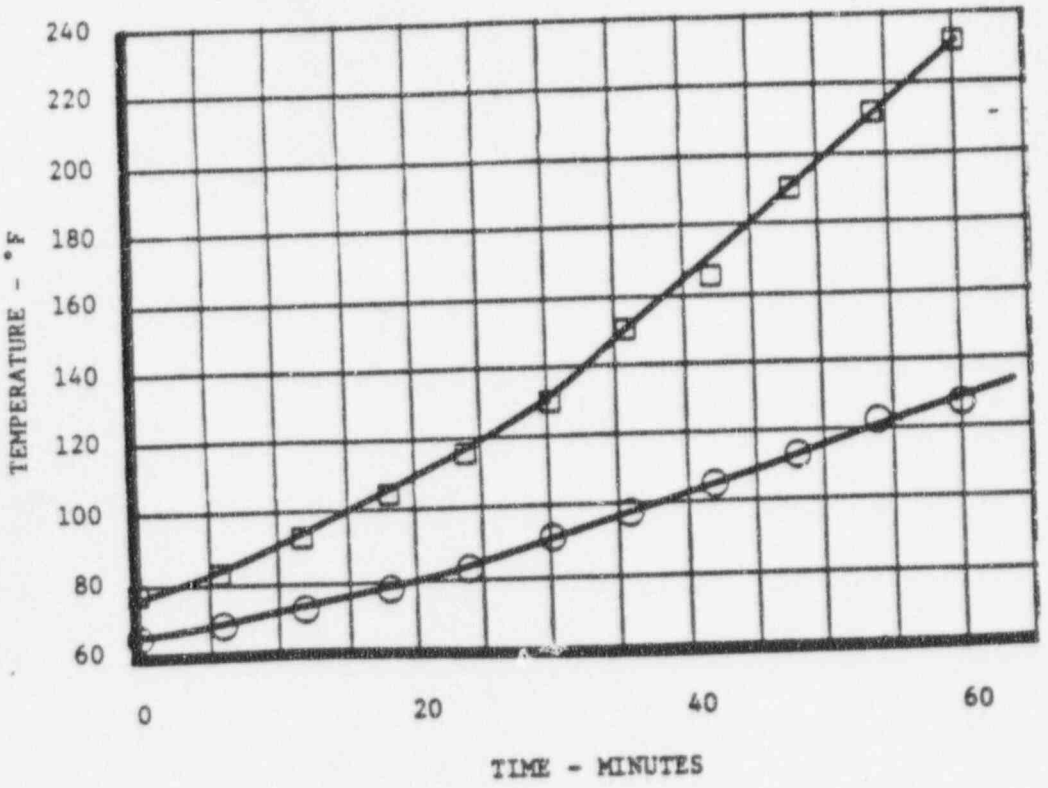
FIGURE 17

AVERAGE AND MAXIMUM OF

ALL CABLE SURFACE TEMPERATURES

RECORDED DURING FIRE ENDURANCE TEST NO. 1

(MINIMUM - ONE HOUR EXPOSURE)



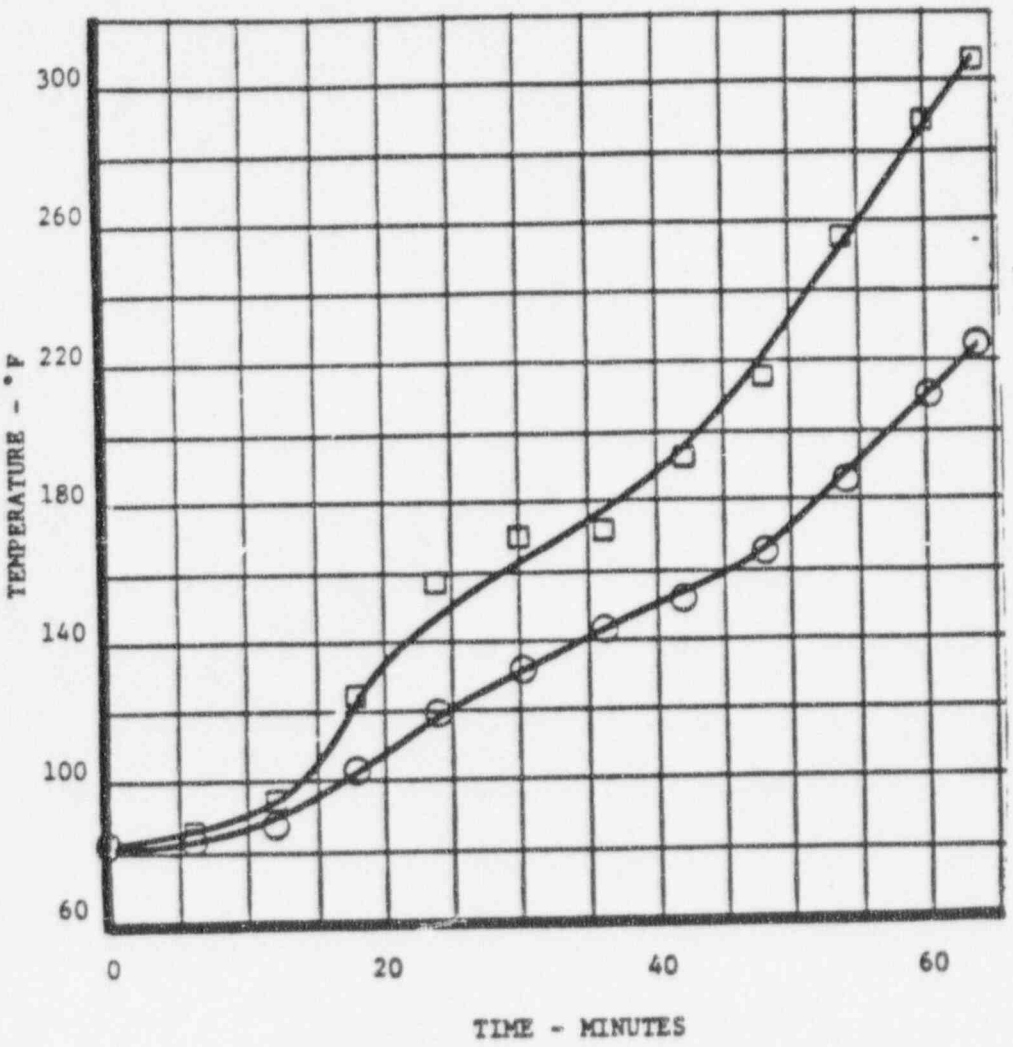
LEGEND

□ HIGHEST CABLE SURFACE TEMPERATURE

○ AVERAGE

FIGURE 18

AVERAGE AND MAXIMUM OF
ALL CABLE SURFACE TEMPERATURES
RECORDED DURING FIRE ENDURANCE TEST NO. 2
(MINIMUM - ONE HOUR EXPOSURE)



LEGEND

□ HIGHEST CABLE SURFACE TEMPERATURE

○ AVERAGE

FIGURE 19

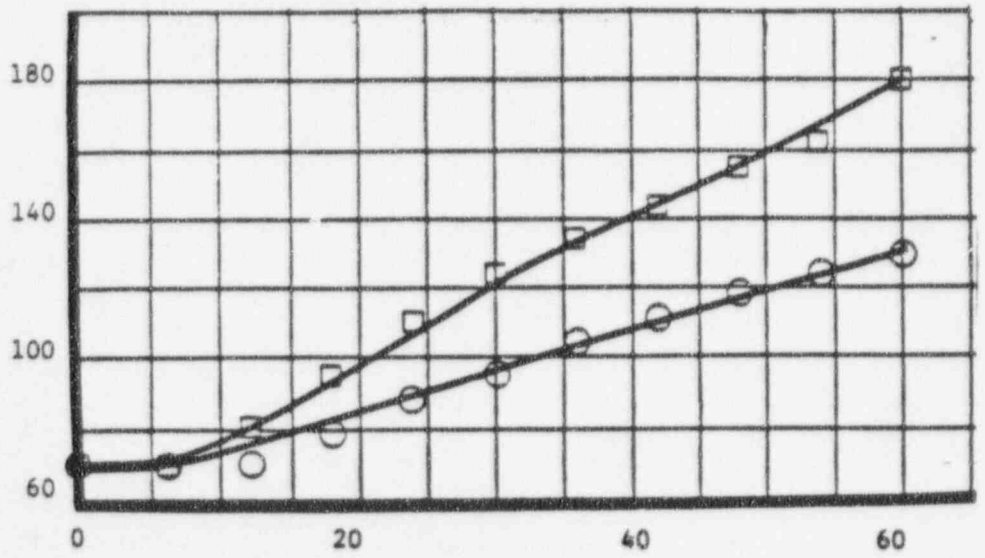
AVERAGE AND MAXIMUM OF

ALL CABLE SURFACE TEMPERATURES

RECORDED DURING FIRE ENDURANCE

TEST NO. 3&5 COMBINED

(MINIMUM - ONE HOUR EXPOSURE)



LEGEND

□ HIGHEST CABLE SURFACE TEMPERATURE

○ AVERAGE

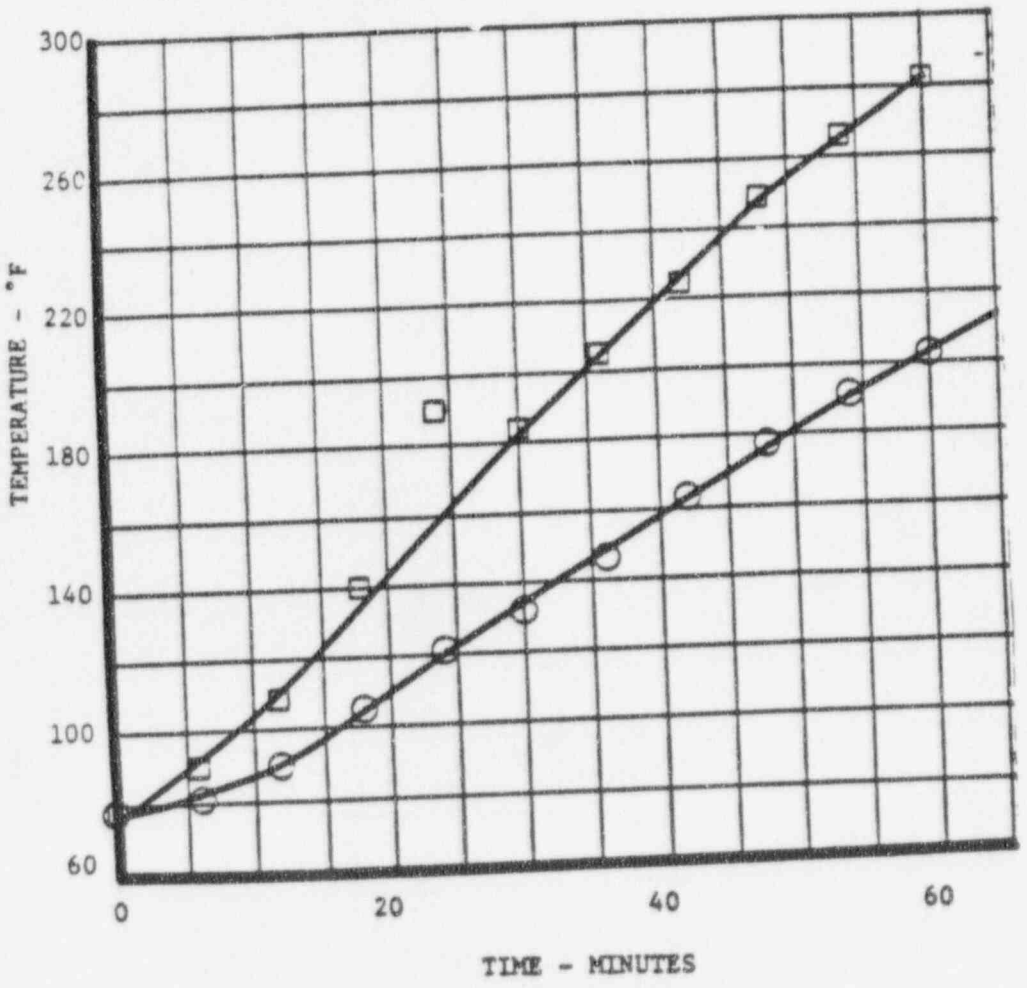
FIGURE 20

AVERAGE AND MAXIMUM OF

ALL CABLE SURFACE TEMPERATURES

RECORDED DURING FIRE ENDURANCE TEST NO. 4

(MINIMUM - ONE HOUR EXPOSURE)



LEGEND

HIGHEST CABLE SURFACE TEMPERATURE

AVERAGE

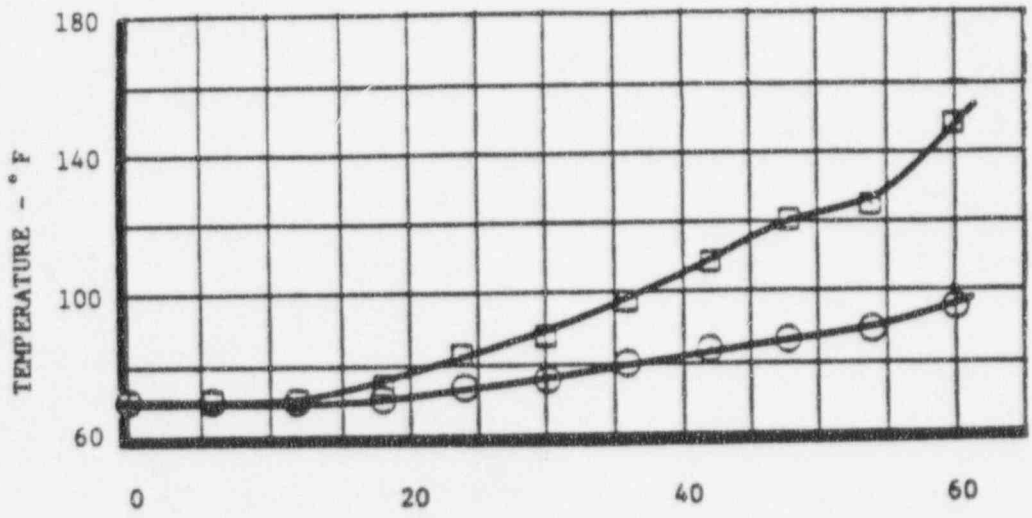
FIGURE 21

AVERAGE AND MAXIMUM OF

ALL CABLE SURFACE TEMPERATURES

RECORDED DURING FIRE ENDURANCE TEST NO. 6

(MINIMUM - ONE HOUR EXPOSURE)



LEGEND

□ HIGHEST CABLE SURFACE TEMPERATURE

○ AVERAGE

FIGURE 22

COMPARISON OF THE

ASTM E119 TEST METHOD TIME/TEMPERATURE CURVE

WITH THE ACTUAL RANGE OF TEMPERATURES RECORDED

DURING FIRE ENDURANCE TEST NO. 1

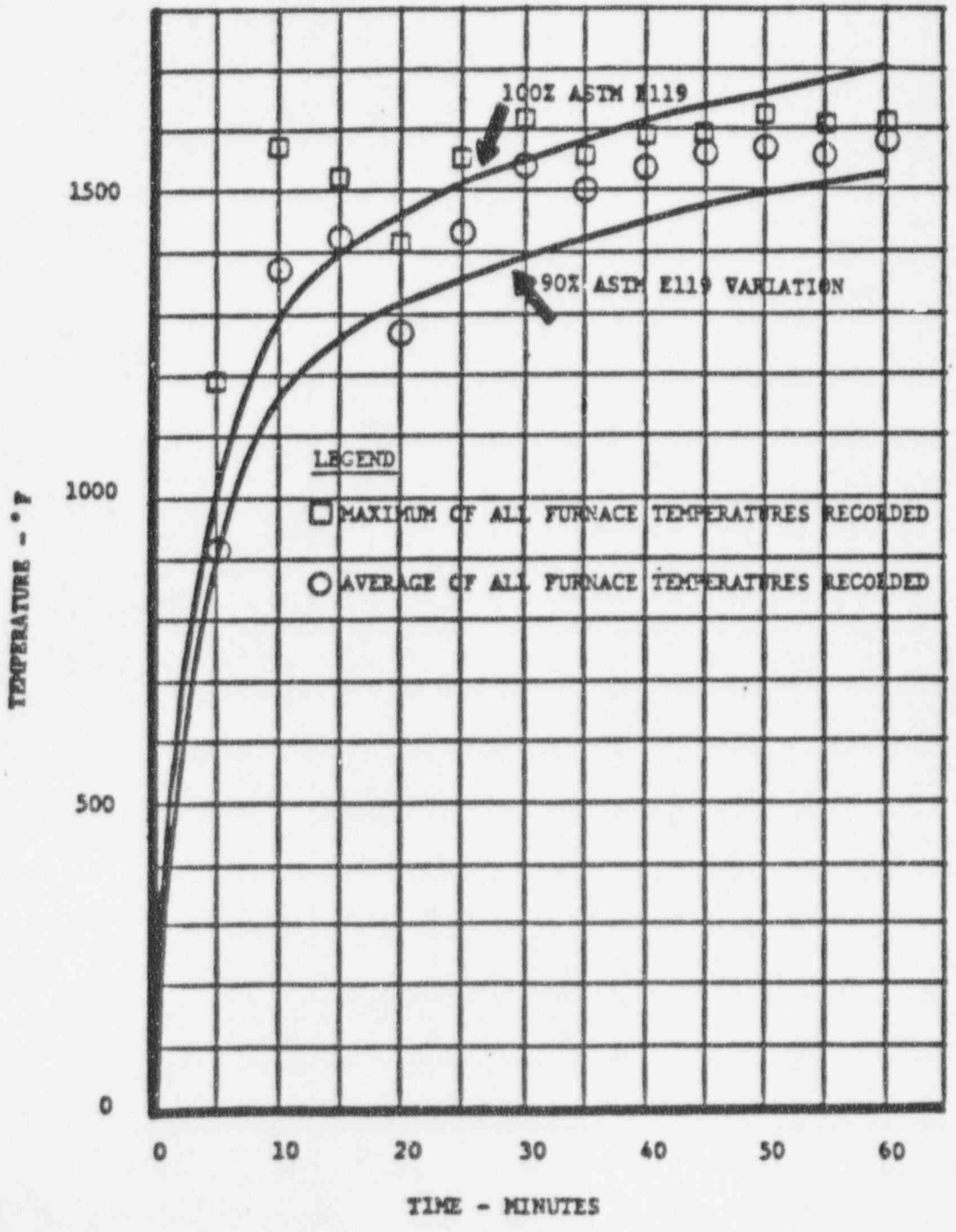


FIGURE 23

COMPARISON OF THE

ASTM E119 TEST METHOD TIME/TEMPERATURE CURVE

WITH THE ACTUAL RANGE OF TEMPERATURES RECORDED

DURING FIRE ENDURANCE TEST NO. 2

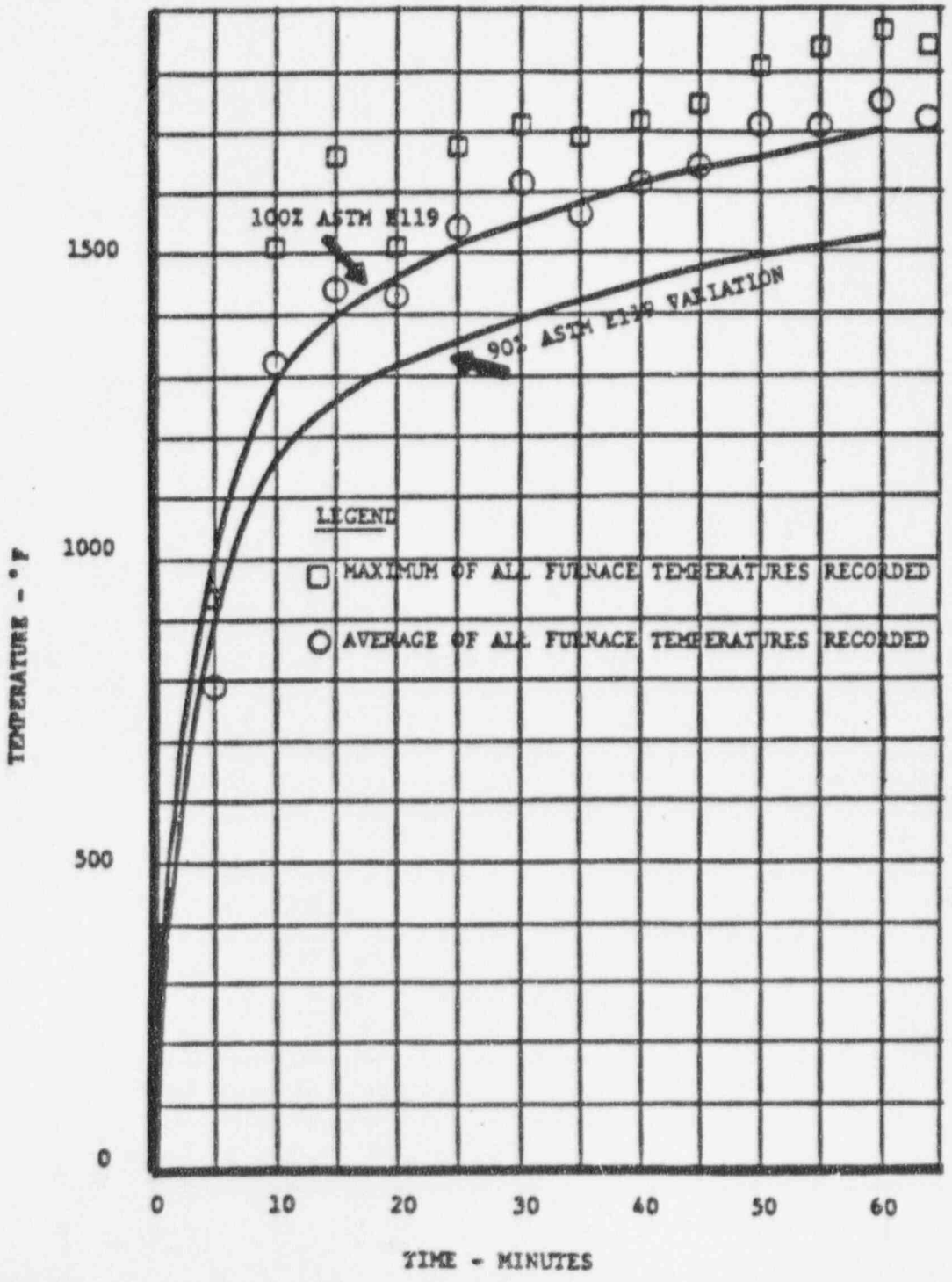


FIGURE 24

COMPARISON OF THE

ASTM E119 TEST METHOD TIME/TEMPERATURE CURVE

WITH THE ACTUAL RANGE OF TEMPERATURES RECORDED

DURING FIRE ENDURANCE TEST NO. 345 COMBINED

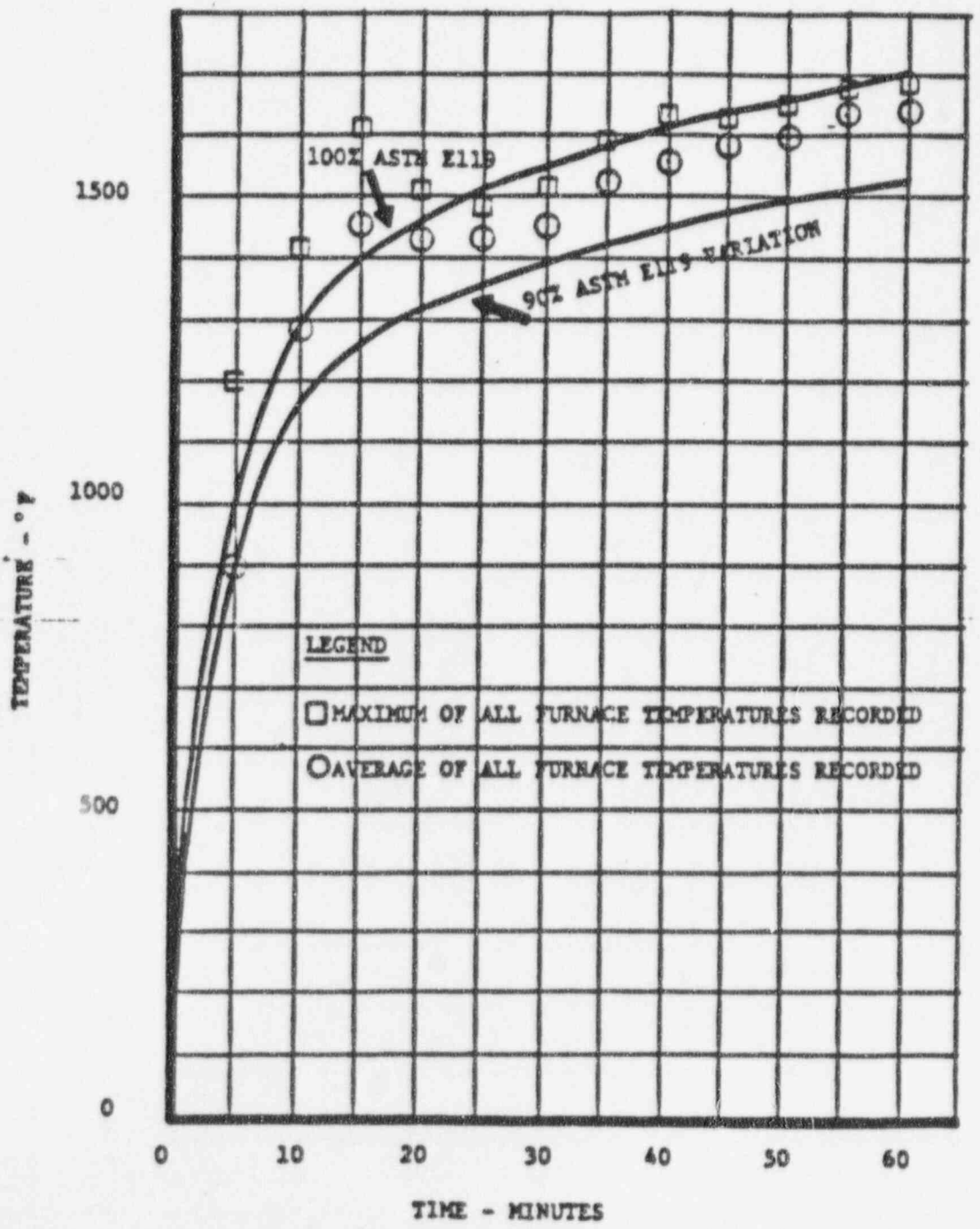


FIGURE 25

COMPARISON OF THE

ASTM E119 TEST METHOD TIME/TEMPERATURE CURVE

WITH THE ACTUAL RANGE OF TEMPERATURES RECORDED

DURING FIRE ENDURANCE TEST NO. 4

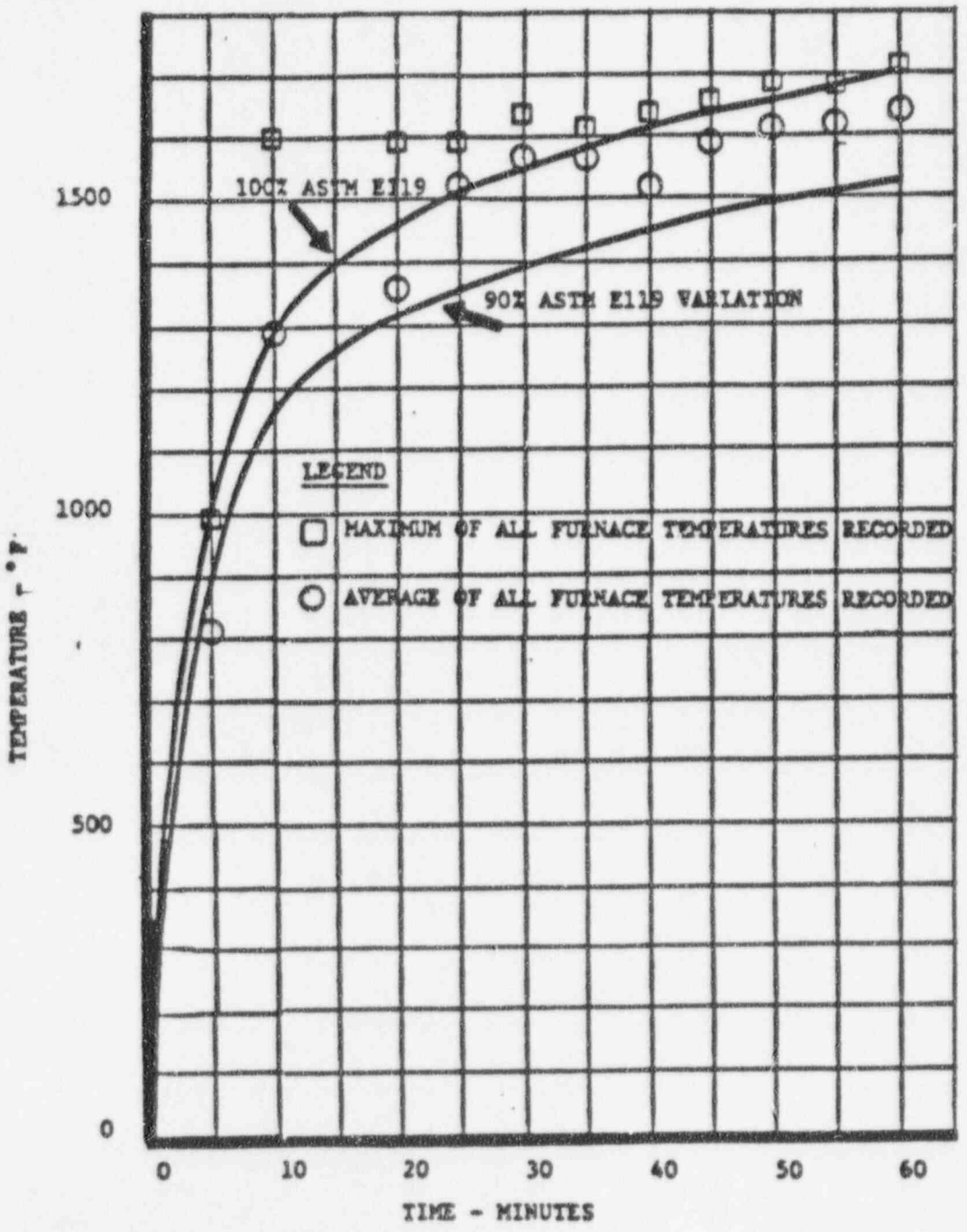


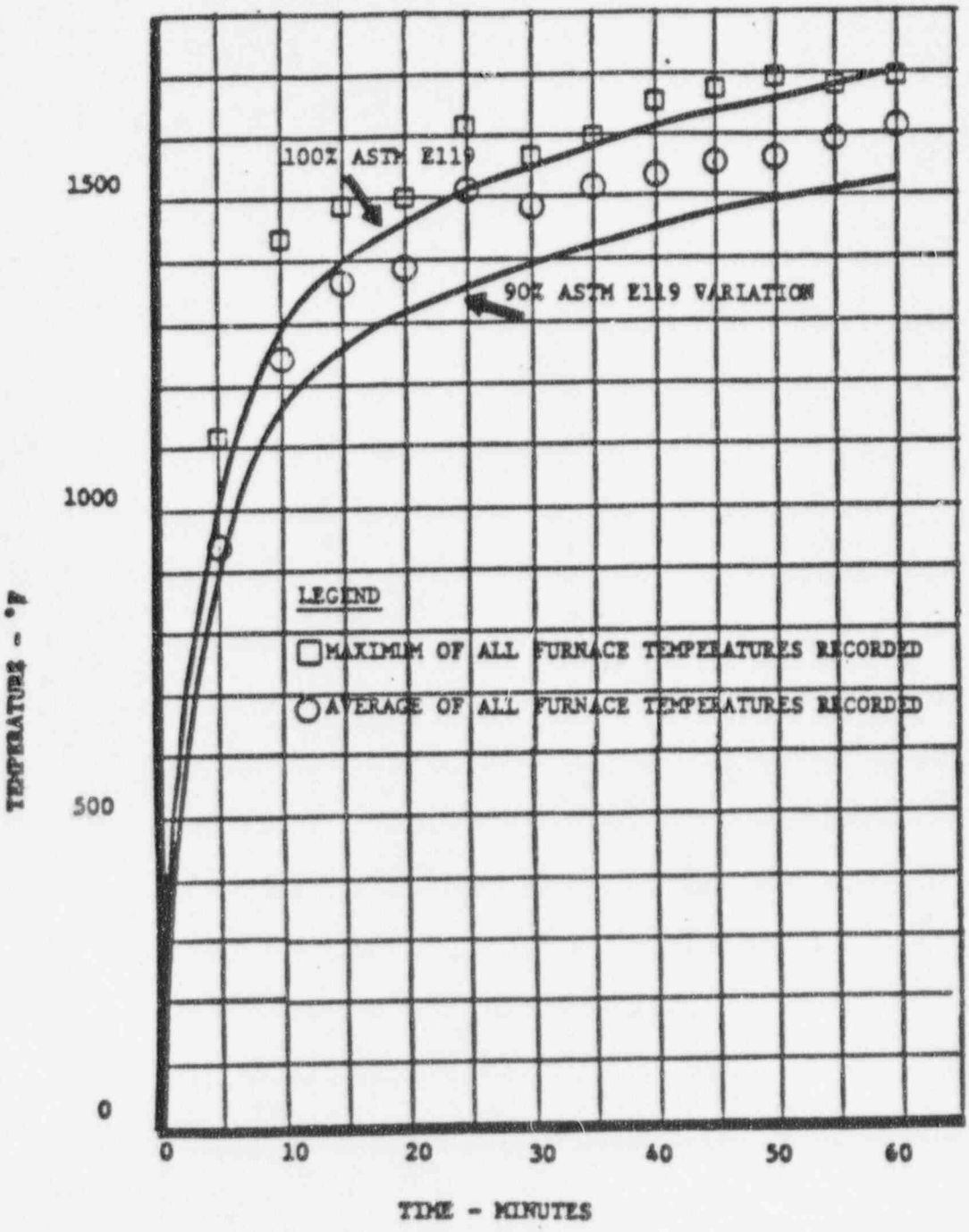
FIGURE 26

COMPARISON OF THE

ASTM E119 TEST METHOD TIME/TEMPERATURE CURVE

WITH THE ACTUAL RANGE OF TEMPERATURES RECORDED

DURING FIRE ENDURANCE TEST NO. 6



13.0 CONCLUSIONS

Based on the test results as well as detailed visual inspection of each test article before and after the one-hour ASTM E119 fire endurance test and the water hose stream test, it can be concluded that:

> The THERMO-LAG 330-1 Subliming Coating Envelope System meets the requirements as specified in Paragraph 3.4.1, 3.4.2(1), and 3.5 of ANI's Bulletin #5(79) entitled: "ANI/MAERP Standard Fire Endurance Test Method To Qualify A Protective Envelope For Class 1E Electrical Circuits", when applied to cable trays, conduit, air drops, instrumentation and equipment containing "generic" cables. This conclusion is supported by the following test results and observations:

1. All test articles were exposed to the standard time/temperature environment of ASTM E119 for a minimum of one (1) hour, followed by a 2½ minute minimum water hose test as required by ANI's Bulletin #5(79). The THERMO-LAG 330-1 Subliming Coating Envelope System successfully met these test requirements in all aspects.

2. There was no loss of circuit integrity in the test circuits of any of the test articles when exposed to the one-hour ASTM E119 fire endurance and water hose stream tests.

3. The water hose stream tests did not adversely effect the virgin THERMO-LAG 330-1 Subliming Coating Envelope System remaining on the test articles following the fire endurance tests.

4. The recorded cable surface temperatures in all test articles, after exposure to the ASTM E119 time/temperature environment for a minimum of 60 minutes did not exceed 288°F.

5. The THERMO-LAG 330-1 Subliming Coating Envelope System was manufactured and applied to each test article in accordance with TSI's Engineering Test Plan, Nuclear Quality Assurance Program Manual and Quality Control Operating Procedures Manual. These documents were accepted by the American Nuclear Insurers, as shown in Section 1 of Appendix I to this report, prior to the commencement of this test program.

   Thus, the protective envelope and the manner in which it was applied can be considered typical of those prescribed by TSI, Inc. for nuclear plant installation.

6. Based on information supplied to TSI, Inc. from Operators, Engineers and Constructors of nuclear power plants, it can be assumed that the cable trays, conduit, air drop, instrumentation, equipment and cables installed in each test article, are typical of those found in various nuclear power generating plants.

Based on the results and observations of this test program, the THERMO-LAG 330-1 Subliming Coating Envelope System meets all the requirements and performance criteria specified in ANI's Bulletin #5(79) for test articles containing "generic" cables. It has also been demonstrated that the protective envelope system provides the required one (1) hour of thermal protection when exposed to the standard ASTM E119 test method fire environment.