ATTACHMENT A

Letter from W. R. Sohlman to R. Bishop,
dated 07/29/1992,
"*RE: Use of Grout as a Fire Seal*"

NUCLEAR
MUTUAL
LIMITED

Suite 1200
Manufacturers Hanover Plaza
1201 Market Street
Wilmington, DE 19801
U.S.A.
TEL 302 888 · 3000
FAX 302 888 · 3007 (Finance)
FAX 302 888 · 3008 (Insurance)

July 29, 1992

Mr. Robert Bishop
Production Services Manager
Commonwealth Edison
1400 Opus Place
Downers Grove, IL 60515

RE: USE OF GROUT AS A FIRE SEAL

Dear Mr. Bishop:

I have received and reviewed your letter of July 8, 1992 along with DIT No. - ZI-ARCH-0002 concerning the use of Masterflow 713 and 816 non-shrink grout.

Based on the material contained in the DIT package, NML agrees with the engineering judgement of Masterbuilders Inc. that Masterflow 713 and 816 non-shrink grout possess the same characteristics of the masonry or concrete fire barrier when installed to the full thickness of the barrier.

Concurrent with a review of "Fire Resistance Ratings Of Reinforced Concrete Walls" by the American Insurance Association, NML will accept Masterflow 713 and 816 as a fire barrier seal material as long as the minimum thickness of the non-shrink grout is as follows:

1 hour barrier requires 3 1/2" thickness
2 hour barrier requires 5" thickness
3 hour barrier requires 6" thickness
4 hour barrier requires 6 1/2" thickness

This acceptance will be generic for all six Commonwealth Edison Nuclear Stations.

Should you have any questions or need any additional information, please feel free to contact me.

Very truly yours,

Wayne R. Sohlman

Wayne R. Sohlman
Loss Control Representative-
Property

cc: J. Pennock
J. Abel
C. Diaz
h:\home\dmc\ws\00108

ATTACHMENT B

ABB Impell Fire Seal Report No. 597-341-001
Rev. 0,
September 1992

ABB Impell Report No. 597-341-001

September 1992
Revision 0

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

1.0 PURPOSE

The purpose of this analysis is to document the review of the Construction Technology Laboratories (CTL) fire test report, "Fire and Hose Stream Tests of Eight Penetration Seal System," dated October 15, 1986 and verify that the penetration seal configurations qualify for a specific fire rating when exposed to the standard fire endurance test method. The original CTL test program was intended to address penetration seals documented on drawings 12E-6508 and 12E-6508A for the Dresden Nuclear Plant and drawings 4E-6508 and 4E-6508A for Quad Cities Nuclear Plant. In addition, the seal details were also used as reference to the configurations used at Zion Station.

Although the results of this analysis will be applied to the seal details on Zion Drawings 22E-0-3130, Sheet 1 in order to furnish a direct correlation to a qualified fire test configuration for Details 1 through 10 the results can also be applied to those similar details which are identified on the above referenced drawings for Dresden and Quad Cities Plants.

Results of the fire test will be evaluated with respect to the acceptance criteria prescribed in the test method and generally accepted industry standards. The seal configuration will be evaluated with respect to the material composition, penetration objects, fire withstand capability and integrity following hose stream impact.

This analysis also documents the development of design detail configurations for ceramic fiber penetration seals that are qualified to maintain a 3 hr. fire endurance rating. Each design detail will be based on the results of the fire tested penetration seal assemblies contained within the test. The critical characteristic for each seal configuration were evaluated in order to establish the bounding parameters for:

- Seal Material Composition
- Opening Dimensions
- Seal Thickness
- Penetrant Types and Sizes
- Distance Between Multiple Penetrants
- Seal Orientation (wall/floor)

2.0 DISCUSSION

2.1 Background

The review of Zion Plant's electrical cable penetration seal drawing 22E-0-3130, Sheet 1 identified that specific seal configuration parameters were not detailed on this drawing to facilitate consistent seal installation practices. Therefore, a review of existing qualified fire tested seal configurations were performed to provide required parameters.

As part of this process, Zion Plant's licensing documents were also reviewed ~~to identify~~ the historical background of commitments made between CECo and the NRC. This historical review identified the following:

On March 10, 1978 the NRC issued Zion Fire Protection Safety Evaluation Report (SER) for Units 1 and 2. Section 4.9 indicates: "The licensee will conduct tests of typical electrical penetration seals to determine their fire resistance rating. A procedure for the test program will be submitted for staff review prior to testing."

On April 14, 1978 CECo issued its proposed test procedure to the NRC for review. On May 26, 1978 the NRC replied, stating the proposed test program was acceptable, but recommended several items which should be included in the test procedure, such as a hose stream test.

CECo made arrangements with the U.S. Gypsum Company to use their test center located in Des Plaines, IL for the conduct of the fire tests. Some of the NRC's recommendations were incorporated into the test plan however others were not, due to limitations with the test facilities and the test slab.

Some of the NRC recommended procedures not included were the lack of performing a hose stream test, and a fire test for a cellular concrete seal detail. On June 19, 1978 several floor penetrations installed in a test slab were subjected to a 3-hour fire endurance test. The fire test report prepared by the Consulting Engineers Group, dated July 27, 1978 documented the test results and were submitted to the NRC on September 29, 1978. The NRC reviewed the results and stated in the Fire Protection Program Safety Evaluation Report, Section 3.2, dated January 28, 1980 the following:

> "We have reviewed the test procedure and results. Our consultant has witnessed the fire barrier test conducted at the U.S. Gypsum facility. We find that the cable penetration fire barriers seals constructed in accordance with those test are acceptable."

In review of this correspondence, the NRC had determined that the fire tests performed on June 19, 1978 were acceptable. Further to this, the subsequent guidelines contained in Generic Letter 86-10 also stipulated that previously approved features would be acceptable in satisfying Appendix R requirements. The CTL test results however, clearly enhance the seal configuration parameter requirements and therefore provide the basis for the seal details discussed in this document.

2.2 Fire Test Review

The Fire Endurance and Hose Stream Tests (Ref. 1) consisted of a horizontal slab with eight (8) distinct blockout configurations. The test method utilized the following guidelines and pass/fail criteria:

- The fire exposure, hose stream tests and thermocouple locations were based on IEEE 634-1978, "Cable Penetration Fire Stop Qualification Test."
- Acceptance criteria regarding the passage of flame or hot gases, unexposed side temperature, and the hose stream test were also reviewed against the ASTM E-119 and NELPIA/MAERP (ANI) guidelines.

Although the test method and acceptance criteria were based on several guidance documents, i.e., ASTM, IEEE, and NELPIA, the qualification criteria is generally consistent with established standards that have been accepted by the nuclear industry and the NRC with minor exceptions. The differences are discussed in detail in Section 4.0, Fire Test Analysis.

2.3 Design Detail Development

The design details contained in this calculation are based on the Fire Endurance and Hose Stream Test (Ref. 1). This analysis examines the critical characteristics associated with the tested configurations to determine which seal features and parameters are necessary for maintaining a 3 hr. fire rating. Table 1.0, provides a summary of the eight configurations which were examined in the fire endurance and hose stream test. In addition, the fire endurance of ceramic fiber in building design has been investigated extensively as documented in the Underwriters Laboratories (U.L) Building Materials Directory. In general, ceramic fiber has demonstrated to be an effective material for fire rated construction. Therefore, the design detail configurations contained in this analysis are representative of typical electrical penetrations as demonstrated by fire test results and generally accepted engineering principles regarding the performance of ceramic fiber.

TABLE 1.0

Test/ Configuration #	Seal Material(s) and Thickness	Opening Dimensions	Penetrating Objects
Penetration #1	12" Cerafiber Bulk Ceramic Fiber, 1/8" Vimasco Cable Coating and 4" Nelson CMP Fix (both sides)	45" x 7" (315 in^2)	32" x 6" Cable Tray 40% Cable Fill
Penetration #2	10" Cerafiber Bulk Ceramic Fiber, 1" Ceraboard and 1/8" Vimasco Cable Coating (both sides)	33" x 8" (264 in^2)	32" x 6" Cable Tray 5% Cable Fill
Penetration #3	12" Cerafiber Bulk Ceramic Fiber, 1/8" Vimasco Cable Coating (both sides)	33" x 8" (264 in^2)	32" x 6" Cable Tray 30% Cable Fill
Penetration #4	12" Cerafiber Bulk Ceramic Fiber, 1/8" Vimasco Cable Coating and 3" C.T. Gypsum (both sides)	33" x 8" (264 in^2)	32" x 6" Cable Tray 40% Cable Fill
.letration #5	12" Cerafiber Bulk Ceramic Fiber, 1/8" Vimasco Cable Coating (both sides)	33" x 8" (264 in^2)	32" x 6" Cable Tray 40% Cable Fill
Penetration #6	1/4" Flamastic 77, 3" Cerafiber Bulk Ceramic Fiber, 4' G.E. 627 Silicone Sealant and Ceramic Fiber Mix	5" Conduit (19.6 in^2)	5" Conduit 41% Cable Fill
Penetration #7	4' Cerafiber Bulk Ceramic Fiber and 1/8" G.E. RTV 133 Sealant (both ends)	5" Conduit (19.6 in^2)	5" Conduit 41% Cable Fill
Penetration #8	12" Cerafiber Bulk Ceramic Fiber	5" Sleeve (19.6 in^2)	32% Cable Fill

3.0 ASSUMPTIONS

1. The intent of the fire test was to qualify the penetration seals for a 3 hr. fire endurance. Seals which serve multi-purposes such as fire, flood, radiation, air/pressure boundary etc. were not within the scope of the test or this evaluation.

2. The penetration seal materials were installed in accordance with the manufacturer's instructions and all gaps and voids, including penetrants and openings, were properly filled such that a minimum of 1/8" of seal material exists between closely spaced objects.

3. The location and spacing of the penetrating objects in the fire test reports are based on equi-distant spacing between multiple objects (eg., cable tray to cable tray, and the seal edge) unless otherwise documented by the actual dimensions listed in the test data.

4. The basis for ignitability temperatures of cable jacket insulation and cotton waste materials were derived from IEEE Standard 634-1978.

4.0 FIRE TEST ANALYSIS

The Fire Test Report includes a detailed description of the penetrating objects, the seal configuration, and the seal materials.

The test method was based on standard fire test documents which were in existence at the time the test was conducted in 1986. As noted previously, IEEE 634 was utilized to establish the criteria for furnace temperature, thermocouple locations and hose stream impingement.

In review of the ASTM and IEEE test criteria, it was noted that the number of unexposed side thermocouples varies in both methods. ASTM requires temperatures to be taken at nine (9) points, whereas, IEEE stipulates a minimum of three (3) thermocouple points. The reason for the nine thermocouples in ASTM is that this test method was developed primarily for large fire rated assemblies such as walls, floors, roofs, etc., whereas IEEE was written specifically for cable penetration fire stops.

The surface area of a penetration seal compared to the area of a wall or ceiling is obviously much smaller therefore, the difference between the number of thermocouples is relative to the size of the test specimen. It was also noted that the larger penetration (eg., 45" x 7") did utilize 9-12 thermocouples for recording unexposed side temperatures. Therefore, good engineering judgement was employed in determining the number of temperature probes to be used for the test. The IEEE guidance criteria regarding thermocouple placement was, therefore, appropriate for analyzing the cold side temperatures.

The acceptance criteria, which followed the IEEE 634 guidelines, was also compared to ASTM E-119 and NELPIA/MAERP criteria, and NRC guidelines. The following chart illustrates the acceptance criteria from each test/guidance document:

	CRITERION 1 Seal Integrity During Fire	CRITERION 2 Max. Cold Side Temperature	CRITERION 3 Hose Stream
NELPIA/MAERP	No fire or flame propagation to unexposed side	325°F plus ambient	No opening occurs in fire stop
ASTM E-119	No passage of flame or gases hot enough to ignite cotton waste (eg. 450°F)	250°F above initial temp.	No passage of hose stream through seal
IEEE 634	No passage of flame or gases hot enough to ignite the cable or fire stop material	700°F or self-ignition temp. of cable jacket, fire stop, or any material in contact with seal	No opening in fire stop
NRC (Appendix A to BTP 9.5-1)	References ASTM E-119 criteria for general guidance		
(10CFR50 Appendix R)	No passage of flame or ignition of cables on un-exposed side	Max. temp. is sufficiently below cable ignition temp.	Seal remains intact with no projection of water beyond unexposed side
(GL 86-10)	References NFPA 251, Ch. 7 - no passage of flame or gases hot enough to ignite cotton waste	325°F	Not specifically addressed
(Information Notice 88-04)	No burn-through of seal nor hot gases sufficient to ignite cotton waste (eg. 450°F)	325°F	Seal remains intact with no projection of water beyond unexposed surface

The acceptance criteria for the seal integrity during fire exposure is similar in that no fire, flame, or burn-through of the seal is allowed. In addition, the ASTM, IEEE, and NRC guidance documents also require that there shall be no passage of hot gases sufficient enough to ignite cotton waste or the cable insulation on the unexposed side of the seal.

During the test, Construction Technology Laboratories (CTL) documented the physical conditions on the unexposed surface and noted the specific instances where flame penetrated the seal or ignition of the cabling occurred. Smoke was also observed coming from some of the penetrations and cabling, however, this condition in itself was not considered a failure of the sealing device. Temperatures recorded on the unexposed surface were utilized to demonstrate that smoke or hot gases were not sufficient enough to ignite or cause degradation of the cable insulation (i.e., approx. 650°F).

In this analysis, Criterion 1 incorporated ASTM, IEEE, and NRC qualification criteria for seal integrity and was based on:

- No passage of flame, burn-through of seal, or ignition of cable insulation on the unexposed side.
- Smoke (i.e., hot gases) observed on the unexposed side of the seal was not sufficient enough to ignite cable insulation (as also demonstrated by cold side surface/penetrant interface temperatures of less than 650°F).

In review of Criterion 2, (maximum cold side temperature), the IEEE 634 limit of 700°F is somewhat less restrictive than the ASTM and NRC limit of 250°F plus ambient or 325°F maximum.

NRC Information Notice 88-04 states that "The cold-side temperature should not exceed 250°F above ambient during the test or 325°F maximum, although higher temperatures at through penetrations are permitted when justified in terms of cable insulation ignitability."

In order to demonstrate seal qualification ASTM/NRC guidelines, this analysis is based on meeting a maximum unexposed side surface temperature of 325°F. However, the higher temperature limits in the test report were evaluated on a case by case basis to justify that the maximum recorded temperature was sufficiently below the ignition temperature for each type of cable.

The final pass/fail criteria (Criterion 3) regarding hose stream testing, requires that no opening occurs in the fire stop during hose stream impact. In addition, this evaluation also incorporated ASTM and NRC guidance that stipulates that there be no projection of water beyond the unexposed surface.

Based on the discussion of the acceptance criteria outlined above, the following Section describes the tested designs which successfully passed these objectives as well as the designs which did not fully satisfy the qualification criteria.

4.1 Penetration #1

Penetration #1 consisted of a 6" x 32" solid back cable tray with a 40% cable fill installed in a 45" x 7" rectangular opening. A total of 13.98 lbs. of Johns-Manville Cerafiber was installed along the full length of the penetration to provide an average density of 9 lb/ft^3. The void area created between the cable tray and the left-hand side of the penetration (approximately 12" x 7") had a 1" thickness of Ceraboard placed flush with the unexposed and exposed surfaces of the concrete slab. After installation of the Ceraboard, a 1/8" thick coating of Vimasco Cable Coating 3I was applied with a 1" overlap all around the penetration opening on both the unexposed and exposed sides of the penetration. Additionally, a 4" Nelson CMP fix was installed in the cable tray area over the Vimasco cable coating on both the unexposed and exposed sides of the penetration.

For Penetration #1, the unexposed side temperatures were measured using a total of eleven thermocouples. The highest temperature readings on the unexposed surface occurred at 180 minutes when thermocouples #49 and #50 both measured 172°F. Slightly higher temperatures were measured at the interface between the penetrating items and the unexposed surface of the seal. Thermocouple #48, located at the cable tray/unexposed side interface, recorded the highest temperature of the test which was 255°F at 180 minutes. In review of the test data, it was noted that none of the unexposed side temperatures exceeded the 325°F limit.

A review of the test results for Penetration #1 indicate the following:

- No passage of flame occurred through the penetration during the 3 hr. fire test.
- Limiting end point temperatures, as defined by ASTM E-119, were not exceeded during the 3 hr. fire test.

Therefore, this configuration is considered acceptable for withstanding an ASTM E-119 3 hr. exposure.

4.2 Penetration #2

Penetration #2 consisted of a 6" x 32" solid back cable tray with a 5% cable fill installed in a 33" x 8" rectangular opening. A total of 13.24 lbs. of Cerafiber ~~was~~ installed along the full length of the penetration to provide an average density of 9 lb/ft^3. Ceraboard, 1" thick, was installed on both the unexposed and exposed sides of the penetration. Additionally, a 1/8" thick layer of Vimasco cable coating was applied to the Ceraboard with a 1" overlap around the penetration opening on both the unexposed and exposed sides of the penetration.

After seal material was allowed to cure, three repairs were installed. The first repair was a 4" diameter hole drilled through the Vimasco coating and Ceraboard on both the unexposed and exposed sides. The Ceraboard was replaced and recoated with a 1/8" thickness of Vimasco.

The second repair was created by making three overlapping circular holes through the Ceraboard approximately 1" diameter on both the exposed and unexposed sides. All three overlapping holes on the exposed and unexposed sides lined up. One of the circular holes was repaired with Flamastic 77, one was repaired with Flamesafe S-100, and one was repaired with General Electric (G.E.) RTV 133 Silicone Adhesive Sealant. All three coatings were installed flush with the seal, as well as being in contact with one another and the original Vimasco cable coating.

The third repair was created by making a 2-1/4" diameter opening through the Ceraboard on both sides of the penetration. The 2-1/4" diameter opening was uncoated and exposed the underlying Cerafiber.

For Penetration #2, the unexposed side temperatures were measured using a total of eleven thermocouples. The highest temperature readings on the unexposed surface occurred at 180 minutes when thermocouple #6 measured 203°F. Slightly higher temperatures were measured at the interface between the penetrating items and the unexposed surface of the seal. Thermocouple #1, located at the power cable/unexposed side interface, recorded the highest temperature of the test which was 266°F at 180 minutes. In review of the test data, it was noted that none of the unexposed side temperatures exceeded the 325°F limit.

A review of the test results for Penetration #2 indicate the following:

- No passage of flame occurred through the penetration during the 3 hr. fire test.

- Limiting end point temperatures, as defined by ASTM E-119, were not exceeded during the 3 hr. fire test.

Therefore, this configu ation is considered acceptable for withstanding an ASTM E-119 3 hr. exposure.

4.3 Penetration #3

Penetration #3 consisted of a 6" x 32" solid back cable tray with a 30% cable fill installed in a 33" x 8" rectangular opening. A total of 12.9 lbs. of Cerafiber was installed along the full length of the penetration to provide an average density of 9 lb/ft^3. Vimasco cable coating was applied in a 1/8" layer to the Cerafiber with a 1" overlap around the penetration opening on both the unexposed and exposed sides of the penetration. After the seal material was allowed to cure, four repairs were installed.

All four repairs were made on intentionally formed breaches. The breaches were formed to line up approximately on the opposite sides (exposed and unexposed). Breaches were of sufficient size to accommodate a #12-9/C cable which was placed in each opening prior to repair. The annular area in all four repair breaches was packed with Kaowool for the full depth of the penetration. Three of the breaches were repaired with either Flamastic 77, Flamesafe S-100, or G.E. 133 RTV sealants. These materials were applied on both sides of the penetration and in contact with the original Vimasco cable coating. The fourth repair was uncoated and exposed and underlying Cerafiber and Kaowool on both sides of the penetration.

For Penetration #3, the unexposed side temperatures were measured using a total of twelve thermocouples. The highest temperature readings on the unexposed surface occurred at 180 minutes when thermocouple #30 measured 210°F. Higher temperatures were measured at the interface between the penetrating items and the unexposed surface of the seal. Thermocouples #25, 73, 74 and 75 all exceeded the 325°F limit during the 180 minute fire test. Thermocouple #25, located on the 250-MCM-1/C power cables, reached 602°F at 180 minutes. Thermocouple #73, located on the Repair #2 interface, reached 397°F at 180 minutes. Thermocouple #74, located on the repair #3 interface, reached 422°F at 180 minutes. Thermocouple #75, located on the repair #4 interface, reached 501°F at 180 minutes. All other thermocouples remained below the 325°F limit.

In review of the thermocouple locations, it is evident that the higher temperatures are associated with the penetrants and specific repair configurations. The cable used in the fire test consisted of polyethylene insulation with PVC jacket, which is a more combustible form of cable insulation. The self ignition temperature of PE/PVC cable insulation and jacketing is approximately 650°F. Therefore, the penetration could be considered acceptable for maintaining a 3 hr. exposure fire as defined by IN 88-04. However, acceptance of this configuration would require a review of ~~the~~ materials which might be exposed to high heat transfer on the unexposed side of the seal. Self ignition temperatures of any materials in contact with the seal would have to be in excess of 602°F.

A review of the test results for Penetration #3 indicates the following:

- No passage of flame occurred through the penetration during the 3 hr. fire test.
- Limiting end point temperatures, as defined by ASTM E-119, were not exceeded on the unexposed surface during the 3 hr. fire test. However, penetrating items and repair locations exceeded the 325°F limit and require a review of the materials in contact with the seal.

Therefore, this configuration is considered acceptable for withstanding an ASTM E-119 3 hr. exposure fire in accordance with IN 88-04. However, this acceptance is based on the condition that materials in contact with the seal surface have a self ignition temperature in excess of 602°F.

4.4 Penetration #4

Penetration #4 consisted of a 6" x 32" solid back cable tray with a 40% cable fill installed in a 33" x 8" rectangular opening. A total of 11.7 lbs. of Cerafiber was installed along the full length of the penetration to provide an average density of 9 lb/ft^3. On both the unexposed and exposed sides of the penetration a 1/8" coating of Vimasco cable coating was applied to the Cerafiber with a 1" overlap around the penetration opening.

After the seal material was allowed to cure, temporary Styrofoam damming was secured and a 3" thickness of Firecode C.T. Gypsum material was placed on both exposed and unexposed surfaces on both of the front and sides of the cable tray. Additionally, a 1/2" maximum bead of Nelson FSP Putty was applied to the back side of the cable tray along with interface of the cable tray and the concrete test slab on both surfaces.

For Penetration #4, the unexposed side temperatures were measured using a total of twelve thermocouples. The highest temperature readings on the unexposed surface occurred at 180 minutes when thermocouple #17 measured 224°F. Higher temperatures were measured ~~at the~~ interface between the penetrating items and the unexposed surface of the seal. Thermocouples #13 and 15 both exceeded the 325°F limit during the 180 minute fire test. Thermocouple #13, located on the 250-MCM-1/C power cables, reached 400°F at 180 minutes. Thermocouple #15, located on the #16-2/C instrument cables, reached 332°F at 180 minutes. All other thermocouples remained below the 325°F limit.

In review of the thermocouple locations, it is evident that the higher temperatures are associated with the cable penetrants. The cable used in the fire test consisted of polyethylene insulation with PVC jacket, which is a more combustible form of cable insulation. The self ignition temperature of PE/PVC cable insulation/jacketing is approximately 650°F. In addition, the highest temperature recorded on the unexposed side was well below the self ignition temperature of cotton waste (i.e., < 450°F). Therefore, the penetration integrity is considered acceptable for maintaining a 3 hr. exposure fire in accordance with IN 88-04.

A review of the test results for Penetration #4 indicates the following:

- No passage of flame occurred through the penetration during the 3 hr. fire test.
- Limiting end point temperatures, as defined by ASTM E-119, were not exceeded on the unexposed surface during the 3 hr. fire test. However, penetrating items and repair locations exceeded the 325°F limit and require a review of the materials in contact with the seal.

Therefore, this configuration is considered acceptable for withstanding an ASTM E-119 3 hr. exposure fire in accordance with IN 88-04.

4.5 Penetration #5

Penetration #5 consisted of a 6" x 32" solid back cable tray with a 40% cable fill installed in a 33" x 8" rectangular opening. A total of 11.7 lbs. of Cerafiber was installed along the full length of the penetration to provide an average density of 9 lb/ft^3. Vimasco cable coating was applied in a 1/8" thickness with a 1" overlap all round the penetration opening on both the unexposed and exposed sides of the penetration.

After the seal material was allowed to cure, four repairs were installed in intentionally formed breaches. All four breaches were approximately lined up on opposite sides (exposed and unexposed). Breaches were of sufficient size to accommodate a #12-9/C cable which was placed in each ope~~ning prior~~ to repair. All four repair breaches were packed with Kaowool around the new cable to the full depth of the penetration. Either Flamastic 77, Flamesafe S-100, or G.E. 133 RTV sealants were applied to these different repair breaches. Material was applied on both surfaces of the penetration and in contact with the original Vimasco cable coating. The fourth repair was uncoated and exposed the underlying Cerafiber and Kaowool on both surfaces of the penetration.

For Penetration #5, the unexposed side temperatures were measured using a total of twelve thermocouples. The highest temperature readings on the unexposed surface occurred at 180 minutes when thermocouple #42 measured 275°F. Higher temperatures were measured at the interface between the penetrating items and the unexposed surface of the seal. Thermocouples #33, 35, and 40 all exceeded the 325°F limit during the 180 minute fire test. Thermocouple #33, located on the 250-MCM-1/C power cables, reached 433°F at 180 minutes. Thermocouple #35, located on the #16-2/C instrument cables, reached 341°F at 180 minutes. Thermocouple #40, located on the repair #4 interface, reached 407°F at 180 minutes. All other thermocouples remained below the 325°F limit.

In review of the thermocouple locations, it is evident that the higher temperatures are associated with the penetrants and specific repair #4, which was uncoated. The cable used in the fire test consisted of polyethylene insulation with PVC jacket, which is a more combustible form of cable insulation. The self ignition temperature of PE/PVC cable insulation/jacketing is approximately 650°F. In addition, the highest temperature recorded on the unexposed side was well below the self ignition temperature of cotton waste (i.e., <450°F). Therefore, the penetration integrity is considered acceptable for maintaining a 3 hr. exposure fire.

A review of the test results for Penetration #5 indicates the following:

- No passage of flame occurred through the penetration during the 3 hr. fire test.
- Limiting end point temperatures, as defined by ASTM E-119, were not exceeded on the unexposed surface during the 3 hr. fire test. However, penetrating items and repair locations exceeded the 325°F limit and require a review of the materials in contact with the seal.

Therefore, this configuration is considered acceptable for withstanding an ASTM E-119 3 hr. exposure fire in accordance with IN 88-04.

4.6 Penetration #6

Penetration #6 was constructed by installing a 5" diameter conduit into an 8" diameter opening in the concrete test slab. Preinstallation of seal material was performed while the conduit was maintained at a 5° angle (to simulate wall installation in as-built plant conditions). A 41% cable fill was installed in the 5" diameter rigid metal conduit. The space on the exposed side of the conduit was sealed with a 3" thickness of Cerafiber and a 1/4" thickness of Flamastic 77. The remaining space within the conduit was sealed with G.E. 627 silicone sealant (unknown quantity). The void area that the G.E. 627 silicone sealant did not fill (due to 5° angle of conduit) was filled and packed with Cerafiber. A 1/2" thickness of Flamastic 77 was then applied to cover the entire sleeve opening on the unexposed end. After seal materials were allowed to cure, the conduit was installed in the concrete test slab.

For Penetration #6, the unexposed side temperatures were measured using a total of six thermocouples. The highest temperature readings on the unexposed surface occurred at 180 minutes when thermocouple #64 measured 98°F. Slightly higher temperatures were measured at the interface between the penetrating items and the unexposed surface of the seal. Thermocouple #65, located at the pipe sleeve/unexposed side interface, recorded the highest temperature of the test which was 163°F at 180 minutes. In review of the test data, it was noted that none of the unexposed side temperatures exceeded the 325°F limit.

A review of the test results for Penetration #6 indicates the following:

- No passage of flame occurred through the penetration during the 3 hr. fire test.
- Limiting end point temperatures, as defined by ASTM E-119, were not exceeded during the 3 hr. fire test.

Therefore, this configuration is considered acceptable for withstanding an ASTM E-119 exposure fire.

4.7 Penetration #7

Penetration #7 was lined with a 5" diameter rigid metal conduit. A 41% cable fill was installed in the conduit. The annular space within the conduit ~~was~~ sealed with 2.91 lbs. of Cerafiber to provide an average density of 9 lb/ft^3. Both the unexposed and exposed ends of the conduit were then sealed with 1/8" of G.E. RTV 133.

For Penetration #7, the unexposed side temperatures were measured using a total of six thermocouples. The highest temperature readings on the unexposed surface occurred at 180 minutes when thermocouple #70 measured 109°F. Slightly higher temperatures were measured at the interface between the penetrating items and the unexposed surface of the seal. Thermocouple #71, located at the pipe sleeve/unexposed side interface, recorded the highest temperature of the test which was 146°F at 180 minutes. In review of the test data it was noted that none of the unexposed side temperatures exceeded the 325°F limit.

A review of the test results for Penetration #7 indicates the following:

- No passage of flame occurred through the penetration during the 3 hr. fire test.
- Limiting end point temperatures, as defined by ASTM E-119, were not exceeded during the 3 hr. fire test.

Therefore, this configuration is considered acceptable for withstanding an ASTM E-119 3 hr. exposure fire.

4.8 Penetration #8

Penetration #8 was lined with a 5" diameter cast-in-place 1/4" thick steel sleeve installed flush with both surfaces of the concrete slab. A 32% cable fill was installed within the sleeve. The annular space within the sleeve was sealed with a 12" thickness of Cerafiber weighing 0.83 lb. Each face of the penetration was uncoated and exposed the Cerafiber.

For Penetration #8, the unexposed side temperatures were measured using a total of six thermocouples. The highest temperature readings on the unexposed surface occurred at 180 minutes when thermocouple #59 measured 331°F. It was noted that at 175 minutes thermocouple #59 at the interface between the penetrating items and the unexposed surface of the seal. Thermocouple #12, located on the 250-MCM-1/C power cables, reached 555°F at 180 minutes. All other thermocouples remained below the 325°F limit.

In review of the thermocouple locations, it is evident that the higher temperatures are associated with the penetrating cables. It was noted that thermocouple #12, used to measure unexposed surface temperature was located within 1/4" of the 250-MCM-1/C power cables. The cable used in the fire test consisted of polyethylene insulation with PVC jacket, which is a more combustible form of cable insulation. The self ignition temperature of PE/PVC cable insulation/jacketing is approximately 650°F. Therefore, the penetration could be considered acceptable for maintaining a 3 hour exposure fire. However, acceptance of this configuration would require a review of the materials which might be exposed to high heat transfer on the unexposed side of the seal. Self ignition temperatures of any cables in contact with the seal would have to be in excess of 555°F.

A review of the test results for Penetration #8 indicates the following:

- No passage of flame occurred through the penetration during the 3 hr. fire test.
- Limiting end point temperatures, as defined by ASTM E-119, were exceeded on the unexposed surface during the 3 hr. fire test. In addition, penetrating items exceeded the 325°F limit and require a review of the materials in contact with the seal.

Therefore, this configuration is considered acceptable for withstanding an ASTM E-119 3 hr. exposure fire in accordance with IN 88-04. However, this acceptance is based on the condition that materials in contact with the seal surface have a self ignition temperature in excess of 555°F.

4.9 Hose Stream Test

After the 3 hour fire exposure, the eight penetration configurations in the test assembly were subjected to the IEEE 634 hose stream test. A 75 psi hose stream was delivered from a distance of 10 feet through a 1-1/2" diameter hose equipped with a fog nozzle set at a discharge angle of 30°. The spray was delivered over an exposed area of 7'-4" x 7'-6" for a duration of 1 minute 23 seconds. Although the duration of the hose stream test met the requirements of ASTM E-119, the hose stream test was not equivalent to the guidelines contained in NRC Information Notice No. 88-04. IN 88-04 states that the hose stream shall be delivered in one of the following ways:

a) A 1-1/2" nozzle set at a discharge angle of 30° with a nozzle pressure of 75 psi and a minimum discharge of 75 gpm with the tip of the nozzle a maximum of 5 ft. from the exposed face.

b) A 1-1/2" nozzle set at a discharge angle of 15° with a nozzle pressure of 75 psi and a minimum discharge of 75 gpm with the tip of the nozzle a maximum of 10 ft. from the exposed face.

c) A 2-1/2" national standard playpipe equipped with 1-1/8" tip, nozzle pressure of 30 psi, located 20 ft. from the exposed face.

Therefore, although no opening developed during the IEEE 634 hose stream test that permitted a projection of water beyond the unexposed surface of the test assembly, the nozzle was placed 10 feet away from the test specimen and not 5 feet as required by IN 88-04. Although the direct impact of a closer hose stream discharge was not demonstrated in this test, the significance is not considered sufficient to effect the acceptance of the test specimens in meeting the ASTM E119 requirements for a 3 hour rated configuration.

5.0 SUPPLEMENTAL FIRE TEST REVIEW

In order to find further evidence of qualified 3 hour fire rated penetration seal assemblies, a review was performed of the tested configurations contained in Underwriters Laboratories (U.L.) Test Fire No. NC601-1 through -4 which was performed on November 17, 1980 for Niagara Mohawk. This test report has been included as Attachment E.

The test method for this supplemental U.L. test report was similar to the CTL test report in that it utilized IEEE 634 to establish the criteria for furnace temperature, thermocouple locations and hose stream impingement. As discussed earlier in Section 4.0, some differences exist between IEEE 634 and NRC accepted standards. For the purpose of this analysis, the tested configurations were reviewed to determine acceptability based on NRC guidance and accepted standards.

5.1 Supplement #1 (Floor Test #1, Penetration #14)

Penetration #14 of Floor Test No. 1 consisted of two 5" x 24" open ladder cable trays each with 40.3% cable fill installed in a 52" x 12" rectangular opening. A total of 29.15 lbs. of Kaowool bulk ceramic fiber was installed along the full length of the penetration to provide an average density of 7.7 lb./ft.^{3}. Additionally, a 1/2" thick layer of Flamastic cable coating was applied to the ceramic fiber with a 1" overlap around the penetration opening on both the unexposed and exposed sides of the penetration. The mastic coating was tapered from full thickness at the barrier surface to a thin brush coat at its termination point approximately 12 in. from the seal surface on both sides.

For Penetration #14, the unexposed side temperatures were measured using a total of sixteen thermocouples. The highest temperature reading on the unexposed surface occurred at 180 minutes when thermocouple #65 measured 321.2°F. Therefore, all of the thermocouples for penetration #14 remained below 325°F for the 3 hour duration of the fire test.

A review of the test results for Penetration #14 indicate the following:

- No passage of flame occurred through the penetration during the 3 hr. fire test.
- Limiting end point temperatures, as defined by ASTM E-119, were not exceeded during the 3 hr. fire test.

Therefore, this configuration is considered acceptable for withstanding an ASTM E-119 3 hr. exposure.

5.2 Supplement #2 (Floor Test #2, Penetration #7)

Penetration #7 of floor test #2 consisted of a nominal 5" diameter metal conduit sleeve with 31.2% cable fill. A total of .33 lbs. of Kaowool bulk ceramic fiber was installed inside the sleeve to provide an average density of 3.5 lb./ft.^{3}. Additionally, a 1/4" thick layer of Flamastic cable coating was applied to the ceramic fiber with a 1" overlap around the penetration opening on both the unexposed and exposed sides of the penetration. The mastic coating was tapered from full thickness at the barrier surface to a thin brush coat at its termination point approximately 12 in. from the seal surface on both sides.

For Penetration #7, the unexposed side temperatures were measured using a total of four thermocouples. The highest temperature reading on the unexposed surface occurred at 180 minutes when thermocouple #31 measured 238.4°F. Therefore, all of the thermocouples for Penetration #7 remained below 325°F for the 3 hour duration of the fire test.

A review of the test results for Penetration #7 indicate the following:

- No passage of flame occurred through the penetration during the 3 hr. fire test.
- Limiting end point temperatures, as defined by ASTM E-119, were not exceeded during the 3 hr. fire test.

Therefore, this configuration is considered acceptable for withstanding an ASTM E-119 3 hr. exposure.

5.3 Supplemental Hose Stream Test

After the 3 hour fire exposure, the penetration configurations in the U.L. tested assemblies were subjected to the IEEE 634 hose stream test. A 75 psi hose stream was delivered from a distance of 10 feet through a 1-1/2" diameter hose equipped with a fog nozzle set at a discharge angle of 30°. The spray was delivered over an exposed area of 8' x 14'-2" for a duration of 2 minutes 43 seconds. Although the duration of the hose stream test met the requirements of ASTM E-119, the hose stream test was not equivalent to the guidelines contained in NRC Information Notice No. 88-04. IN 88-04 states that the hose stream shall be delivered in one of the following ways:

a) A 1-1/2" nozzle set at a discharge angle of 30° with a nozzle pressure of 75 psi and a minimum discharge of 75 gpm with the tip of the nozzle a maximum of 5 ft. from the exposed face.

b) A 1-1/2" nozzle set at a discharge angle of 15° with a nozzle pressure of 75 psi and a minimum discharge of 75 gpm with the tip of the nozzle a maximum of 10 ft. from the exposed face.

c) A 2-1/2" national standard playpipe equipped with 1-1/8" tip, nozzle pressure of 30 psi, located 20 ft. from the exposed face.

Therefore, although no opening developed during the IEEE 634 hose stream test that permitted a projection of water beyond the unexposed surface of the test assembly, the nozzle was placed 10 feet away from the test specimen and not 5 feet as required by IN 88-04. Although the direct impact of a closer hose stream discharge was not demonstrated in this test, the significance is not considered sufficient to effect the acceptance of the test specimens in meeting the ASTM E119 requirements for a 3 hour rated configuration.

6.0 DESIGN DETAIL ANALYSIS

The design details in Attachments A through D consist of a thermal resistive component (ceramic fiber) and one or more insulative/mechanical strength components (damming board and/or mastic coating).

The ceramic fiber is an insulative material which reduces heat conduction through the seal to the unexposed side. Kaowool, manufactured by Babcock and Wilcox, and Cerafiber, manufactured by Johns-Manville, are two types of ceramic fiber used for this purpose.

The review of vendor literature for Kaowool and Cerafiber shows that both are good insulators with similar thermal conductivities as detailed below:

Material	Density	Thermal Conductivity BTU-in/sq ft-hr°F @ mean temp of 1,200°F
Cerafiber	9 lb/Ft^2	± 1.40
Kaowool	9 lb/Ft^2	± 0.88

A comparison of the heat transfer rates for both materials at a constant cross sectional area and mean temperature of 1,200°F also shows this:

Material and Thickness	Heat Transfer Rate Per Unit Area and Temperature Gradient (BTU/sq. ft-hr-°F)
12 in. Cerafiber (9 lb/ft^3)	.117
12 in. Kaowool (9 lb/ft^3)	.073

Based on the above similarities and the fact that both Cerafiber and Kaowool were tested successfully in similar configurations, both Cerafiber or Kaowool can be used separately or in combination as the primary seal material to form a 3 hr. rated sealing device.

The CTL test penetrations typically consisted of 9 lb./ft.^{3} Cerafiber with a 1/8" thick mastic coating. Although the tests conducted by U.L. showed that openings could be sealed with between 3.5 lb./ft.^{3} and 7.7 lb./ft.^{3}, the seal configurations in the U.L. test report were coated with 1/2" thick mastic which extended 12" out from the seal surface on both ends. Since the CTL test is more representative of penetrations at the Zion Station, the design details include the more conservative 9 lb./ft.^{3} requirement.

Cerafiber and Kaowool are the only two fiber products discussed here. However, these may not be the only two ceramic fiber materials available today or in the future. Others may become available with similar thermal characteristics which are noncombustible. These materials could also be appropriately substituted, if they have been fire tested and/or determined to be at least equivalent to the ceramic fiber products discussed above with respect to their performance to a standard 3 hr. fire exposure. Any substitution of the fiber products should be performed by qualified individuals and documented, as to the reasons for the proposed substitution and the materials equivalency.

Non-combustible damming boards vary in material and density but are typically a compressed form of ceramic fiber. Their primary function is to minimize the direct flame exposure to the primary seal material and increase the durability of the configuration during fire exposure. Marinite XL Board and Ceraboard, produced by Johns-Manville, Kaowool M Board, produced by Babcock and Wilcox, and Fiberfrax GH Board, produced by Carborundum are all types of non-combustible damming boards which exhibit similar properties with respect to thermal conductivity. Based on the use of damming boards as a strength component and not a primary seal material, all types of non-combustible damming boards are acceptable provided that they exhibit similar thermal conductivity properties to the damming boards addressed above.

Mastic coatings vary in the types of thermo plastic resins, flame retardant chemicals and inorganic incombustible fibers which make them up. Their primary function is to insulate flammable surfaces from heat and flame exposures by reducing the heat transmission to the protected surface and producing by-products which inhibit the combustion process. Flamastic 77, Vimasco 31, Flamesafe S-100 (formerly Quelpyre) and GE RTV-133 are four types of mastic coatings currently being used.

Although all of these mastic coatings will help to reduce the exposure to the primary seal material and keep cable insulation from contributing to the fire, testing indicated that the best results were developed with the use of Vimasco 31 and Flamastic 77. These mastics will adhere to each other and can be used separately or in combination. It should be noted that the four mastic materials discussed are not the only materials on the market. These materials are only being addressed because the testing performed evaluated the four materials simultaneously, in addition to the use of the materials at the station. Should other mastics may become available in the future, an evaluation by qualified individuals should be performed to document the similarity of these materials to Vimasco 31 or Flamastic 77.

The design details generated by this calculation are included in Attachments A, B, C, and D. The seal features and design parameters were derived by a comparison of the qualified tested configurations and the analysis of material composition. Each of the parameters is discussed below.

6.1 Design Detail A

- Seal Material Composition and Thickness

  The seal material and thickness for Design Detail A is based on CTL test Penetration #5 and provides an equivalency for Details 8 and 10 on CECo Drawings 22E-0-3130, Sheet 1. CTL test

Penetration #5 consisted of 12" of Cerafiber bulk ceramic fiber with 1/8" Vimasco Cable Coating 3I on both sides. The Vimasco Cable Coating was applied with a minimum 1" overlap around the entire seal edge. The density of the Cerafiber was an average of 9 lb/ft^3. This configuration maintained the unexposed surface temperature below 325°F for the duration of the 3 hr. exposure fire. In addition, the temperature of the unexposed side of the penetrating objects was maintained below the self ignition temperature of the cable and below the self ignition temperature of cotton waste (i.e., < 450°F).

Design Detail A is also consistent with the results of U.L. test Penetration #14 of Floor Test #1 which consisted of 12" of Kaowool bulk ceramic fiber with 1/2" Flamastic 77 on both sides. The density of the ceramic fiber was 7.7 lb./ft.^{3}. This configuration maintained the unexposed surface and penetrant temperatures below 325°F for the duration of the 3 hr. exposure fire. the primary difference between this configuration and CTL test Penetration #5 is that the mastic coating was applied to the penetrating cables 12" beyond the barrier on both sides of the penetration. Applying the mastic coating in this manner decreases the exposure to the penetrating cables and thus limits the heat transfer through to the unexposed side. Since the results of CTL test Penetration #5 show that penetrants coated with only 1/8" mastic are maintained at acceptable temperatures, 1/8" was specified as the minimum mastic coating thickness.

Therefore, the minimum material thickness included in Design Detail A is 12" of ceramic fiber with 1/8" mastic coating on both sides to match the tested configurations and provide assurance that the seal design will result in a minimum 3 hr. fire rated assembly.

- Opening Dimensions

The maximum opening size of 624 sq. in. in Design Detail A is consistent with the maximum size tested in U.L. Floor Test #1, test Penetration #14. For the purpose of this calculation, the maximum size opening was selected based on the fire test data for this test configuration. It is also reasonable to conclude, based on test results, that smaller size openings can also be fire sealed with ceramic fiber material.

U.L. Floor Test No. 2, Penetration No. 11 consisted of an 18" diameter pipe sleeve which was filled with Kaowool bulk ceramic fiber coated with 1/4" Flamastic 77 on both sides. This 254 sq. in. opening, without penetrating items, was capable of withstanding the 3 hour fire test and subsequent hose stream test. It is generally accepted that the penetrating items add structural support to the penetration seal materials and that penetration seals which do not contain penetrants are more susceptible to failed hose stream testing. Therefore, although 624 sq. in. is the largest acceptable opening size, 254 sq. in. is the maximum unused seal area where penetrants do not exist. Unused seal areas above 254 sq. in. should be provided with a 1" damming board on both sides to increase the structural stability of the seal.

Sleeves for openings in barriers are typically installed to provide additional structural support to the opening. From a fire barrier penetration seal standpoint, sleeves transmit additional heat through and around the seal. However, the sleeves also provide an interface between the seal material and the barrier, thus providing a less restrictive path for heat to dissipate away from the seal and into the barrier. This statement was verified by the test results of CTL Penetration #5, thermocouple #58, which recorded a temperature of 225°F at the unprotected pipe sleeve for this seal. Therefore, it is reasonable to conclude that an opening without a sleeve would perform similar to the same size sleeved opening.

- Penetrant Types and Sizes

Design Detail A is intended to specify the requirements for electrical cable tray penetrations only. Therefore, mechanical penetration requirements have not been specified.

Cable Types: The cable used in the CTL fire test consisted of polyethylene insulation with PVC jacketing. The intent of the test was to qualify the most combustible type of cable so that the fire test results could be applied to all types of cable. Therefore, Design Detail A does not place a restriction on the types of cable to be used.

Cable Loading and Fill: Cable loading for a particular fire test (total cross section area of cables divided by the inside cross sectional area of tray/conduit) can be used to qualify configurations with the same or less cable loading. CTL Penetration #5 consisted of a tray with 40% cable fill. This is also consistent with U.L. Floor Test #1, Penetration #14 which consisted of two trays each with 40.3% cable fill. Therefore, Design Detail A specifies a maximum 40% cable fill.

Cable Trays: Cable trays fire tested can be used to qualify cable trays constructed from the same materials of the same or smaller size. CTL test Penetration #5 consisted of a 32" x 6" solid back steel cable tray. From a fire barrier penetration seal standpoint, solid back steel cable trays transmit more heat through the seal than open ladder type cable trays. This is evident when reviewing the results of U.L. Floor Test #1, Penetration #14 which consisted of two 24" x 5" steel ladder back cable trays. Observed temperatures at the cable tray interface with the seal were slightly lower than those recorded for CTL Penetration #5. Therefore, Design Detail A specifies a maximum cable tray size of 32" x 6" and does not place a restriction on the tray type.

Conduits: Design Detail A was developed to depict typical configurations for electrical cable tray penetrations only. Conduits were not considered.

- Distance Between Penetrating Items

The minimum dimension between the penetrating item and the wall/floor or between penetrating items is based on the configuration of CTL test Penetration #5. In this configuration, the cable tray was placed into the opening with a 1/2" space between the tray and the seal opening edge. Cable trays represent the worst case for testing spacing dimensions. The ability of the seal material to be applied to an uneven annular space has been demonstrated successfully by test Penetration #5. U.L. Floor Test #1, Penetration #14, which tested two 40.3% filled cable trays approximately 1" apart also helps to verify the acceptability of multiple penetrants in a single opening. Although these trays were tested 1" apart, temperatures on the unexposed side between the cable trays and at the cable tray seal interface, indicate that spacing at the 1/2" distance would not significantly alter the test results. Therefore, Design Detail A specifies a minimum distance of 1/2" between the penetrating items and between the cable tray and the seal opening edge. This requirement ensures that the penetrants are spaced sufficiently such that the seal material is evenly dispersed, thereby maintaining adequate fire resistance.

- Seal Orientation (wall/floor)

Penetration seals tested in a horizontal configuration are considered to be worst case scenarios, thus qualify for application in either wall or floor/ceiling configurations, provided the designs are symmetrical (e.g., damming material on both sides). Both CTL Penetration #5 and U.L Penetration #14 were tested in the horizontal position. Therefore, Design Detail A is valid for both floor/ceiling and wall installations.

6.2 Design Detail B

- Seal Material Composition and Thickness

The seal material and thickness for Design Detail B is based on CTL test Penetration #5 and provides an equivalency for Details 1, 3, 4, 6, and 7 identified on CECo Drawing 22E-0-3130, Sheet 1. CTL test Penetration #5 consisted of 12" of Cerafiber bulk ceramic fiber with 1/8" Vimasco Cable Coating 3I on both sides. The Vimasco Cable Coating was applied with a minimum 1" overlap around the entire seal edge. The density of the Cerafiber was an average of 9 lb/ft^3. This configuration maintained the unexposed surface temperature below 325°F for the duration of the 3 hr. exposure fire. In addition, the temperature of the unexposed side of the penetrating objects was maintained below the self ignition temperature of the cable and below the self ignition temperature of cotton waste (i.e., < 450°F).

Design Detail B is also consistent with the results of U.L test Penetration #14 of Floor Test #1 which consisted on 12" Kaowool bulk ceramic fiber with 1/2" Flamastic 77 on both sides. The density of the ceramic fiber was 7.7 lb./ft.^{3}. This configuration maintained the unexposed surface and penetrant temperature below 325°F for the duration of the 3 hr. exposure fire. The primary difference between this configuration and CTL test Penetration #5 is that the mastic coating was applied to the penetrating cables 12" beyond the barrier on both sides of the penetration. Applying the mastic coating in this manner decreases the exposure to the penetrating cables and thus limits the heat transfer through to the unexposed side. Since the results of CTL test Penetration #5 show that penetrants coated with only 1/8" mastic are maintained at acceptable temperatures, 1/8" was specified as the minimum mastic coating thickness.

This design detail is also supported by the results of test Penetration #8 which consisted of a 5" diameter sleeve with 32% cable fill sealed with 12" of Cerafiber with a density of 9 lb./ft.^{3} only. This configuration maintained the unexposed surface temperature only slightly above the 325°F limit (thermocouple #12 reached 331°F) without the use of the mastic coating. It was also noted that thermocouple #12 was located within 1/4" of the 250-MCM-1/C power cables and was not representative of the average unexposed surface temperature.

For unused conduit sleeves which penetrate the seal, the internal opening of the sleeve shall also be filled with a minimum 12" of ceramic fiber. As an alternative to mastic coating on both ends, however, pipe caps may be used. The pipe caps serve the same purpose as the mastic coating by reducing the direct fire exposure to the primary seal material, which is the ceramic fiber. The transmission of heat to the unexposed side of the seal was demonstrated as being within the maximum cold side temperature of 325°F in CTL test Penetration #8. Thermocouple #58 indicated that the maximum temperature achieved was 225°F which is well within this temperature criteria.

Non-combustible damming boards vary in material and density but are typically a compressed form of ceramic fiber. Their primary function is to minimize the direct flame exposure to the primary seal material and increase the durability of the configuration during fire exposure. In this aspect they perform similar to mastic coatings. The primary advantage that mastics have over damming boards, however, is that mastics, when used on combustible penetrating objects, such as cable, are able to be applied to the surface of the combustible penetrant and thus, reduce the penetrants contribution to the fire. Therefore, mastics should be used to coat combustible penetrants, and damming boards may be provided in seal areas where no combustible penetrants exist. Design Detail B, which was developed to depict typical unused penetrations follows this criteria and allows the use of a 1" damming board in lieu of the mastic coating.

Therefore, the minimum material thickness included in Design Detail B is 12" of ceramic fiber at 9 lb./ft.^{3} with either a 1/8" thickness of mastic coating or a 1" non-combustible damming board (pipe caps may be provided for conduits extending beyond the barrier) on both sides to match the tested configurations and provide assurance that the seal design will result in a minimum 3 hr. fire rated assembly.

- Opening Dimensions

The maximum opening size of 624 sq. in. in Design Detail B is consistent with the maximum size tested in U.L. Floor Test #1, test Penetration #14. For the purpose of this calculation, the maximum size opening was selected based on the fire test data for this tested configuration. It is also reasonable to conclude, based on test results, that smaller size openings can also be fire sealed with ceramic fiber material.

U.L. Floor Test No. 2, Penetration No. 11 consisted of an 18" diameter pipe sleeve which was filled with Kaowool bulk ceramic fiber coated with 1/4" Flamastic 77 on both sides. This 254 sq. in. opening, without penetrating items, was capable of withstanding the 3 hour fire test and subsequent hose stream test. It is generally accepted that the penetrating items add structural support to the penetration seal materials and that penetration seals which do not contain penetrants are more susceptible to failed hose stream testing. Therefore, although 624 sq. in. is the largest acceptable opening size, 254 sq. in. is the maximum unused seal area where penetrants do not exist. Unused seal areas above 254 sq. in. should be provided with a 1" damming board on both sides to increase the structural stability of the seal.

Sleeves for openings in barriers are typically installed to provide additional structural support to the opening. From a fire barrier penetration seal standpoint, sleeves transmit additional heat through and around the seal. However, the sleeves also provide an interface between the seal material and the barrier, thus providing a less resistive path for heat to dissipate away from the seal and into the barrier. This statement was verified by the results of CTL test Penetration #8, thermocouple #58, which record a maximum temperature of 225°F at the unprotected pipe sleeve for this seal. Therefore, it is reasonable to conclude that an opening without a sleeve would perform similar to the same size sleeved opening.

- Penetrant Types and Sizes

Design Detail B is intended to specify the requirements for unused electrical penetrations which include conduit sleeves. Based on the review of CTL Penetration #8 and U.L. Floor Test #2, Penetration #7, the maximum penetrating item size requirements would be a 5" diameter metal conduit.

- Seal Orientation (wall/floor)

  Penetration seals tested in a horizontal configuration are considered to be worst case scenarios, thus qualify for application in ~~either~~ wall or floor/ceiling configurations, provided the designs are symmetrical (e.g., damming material on both sides). CTL test Penetrations #5 & 8 as well as U.L. Floor Test #2, Penetration #7 were tested in the horizontal position. Therefore, Design Detail B is valid for both floor/ceiling and wall installations.

6.3 Design Detail C

- Seal Material Composition and Thickness

  The seal material and thickness for Design Detail C is based on CTL test Penetrations #5 and provides an equivalency for details 2 and 5 as indicated on CECo Drawing 22E-0-3130, Sheet 1. CTL test Penetration #5 consisted of 12" of Cerafiber bulk ceramic fiber with 1/8" Vimasco Cable Coating 3I on both sides. The Vimasco Cable Coating was applied with a minimum 1" overlap around the entire seal edge. The density of the Cerafiber was an average of 9 lb/ft^3. This configuration maintained the unexposed surface temperature below 325°F for the duration of the 3 hr. exposure fire. In addition, the temperature of the unexposed side of the penetrating objects was maintained below the self ignition temperature of the cable and below th self ignition temperature of cotton waste (i.e., < 450°F).

  Design Detail C is also consistent with the results of U.L. test Penetration #14 of Floor Test #1 which consisted on 12" Kaowool bulk ceramic fiber with 1/2" Flamastic 77 on both sides. The density of the ceramic fiber was 7.7 lb./ft.^{3}. This configuration maintained the unexposed surface and penetrant temperature below 325°F for the duration of the 3 hr. exposure fire. The primary difference between this configuration and CTL test Penetration #5 is that the mastic coating was applied to the penetrating cables 12" beyond the barrier on both sides of the penetration. Applying the mastic coating in this manner decreases the exposure to the penetrating cables and thus limits the heat transfer through to the unexposed side. Since the results of CTL test Penetration #5 show that penetrants coated with only 1/8" mastic are maintained at acceptable temperatures, 1/8" was specified as the minimum mastic coating thickness.

This design detail is also supported by the results of CTL test Penetration #8 which consisted of a 5" diameter sleeve with 32% cable fill sealed with 12" of Cerafiber with a density of 9 lb./ft.^{3} only. This configuration maintained the unexposed surface temperature only slightly above the 325°F limit (thermocouple #12 reached 331°F) without the use of the mastic coating. It was also noted that thermocouple #12 was located within 1/4" of the 250-MCM-1/C power cables and was not representative of the average unexposed surface temperature.

Non-combustible damming boards vary in material and density but are typically a compressed form of ceramic fiber. Their primary function is to minimize the direct flame exposure to the primary seal material and increase the durability of the configuration during fire exposure. In this aspect they perform similar to mastic coatings. The primary advantage that mastics have over damming boards, however, is that mastics, when used on combustible penetrating objects, such as cable, are able to be applied to the surface of the combustible penetrant and thus, reduce the penetrants contribution to the fire. Therefore, mastics should be used to coat combustible penetrants, and damming boards may be provided in seal areas where no combustible penetrants exist. Design Detail C, which was developed to depict typical conduit sleeve penetrations follows this criteria and allows the use of a 1" damming board in lieu of the mastic coating.

Therefore, the minimum material thickness included in Design Detail C is 12" of ceramic fiber at 9 lb./ft.^{3} with either a 1/8" thickness of mastic coating or a 1" non-combustible damming board on both sides to match the test configuration and provide reasonable assurance that the seal design will result in a minimum 3 hr. fire rated assembly.

For conduit sleeves which extend beyond the face of the barrier and end in a conduit bushing or coupling with chase nipple, the 1/8" Vimasco cable coating should be applied to the exposed cables and any exposed ceramic fiber at the conduit bushing. It should be noted that for conduit sleeves which penetrate through and extend past a barrier and then terminate in a cable pan, box, panel, etc., may omit the Vimasco coating may be omitted on one side based on the test results of CTL test Penetration #8.

- Opening Dimensions

  - The maximum opening size of 624 sq. in. in Design Detail C is consistent with the maximum size tested in U.L. Floor Test #1, Penetration #14. For the purpose of this calculation, the maximum size opening was selected based on the fire test data for this test configuration. It is also reasonable to conclude, based on test results, that smaller size openings can also be fire sealed with ceramic fiber material.

    U.L. Floor Test No. 2, Penetration No. 11 consisted of an 18" diameter pipe sleeve which was filled with Kaowool bulk ceramic fiber coated with 1/4" Flamastic 77 on both sides. This 254 sq. in. opening, without penetrating items, was capable of withstanding the 3 hour fire test and subsequent hose stream test. It is generally accepted that the penetrating items add structural support to the penetration seal materials and that penetration seals which do not contain penetrants are more susceptible to failed hose stream testing. Therefore, although 624 sq. in. is the largest acceptable opening size, 254 sq. in. is the maximum unused seal area where penetrants do not exist. Unused seal areas above 254 sq. in. should be provided with a 1" damming board on both sides to increase the structural stability of the seal.

    Sleeves for openings in barriers are typically installed to provide additional structural support to the opening. From a fire barrier penetration seal standpoint, sleeves transmit additional heat through and around the seal. However, the sleeves also provide an interface between the seal material and the barrier, thus providing a less resistive path for heat to dissipate away from the seal and into the barrier. This statement was verified by the results of CTL test Penetration #8, thermocouple #58, which record a maximum temperature of 225°F at the unprotected pipe sleeve for this seal. Therefore, it is reasonable to conclude that an opening without a sleeve would perform similar to the same size sleeved opening.

- Penetrant Types and Sizes

  - Design Detail C is intended to specify the requirements for electrical cable conduit sleeve penetrations only. Based in the review of CTL test Penetrations #5 & 8 and U.L. Floor Test #2, Penetration #7, the maximum penetrating item size would be a 5" metal conduit.

Cable Types: The cable used in the CTL fire test consisted of polyethylene insulation with PVC jacketing. The intent of the test was to qualify the most combustible type of cable so that the fire test results could be applied to all types of cable. Therefore, Design Detail C does not place a restriction on the types of cable to be used.

Cable Loading and Fill: Cable loading for a particular fire test (total cross sectional area of cables divided by the inside cross sectional area of tray/conduit) can be used to qualify configurations with the same or less cable loading. Based on CTL test Penetration #5 consisting of a tray with 40% cable fill and CTL test Penetrations #7 and #8 having cable fills of 41 and 32% for conduits, Design Detail C specifies a maximum 40% cable fill.

Cable Trays: Design Detail C was developed to depict typical configurations for electrical cable conduit sleeve penetrations only. Cable trays were not considered.

Conduits: The maximum conduit/conduit sleeve size for Design Detail C was developed based on the results of CTL test Penetrations #6, 7, and 8 and U.L. Floor Test #2, Penetration #7 which all consisted of 5" diameter conduit/conduit sleeves. Therefore, a nominal 5" diameter maximum conduit/conduit sleeve size was shown in Design Detail C.

- Distance Between Penetrating Items

The minimum dimension between the penetrating item and the wall/floor or between penetrating items is based on the configuration of CTL test Penetration #5. In this configuration, the cable tray was placed into the opening with a 1/2" space between the tray and the seal opening edge. Cable trays represent the worst case for testing spacing dimensions. The ability of the seal material to be applied to an uneven annular space has been demonstrated successfully by CTL test Penetration #5. U.L. Floor Test #1, Penetration #14 which tested two 40.3% filled cable trays approximately 1" apart also helps to verify the acceptability of multiple penetrants in a single opening. Although these trays were tested 1" apart, temperatures on the unexposed side between the cable trays and at the cable tray seal interface, indicate that spacing at the 1/2" distance would not significantly alter the test results. Therefore, Design Detail C specifies a minimum distance of 1/2" between the penetrating items. This requirement ensure that the penetrants are spaced sufficiently such that the seal material is evenly dispersed, thereby maintaining adequate fire resistance.

- Seal Orientation (wall/floor)

Penetration seals tested in horizontal configuration are considered to be worst case scenarios, thus qualify for application in either wall or floor/ceiling configurations, provided the designs are symmetrical (e.g., damming material on both sides). CTL test Penetrations #5 & 8 as well as U.L. Floor Test #2, Penetration #7 were tested in the horizontal position. Therefore, Design Detail C is valid for both floor/ceiling and wall installations.

6.4 Design Detail D

- Seal Material Composition and Thickness

The seal material and thickness for Design Detail D is based on CTL test Penetration #5 and provides an equivalency for Detail 9 as indicated on CECo Drawing 22E-0-3130, Sheet 1. Test Penetration #5 consisted of 12" of cerafiber bulk ceramic fiber with 1/8" Vimasco Cable Coating 3I on both sides. The Vimasco cable coating was applied with a minimum 1" overlap around the entire seal edge. The density of the cerafiber was an average of 9 lbs/ft^3. This configuration maintained the unexposed surface temperature below 325°F for the duration of the 3 hr. exposure fire. In addition, the temperature of the unexposed side of the penetrating objects was maintained below the self ignition temperature of the cable and below the self ignition temperature of cotton waste (i.e., < 450°F).

Design Detail D is also consistent with the results of U.L. test Penetration #14 of Floor Test #1 which consisted on 12" Kaowool bulk ceramic fiber with 1/2" Flamastic 77 on both sides. The density of the ceramic fiber was 7.7 lb./ft.^{3}. This configuration maintained the unexposed surface and penetrant temperature below 325°F for the duration of the 3 hr. exposure fire. The primary difference between this configuration and CTL test Penetration #5 is that the mastic coating was applied to the penetrating cables 12" beyond the barrier on both sides of the penetration. Applying the mastic coating in this manner decreases the exposure to the penetrating cables and thus limits the heat transfer through to the unexposed side. Since the results of CTL test Penetration #5 show that penetrants coated with only 1/8" mastic are maintained at acceptable temperatures, 1/8" was specified as the minimum mastic coating thickness.

Therefore, the minimum material thickness included in Design Detail D is 12" of ceramic fiber at 9 lb./ft.^{3} with 1/8" mastic coating on both sides to match the tested configurations. This provides reasonable assurance that the seal design will result in a reasonable fire break to limit flame propagation within a cable tray that is located in an open area.

- Opening Dimensions

Design Detail D was developed to depict typical configurations for electrical cable tray fire breaks. Therefore, the maximum opening size is defined by the maximum tray size for which the fire break can be installed. In order to provide an enclosure, the cable tray must be provided with a cover.

Cable Types: The cable used in the CTL fire test consisted of polyethylene insulation with PVC jacketing. The intent of the test was to qualify the most combustible type of cable so that the fire test results could be applied to all types of cable. Therefore, Design Detail D does not place a restriction on the types of cable to be used.

Cable Loading and Fill: Cable loading for a particular fire test (total cross sectional area of cables divided by the inside cross sectional area of tray/conduit) can be used to qualify configurations with the same or less cable loading. CTL test Penetration #5 consisted of a tray with 40% cable fill. Therefore, Design Detail D specifies a maximum 40% cable fill.

Cable Trays: Cable trays fire tested can be used to qualify cable trays constructed from the same materials of the same or smaller size. CTL test Penetration #5 consisted of a 32" x 6" solid back steel cable tray. Therefore, Design Detail D specifies a maximum cable tray fire break size of 32" x 6" x 12".

Conduits: Design Detail D was developed to depict typical configurations for electrical cable tray fire breaks only. Conduits are not applicable for this design.

- Seal Orientation (wall/floor)

  Penetration seals tested in a horizontal configuration are considered to be worst case scenarios, thus qualify for application in either horizontal or vertical configurations, provided the designs are symmetrical (e.g., damming material on both sides). CTL test Penetration #5 was tested in the horizontal position. Therefore, Design Detail D is valid for the horizontal and vertical positions.

Design Details A through D documented in the Attachments reflect the configuration of representative fire barrier penetrations based on the tested configurations and generally accepted engineering principles regarding the performance of ceramic fiber. The design details also document the various penetrant types/sizes, the minimum clearances between penetrating objects and the recommended composition of the seal material.

The parameters developed for Design Details A through D can also be applied when sealing voids/cracks in 3 hour rated fire barriers. Voids or cracks 1/4" and below, since they do not present a significant fire propagation hazard, can be sealed with a flame retardant material such as G.E. RTV 627. For cracks or voids larger than 1/4", the void should be filled with ceramic fiber for the entire thickness of the barrier or a minimum of 12". Mastic coating should then be applied on both sides to hold the loose fiber in place.

7.0 REFERENCES

1. Construction Technology Laboratories, Fire and Hose Stream Tests of Eight Penetration Seal Systems, 1788E, dated December, 1986.

2. IEEE 634-1978, IEEE Standard Cable Penetration Fire Stop Qualification Test.

3. 10CFR50, Appendix R.

4. NRC Information Notice No. 88-04, Inadequate Qualification and Documentation of Fire Barrier Penetration Seals.

5. NFPA 251-1990, Standard Methods of Fire Tests of Building Construction and Materials.

6. IEEE 383-1974, IEEE Standard for Type Test of Class 1E Electrical Cables, Field Splices, and Connections for Nuclear Power Generating Stations.

7. U.L. Fire Test File No. NC601-1 through -4.

8. U.L. Building Materials Director, 1991.

9. NRC Generic Letter 86-10.

10. NRC SER's and Supplements Dated March 10, 1978, May 26, 1978 and January 28, 1980.

11. CECo Letters Dated April 14, 1978, June 29, 1978 and September 29, 1978.

12. The Consulting Engineers Group Fire Test Report Dated July 27, 1978.

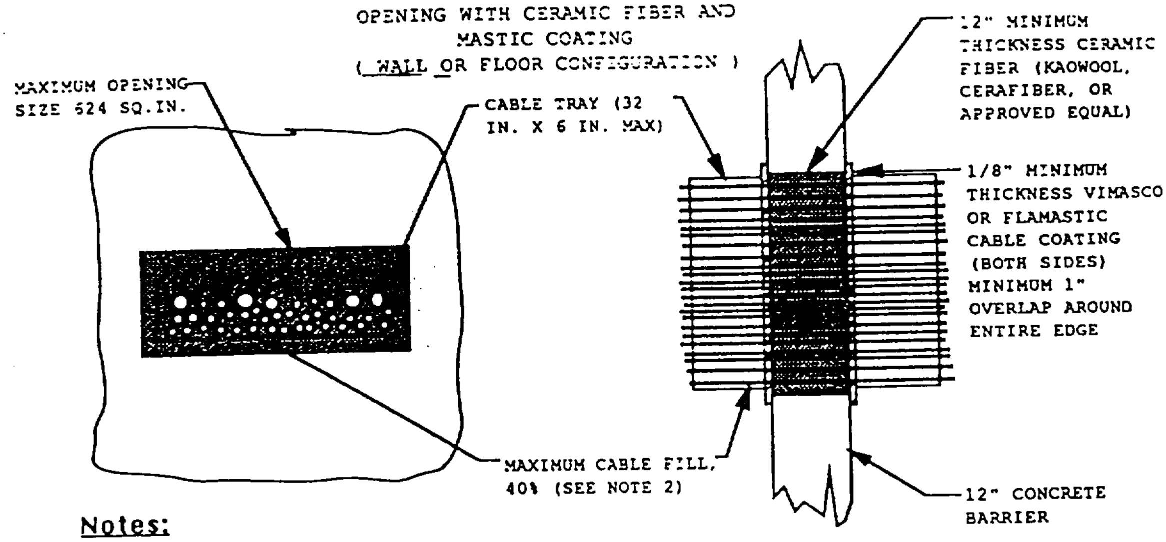
ATTACHMENT A

DESIGN DETAIL A

(CABLE TRAY PENETRATIONS)

DESIGN (A) DETAIL

3 HOUR PENETRATION SEAL DETAIL FOR CABLE TRAY PENETRATIONS IN TYPICAL OPENING WITH CERAMIC FIBER AND MASTIC COATING (WALL OR FLOOR CONFIGURATION)



Notes:

1. Ceramic fiber thickness: Minimum 12" thick, with a minimum density of 9 lbs per cubic foot, covered with 1/8" minimum thickness mastic cable coating, overlapping a minimum of 1" around the entire edge on both sides.
2. The number and types of penetrants and their locations may vary according to the following:
   - Maximum size cable tray may be 32" X 6" (192 sq. in..) with up to 40% cable fill.
3. Free cables should be moved around during installation to assure proper distribution of seal material.
4. A minimum distance of 1/2" should be maintained between the penetrating item(s) and the seal edge to allow for proper distribution of seal material.
5. Design Detail A provides an equivalency for Details 8 and 10 identified on CECo Drawing 22E-0-3130, Sheet 1.
6. Design Detail A has been tested for the installation as a 3 hour fire rated assembly under CTL Test Report No. 1788E, Penetration No. 5.
7. Voids or cracks 1/4" or less may be sealed with G. E. RTV 625 Silicone Sealant or approved equal.
8. Voids or cracks larger than 1/4" may be sealed, as indicated above, with 12" thick ceramic fiber and coated with 1/8" mastic on both sides.
9. Unused openings above 254 sq. in. which do not contain penetrating items must also include a 1" non-combustible damming board on both sides to ensure structural integrity.

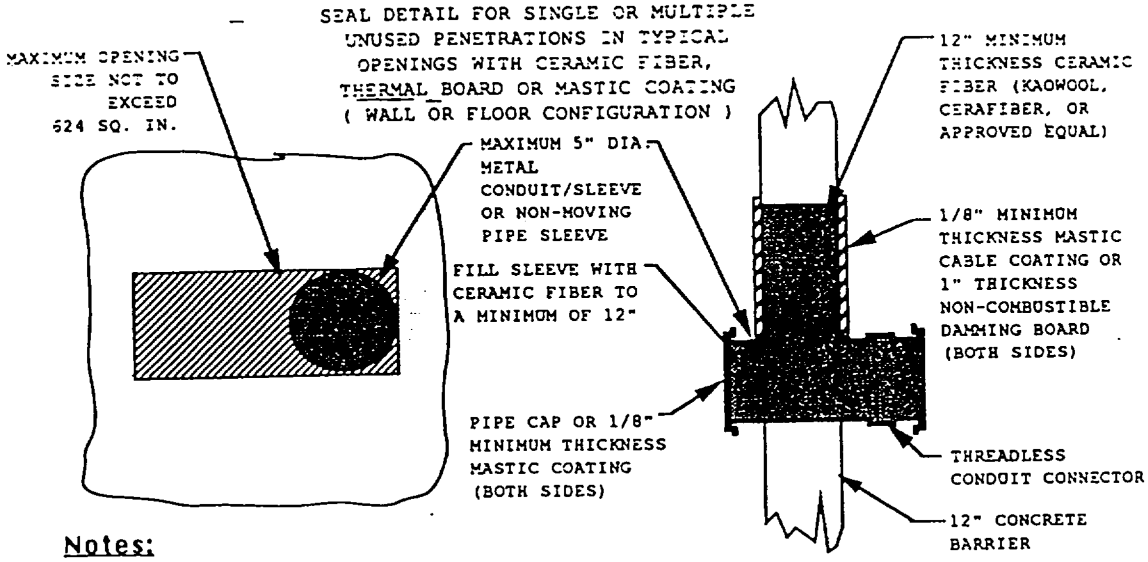
ATTACHMENT B

DESIGN DETAIL B

(UNUSED CONDUIT/SLEEVE PENETRATIONS)

DESIGN (B) DETAIL

3 HOUR INTERNAL SLEEVE PENETRATION SEAL DETAIL FOR SINGLE OR MULTIPLE UNUSED PENETRATIONS IN TYPICAL OPENINGS WITH CERAMIC FIBER, THERMAL BOARD OR MASTIC COATING (WALL OR FLOOR CONFIGURATION)



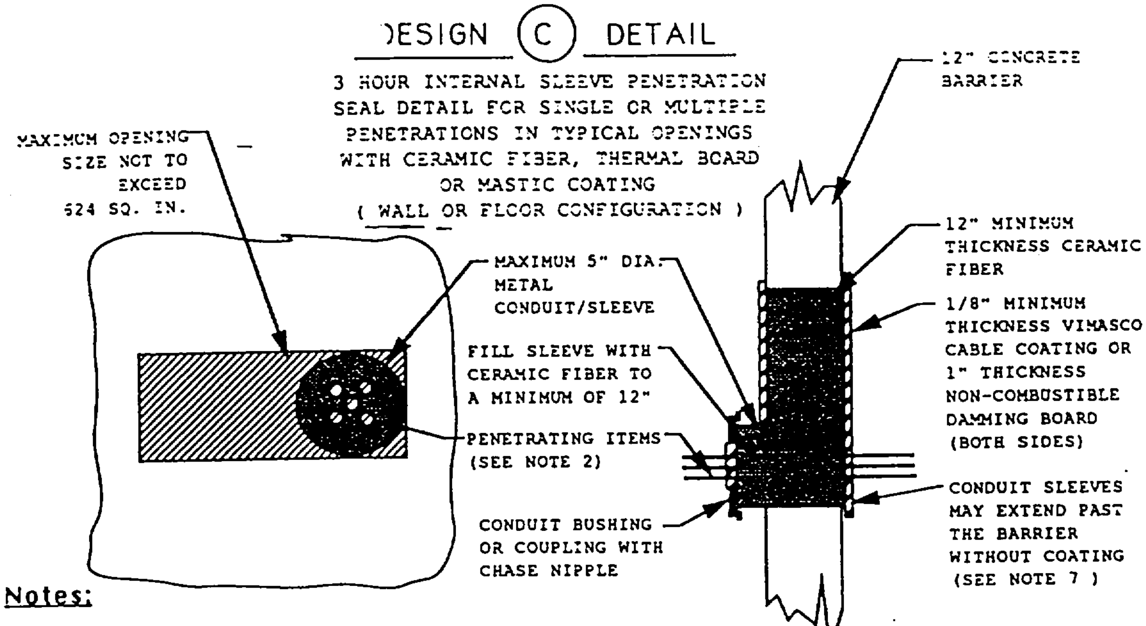
Notes:

1. Ceramic fiber thickness: Minimum 12" thick, with a minimum density of 9 lbs per cubic foot, covered with 1/8" minimum thickness Vimasco cable coating, Flamastic 77, or approved equal.
2. When 1/8" cable coating is used, it shall be applied with a minimum 1" overlap around the entire edge.
3. In lieu of providing the 1/8" thickness of mastic cable coating, a 1" non-combustible damming board may be used.
4. For unused metal conduit sleeves which extend beyond the face of the barrier, pipe caps may be used in lieu of the 1/8" mastic cable coating.
5. Design Detail B provides an equivalency for Details 1, 3, 4, 6 and 7 identified on CECo Drawing 22E-0-3130, Sheet 1.
6. Design Detail B has been tested for the installation as a 3 hour fire rated assembly, utilizing the test results of CTL Test Report No. 1788E, Penetration Nos. 5 and 8, for penetrations with conduit or pipe sleeves.
7. Voids or cracks 1/4" or less may be sealed with G. E. RTV 625 Silicone Sealant or approved equal.
8. Voids or cracks larger than 1/4" may be sealed, as indicated above, with 12" thick ceramic fiber and coated with 1/8" mastic on both sides.
9. Unused openings above 254 sq. in. which do not contain penetrating items must also include a 1" non-combustible damming board on both sides to ensure structural integrity.

ATTACHMENT C

DESIGN DETAIL C

(CONDUIT/SLEEVE PENETRATIONS)



Notes:

1. Ceramic fiber thickness: Minimum 12" thick, with a minimum density of 9 lbs per cubic foot, covered with 1/4" minimum thickness Vimasco cable coating, Flamastic 77 or approved equal.

   When 1/8" cable coating is used, it shall be applied with a minimum 1" overlap around the entire edge. In lieu of providing the 1/8" thickness of mastic coating, a 1" non-combustible damming board may be used.

3. The number and types of penetrants and their locations may vary according to the following:

   - Maximum 5" nominal metal conduit/sleeve with up to 40% cable fill.

4. A minimum distance of 1/2" should be maintained between the penetrating item(s) and the seal edge to allow for proper distribution of seal material. Free cables should be moved around during installation to assure proper distribution of seal material.

5. For conduit sleeves that extend past the barrier and terminate in a cable pan, box, panel, etc., the internal 1/8" vimasco cable coating may be omitted.

6. Design Detail C provides an equivalency for Details 2 and 5 identified on CECo Drawing 22E-0-3130, Sheet 1.

7. Design Detail C has been tested for the installation as a 3 hour fire rated assembly, utilizing the test results of CTL Test Report No. 1788E, Penetration No. 5 and U. L. Test NC601-3, Penetration No. 7.

8. Voids or cracks 1/4" or less may be sealed with G. E. RTV 625 Silicone Sealant or approved equal.

   Voids or cracks larger than 1/4" may be sealed, as indicated above, with 12" thick ceramic fiber and coated with 1/8" mastic on both sides.

10. Unused openings above 254 sq. in. which do not contain penetrating items must also include a

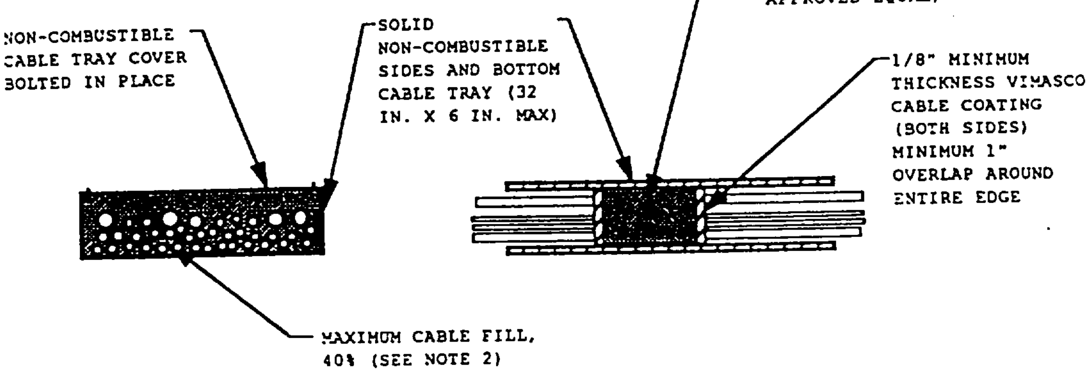
ATTACHMENT D

DESIGN DETAIL D

(CABLE TRAY FIRE BREAKS)

DESIGN (D) DETAIL

CABLE TRAY FIRE BREAK WITH CERAMIC FIBER AND MASTIC COATING
(HORIZONTAL OR VERTICAL CONFIGURATION)



Notes:

1. Ceramic Fiber thickness: Minimum 12" thick, with a minimum density of 9 lbs per cubic foot, covered with 1/8" minimum thickness Vimasco Cable Coating, Flamastic 77, or approved equal.

2. The number and types of penetrants and their locations may vary according to the following:

   - Maximum size cable tray may be 32" X 46" (192 sq. in..) with up to 40% cable fill.

3. Free cables should be moved around during installation to assure proper distribution of seal material.

4. Design Detail D provides an equivalency for Detail 9 identified on CECo Drawing 22E-0-3130, Sheet 1.

5. Design Detail D has been developed for the installation as a cable tray fire break assembly, utilizing the results of CTL Test Report No. 1788E, Penetration No. 5.

ATTACHMENT E

SUPPLEMENTAL FIRE TEST

NIAGARA MOHAWK

SYCS92-0884

NIAGARA MOHAWK POWER CORPORATION 301 PLAINFIELD ROAD, SYRACUSE, N.Y. 13212 TELEPHONE (315) 474-1511

September 16, 1992

Mr. David Kipley
ABB Impell Corporation
300 TriState International
Lincolnshire, Illinois 60069

Subject: Underwriter's Laboratories Report on
Floor and Wall Penetration Fire Stops
File NC601-1,-2,-3,-4
November 17, 1980

Dear Dave:

Per our telephone conversation on September 11, 1992, you are authorized to utilize the subject report for comparison purposes in engineering activities for Commonwealth Edison Company. The original test report with photos is in my possession should you require enhanced details of any portion of the test.

While not a prerequisite for this authorization, Niagara Mohawk Power Corporation would appreciate a copy (or brief synopsis) of your comparison. Such an effort may be of benefit to us in future documentation efforts. You should direct any such information to my attention.

Very truly yours,

Steven D. Einbinder
Fire Protection Program Mgr.

SDE:st
001259AG

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

[redacted]

November 17, 1980

REPORT

on

FLOOR AND WALL PENETRATION FIRE S[illegible]

[redacted]

NOT FOR COMMERCIA USE

Underwriters Laboratories Inc. authorizes the above named company to reproduce this Report provided it is reproduced in its entirety.

The issuance of this Report in no way implies Listing, Classification, or other Recognition by UL and does not authorize the use of UL Listing or Classification Marks or any other reference to Underwriters Laboratories Inc. on or in connection with the materials used in this investigation.

Underwriters Laboratories Inc., its employees, or its agents shall not be responsible to anyone for the use or nonuse of the information contained in this Report, and shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use of, or inability to use, the information contained in this Report.

[redacted] Page i Issued: 11-17-80

1. A B S T R A C T

This Report describes a testing program which was undertaken to assess the adequacy of various cable and pipe penetration fire stops installed in concrete floor assemblies and in concrete and masonry wall assemblies when tested in accordance with the applicable provisions outlined for power-generating stations in IEEE Standard 634-1978 entitled "Standard Cable Penetration Fire Stop Qualification Test." The performance of the cable penetration fire stops in each of the four test assemblies was found to meet requirements for a 3 hr rating in accordance with the criteria specified in IEEE 634-1978.

The IEEE Standard 634-1978 does not address mechanical service penetrations such as pipe. Accordingly, the criteria of no flame passage during the fire endurance test and no water passage during the hose stream test were imposed for the pipe penetration fire stops. The performance of the pipe penetration fire stops in each of the four test assemblies was found to meet the imposed requirements.

2. TABLE OF CONTENTS

A P P E N D I C E S

[redacted] Page iv Issued: [illegible]

3. LIST OF ILLUSTRATIONS

[redacted] Page v Issued: [illegible]

Ill. No.	Description
42	Construction details-Wall Assembly No. 1
43	Construction details-Wall Assembly No. 1, Penetration No. 1
44	Construction details-Wall Assembly No. 1, Penetration No. 2
45	Construction details-Wall Assembly No. 1, Penetration No. 3
46	Construction details-Wall Assembly No. 1, Penetration No. 4
47	Construction details-Wall Assembly No. 1, Penetration No. 5
48	Construction details-Wall Assembly No. 1, Penetration No. 6
49	Construction details-Wall Assembly No. 1, Penetration No. 7
50	Exposed surface before fire test, Wall Assembly No. 1
51	Unexposed surface before fire test, Wall Assembly No. 1
52	Furnace temperatures, Wall Assembly No. 1
53	Construction details-Wall Assembly No. 2
54	Construction details-Wall Assembly No. 2, Penetration No. 1
55	Construction details-Wall Assembly No. 2, Penetration No. 2
56	Construction details-Wall Assembly No. 2, Penetration No. 3
57	Construction details-Wall Assembly No. 2, Penetration No. 4
58	Construction details-Wall Assembly No. 2, Penetration No. 5
59	Construction details-Wall Assembly No. 2, Penetration No. 6
60	Construction details-Wall Assembly No. 2, Penetration No. 7
61	Exposed surface before fire test, Wall Assembly No. 2
62	Unexposed surface before fire test, Wall Assembly No. 2
63	Furnace temperatures, Wall Assembly No. 2
64	Appearance of floor and wall assembly during hose stream tests
65	Appearance after fire and hose stream tests, Floor Assembly No. 1
66	Appearance after fire and hose stream tests, Floor Assembly No. 1
67	Appearance after fire and hose stream tests, Floor Assembly No. 1
68	Appearance after fire and hose stream tests, Floor Assembly No. 2
69	Appearance after fire and hose stream tests, Floor Assembly No. 2
70	Appearance after fire and hose stream tests, Floor Assembly No. 2
71	Appearance after fire and hose stream tests, Floor Assembly No. 2
72	Appearance after fire and hose stream tests, Wall Assembly No. 1
73	Appearance after fire and hose stream tests, Wall Assembly No. 1
74	Appearance after fire and hose stream tests, Wall Assembly No. 1
75	Appearance after fire and hose stream tests, Wall Assembly No. 1
76	Appearance after fire and hose stream tests, Wall Assembly No. 2
77	Appearance after fire and hose stream tests, Wall Assembly No. 2
78	Appearance after fire and hose stream tests, Wall Assembly No. 2
79	Appearance after fire and hose stream tests, Wall Assembly No. 2
80	Appearance after fire and hose streamQtests, Wall Assembly No. 2
81	Appearance after fire and hose stream tests, Wall Assembly No. 2

[redacted] Page vi Issued: [illegible]

[illegible] No.	Description
A1	Reinforcement details for concrete floor slab.
A2	Location and sizes of penetrations in concrete floor slab
B1	Welded wall sleeve for Wall Assemblies 1 and 2
B2	Reinforcement details for concrete wall inserts

[redacted] Page 1 Issued: 11-17-80

NOT FOR COMMERCIAL USE

4. GENERAL

The subject of this Report is the fire test investigation of various cable and pipe penetration fire stops installed in concrete floors and in concrete and masonry walls. The purpose of this program was to evaluate the performance of these fire stops when tested in general accordance with the method outlined in IEEE Standard 634-1978 entitled "Standard Cable Penetration Fire Stop Qualification Test." Since mechanical service penetrations such as pipe are not addressed in IEEE Standard 634-1978, the criteria of no flame passage during the fire endurance test and no water passage during the hose stream test were imposed for the pipe penetration fire stops.

The test program consisted of constructing two concrete floor assemblies and two concrete and masonry wall assemblies, each of which was provided with various cable and pipe penetrations. One fire stop system (cables, pipes, or cable trays and the associated materials used to fill the opening) was installed in each through penetration. In addition to active penetrations, spare or abandoned penetrations were included in three of the four test assemblies. The floor and wall assemblies were then subjected to fire exposure with the furnace temperatures controlled in accordance with the standard Time-Temperature Curve as described in IEEE 634-1978 (ASTM E119, UL 263, NFPA No. 251).

During each test, a positive pressure with respect to the atmosphere was maintained within the furnace chamber. Temperatures on the unexposed side of each assembly were recorded. Immediately after fire exposure, a water spray stream hose stream test was conducted in accordance with the provisions outlined for power-generating stations in the Standard, IEEE 634-1978. For Wall Assembly No. 1 only, the water spray stream hose stream test was immediately followed by a second hose stream test conducted in accordance with the provisions outlined for industrial and commercial establishments in the Standard, IEEE 634-1978.

Information was obtained during construction with respect to the composition and physical properties of the materials used in each assembly.

5. DESCRIPTION

5.1 MATERIALS:

The following is a description of the materials used in the test assemblies.

5.1.1 FLOOR ASSEMBLY NO. 1

Concrete Slab - The 12 in. (305 mm) thick reinforced concrete slab containing various through penetrations was constructed as described in Appendix A. The location and sizes of the various through penetrations are shown in Appendix A, ILL. A2.

Filler Slabs - Nominal 4 ft, 8 in. (1.42 m) wide by 13 ft, 8 in. (4.17 m) long by 12 in. (305 mm) thick reinforced vermiculite concrete slabs were used to fill the remaining test frame openings at the north and south sides of the concrete slab.

Steel Supports - The concrete slab and the two filler slabs were supported at the east and west walls of the test frame by 6 by 6 by 1/2 in. (152 by 152 by 12.7 mm) structural steel angles.

Pipe - The 4 in. (102 mm) steel Schedule 40 pipe used as a mechanical service penetration in Penetration No. 11 was 33 in. (838 mm) long with an outside diameter of 4.500 in. (114.3 mm) and a wall thickness of 0.237 in. (6.02 mm). One end of the steel pipe was sealed by a 6 by 6 by 1/4 in. (152 by 152 by 6.4 mm) thick steel plate welded to the pipe.

Cable Trays - The nominal 24 in. (610 mm) wide open-ladder cable trays used in Penetration No. 14 consisted of 5-1/4 in. (133 mm) deep side rail members formed from 0.060 in. (1.52 mm) thick galvanized steel with 1 in. (25.4 mm) deep by 5/8 in. (15.9 mm) high box channel rungs formed from 0.060 in. (1.52 mm) thick galvanized steel and spaced 9 in. (229 mm) on center. The inside width of each cable tray, between side rail members, was 24 in. (610 mm). The loading depth of each cable tray was 4 in. (102 mm). The cable trays were supplied in nominal 12 ft (3.66 m) lengths.

Cables - The cable used in Penetration Nos. 1 through 9, inclusive, and in Penetration Nos. 14, 15, and 16 was manufactured by General Electric Company, Bridgeport, CT and designated Vulkene Flamenol Control Cable, 1000 v, 90 C. The cable had seven No. 12 AWG copper conductors, each of which consisted of seven 0.030 in. (0.76 mm) diameter strands. The conductor insulation was cross-linked polyethylene, the conductor wrap was mylar, the cable jacket was polyvinyl chloride and the outside diameter of the cable was 0.705 in. (17.9 mm). Each spool of cable bore a metal tag imprinted with "79-101865."

The cable used in Penetration No. 13 was manufactured by Rockbestos Co., New Haven, CT. The cable had three No. 12 AWG copper conductors, each of which consisted of seven 0.030 in. (0.76 mm) diameter strands. The conductor insulation was cross-linked polyethylene, the filler was stranded plastic, the conductor and filler wrap was treated paper, the cable jacket was chlorosulphinated polyethylene (Hypalon), and the outside diameter of the cable was 0.450 in. (11.4 mm). The cable jacket was marked "12 AWG 3/C ROCKBESTOS R COPPER XLPE 600 V XHHW TYPE TC (UL)-NJP-88 1977-7A94 7."

Cable And Cable Tray Support Racks - The racks used on the unexposed surface to support and secure the cables and cable trays consisted of 2 by 2 by 1/4 in. (51 by 51 by 6.4 mm) thick steel angles, 36 in. (914 mm) high, welded to nominal 4 by 5 by 1/4 in. (102 by 127 by 6.4 mm) thick steel base plates and with 3 in. (76 mm) wide by 1/4 in. (6.4 mm) thick steel plate cross members welded to the top of the steel angles. The support rack for the cable trays in Penetration No. 14 was additionally provided with a 3 by 3 by 3/16 in. (76 by 76 by 4.8 mm) thick steel angle cross member near its midheight.

Cable Ties - The cable ties used to secure the cables to the support racks and cable tray rungs were 0.056 in. (1.42 mm) diameter galvanized steel wire.

Ceramic Fiber - The loose alumina silica fiber material used in Penetration Nos. 1 through 9, inclusive, and in Penetration Nos. 13 through 16, inclusive, was manufactured by Babcock & Wilcox Company, Augusta, GA, and designated Kaowool Bulk A. The fiber was supplied in cardboard cartons containing approximately 50 lb (222.4 n) of product. The cartons were marked "P.R. 4229-B-AF," "P.R. 4229-C-JM," and "8021 B-WA."

Ceramic Fiber Blanket - The unfaced ceramic fiber blanket used in Penetration No. 11 was manufactured by Babcock & Wilcox Company, Augusta, GA, and designated "Kaowool Needled Blanket," 8 pcf (1.26×10^3 n/m^3) density. The blanket was 1 in. (25.4 mm) thick, 24 in. (610 mm) wide, and was supplied in a 25 ft (7.62 m) long roll. The carton containing the blanket was marked "PR9047BBB."

Mastic Coating - The mastic coating used on the exposed and unexposed sides of the test assembly was manufactured by The Flamemaster Corporation, Sun Valley, CA, and designated "Flamemastic 77." The mastic coating was supplied in 5 gal (18.9 l) pails. The pails were marked with Serial Nos. 100068, 100073, and 100078.

Concrete - The concrete used in Penetration Nos. 10, 11, and 12 was "Sakrete" brand gravel mix concrete supplied in 90 lb (400.4 n) bags. Per the directions on the bag, one gallon of water was added for each bag of gravel mix concrete. The compressive strength and unit weight of the concrete at 28 days, as determined from two standard 6 by 12 in. (152 by 305 mm) cylinders, averaged 4120 psi (2.84×10^7 n/m^2) and 149.4 pcf (2.35×10^4 n/m^3), respectively.

Anchors - The anchors used in Penetration Nos. 10, 11, and 12 to mechanically secure the concrete fill in the pipe sleeves were No. 3 deformed steel bars (ASTM A36 steel). The anchors were 13 in. (330 mm) long with a 2 in. (51 mm) long, 90 deg bend at one end. The other end of each anchor was bent into a hook, in the opposing direction, to engage the lip of the floor sleeve.

5.1.2 FLOOR ASSEMBLY NO. 2

Floor Assembly No. 2 employed the previously fire tested concrete slab, filler slabs, and steel supports from Floor Assembly No. 1.

Pipe - The 4 in. (102 m) steel Schedule 40 pipe used as a mechanical service penetration in Penetration No. 10 was 60 in. (1.52 m) long with an outside diameter of 4.500 in. (114.3 mm) and a wall thickness of 0.237 in. (6.02 mm). One end of the steel pipe was sealed by a 6 by 6 by 1/4 in. (152 by 152 by 6.4 mm) thick steel plate welded to the pipe.

[redacted] Page 5 Issued: 11-17-80

Cable Trays - The nominal 24 in. (610 mm) wide open-ladder cable trays used in ~~Penetration~~ Penetration No. 14 consisted of 4-1/4 in. (108 mm) deep side rail members formed from 0.105 in. (2.67 mm) thick galvanized steel with 1.000 in. (25.4 mm) diameter flattened-tubing rungs formed from galvanized steel and spaced 9 in. (229 mm) on center.. The inside width of each cable tray, between side rail members, was 24 in. (610 mm). The loading depth of each cable tray was 3 in. (76.2 mm). The cable trays, manufactured by T. J. Cope Inc. of Collegeville, PA, and designated No. 3237-24SL-12-09 were supplied in nominal 12 ft (3.66 m) lengths.

Cables - The cable used in the various penetrations were manufactured by General Electric Company, Bridgeport, CT, and designated Vulkene Flamenol Control Cable, 1000 v, 90 C. The cable had seven No. 12 AWG copper conductors, each of which consisted of seven 0.030 in. (0.76 mm) diameter strands. The conductor insulation was cross-linked polyehtylene, the conductor wrap was mylar, the cable jacket was polyvinyl chloride, and the outside diameter of the cable was 0.705 in. (17.9 mm). Each spool of cable bore a metal tag imprinted with "79-101865."

Cable And Cable Tray Support Racks - Floor Assembly No. 2 employed the same cable and cable tray support racks from Floor Assembly No. 1.

Cable Ties - The cable ties used to secure the cables to the support racks and cable tray rungs were 0.056 in. (1.42 mm) diameter galvanized steel wire.

Ceramic Fiber - The loose alumina silica fiber material used in Penetration Nos. 1 through 8, inclusive, and in Penetration Nos. 14, 15, and 16 was manufactured by Babcock & Wilcox Company, Augusta, GA, and designated Kaowool Bulk A. The fiber was supplied in cardboard cartons containing approximately 50 lb (222.4 n) of product. The cartons were hand-marked "ONE 50 LB. BOX BULK A 57#."

Ceramic Fiber Blanket - The unfaced ceramic fiber blanket used in Penetration Nos. 10 and 11 was manufactured by Babcock & Wilcox Company, Augusta, GA, and designated "Kaowool Needled Blanket," 8 pcf (1.26×10^3 n/m^3) density. The blankets were 1 in. (25.4 mm) thick, 24 in. (610 mm) wide, and were supplied in 25 ft (7.62 m) long rolls. The cartons containing the blankets were marked "PR0094CIM."

Mastic Coating - The mastic coating used on the exposed and unexposed sides of Penetration Nos. 1, 3, 5, 7, 10, 11, 14, 15, and 16 was manufactured by The Flamemaster Corporation, Sun Valley, CA, and designated "Flamemastic 77." The mastic coating was supplied in 5 gal (18.9 l) pails. The pails were marked with Serial Nos. 10068, 10073, and 10078.

The mastic coating used on the exposed and unexposed sides of Penetration Nos. 2, 4, 6, and 8 was manufactured by the Flamemaster Corporation, Sun Valley, CA, and designated "Flamemastic 71-A." The mastic coating was supplied in 5 gal (18.9 l) pails. The pails were marked with Serial No. 050170.

Vermiculite Concrete - The vermiculite concrete used in Penetration Nos. 9 and 13 consisted of six parts of vermiculite aggregate to one part Portland cement, proportioned by volume, mixed with water to form a thick slurry.

5.1.3 WALL ASSEMBLY NO. 1

Concrete Inserts - The nominal 12 in. (305 mm) thick reinforced concrete inserts containing various size and type penetrations were constructed as described in Appendix B.

Concrete Blocks - The concrete blocks were nominally 8 by 16 by 12 in. (203 by 406 by 305 mm) thick, formed with two core holes and having a minimum 1-1/2 in. (38.1 mm) face shell and a 1-3/16 in. (30.2 mm) minimum web thickness.

Brick - The common clay bricks were nominally 2-1/2 by 8 by 4 in. (63.5 by 203 by 102 mm) thick.

Mortar - The mortar consisted of three parts of clean sharp sand to one part Portland cement (proportioned by volume) and 15 percent hydrated lime (by cement volume) mixed with water.

Split Sleeve - The two-piece sleeve used for Penetration No. 7 was 18 in. (457 mm) long with an inside diameter of 21 in. (533 mm) and a wall thickness of 0.250 in. (6.4 mm). The coupling flanges/wall anchors were 6-in. (152 mm) wide by 18 in. (457 mm) long. Each coupling flange was provided with two 9/16 in. (14.3 mm) diameter holes for bolt-attachment of the two sleeve sections with 1/2 in. (12.7 mm) diameter by 1-1/2 in. (38.1 mm) long steel machine bolts with nuts.

Pipe - The 18 in. (457 mm) steel Schedule ST pipe used as a mechanical service penetration in Penetration No. 7 was 30 in. (762 mm) long with an outside diameter of 18 in. (457 mm) and a wall thickness of 0.375 in. (9.53 mm). One end of the pipe was sealed by an 18 by 18 by 1/4 in. (457 by 457 by 6.4 mm) thick steel plate welded to the pipe.

Cable Trays - The nominal 24 in. (610 mm) wide open-ladder cable trays used in Penetration No. 4 consisted of 5-1/4 in. (133 mm) deep side rail members formed from 0.060 in. (1.52 mm) thick galvanized steel with 1 in. (25.4 mm) deep by 5/8 in. (15.9 mm) high box channel rungs formed from 0.060 in. (1.52 mm) thick galvanized steel and spaced 9 in. (229 mm) on center. The inside width of each cable tray, between side rail members, was 24 in. (610 mm). The loading depth of each cable tray was 4 in. (102 mm). The cable trays were supplied in nominal 12 ft (3.66 m) lengths.

Cables - The cable used in the various penetrations was manufactured by General Electric Company, Bridgeport, CT, and designated Vulkene Flamenol Control Cable, 1000 v, 90 C. The cable had seven No. 12 AWG copper conductors, each of which consisted of seven 0.030 in. (0.76 mm) diameter strands. The conductor insulation was cross-linked polyethylene, the conductor wrap was mylar, the cable jacket was polyvinyl chloride, and the outside diameter of the cable was 0.705 in. (17.9 mm). Each spool of cable bore a metal tag imprinted with "79-101865."

Cable And Cable Tray Support Racks - The racks used on the exposed and unexposed sides to support the cables and cable trays consisted of 2 by 2 by 1/4 in. (51 by 51 by 6.4 mm) thick steel angles, 12 and 36 in. (305 and 914 mm) long, welded to nominal 4 by 5 by 1/4 in. (102 by 127 by 6.4 mm) thick steel base plates and with 3 in. (76 mm) wide by 1/4 in. (6.4 mm) thick steel plate cross members welded to the steel angles.

Ceramic Fiber - The loose alumina silica fiber material used in Penetration Nos. 1, 2, 4, 5, and 6 was manufactured by Babcock & Wilcox Company, Augusta, GA, and designated Kaowool Bulk A. The fiber was supplied in cardboard cartons containing approximately 50 lb (222.4 n) of product. The cartons were marked "P.R. 4228-C-J.M."

Ceramic Fiber Blanket - The unfaced ceramic fiber blanket used in Penetration No. 7 was manufactured by Babcock & Wilcox Company, Augusta, GA, and designated "Kaowool Needled Blanket," 8 pcf (1.26×10^3 n/m^3) density. The blanket was 1 in. (25.4 mm) thick, 24 in. (610 mm) wide, and was supplied in a 25 ft (7.62 m) long roll. The carton containing the blanket was marked "P.R. 4229-B-AF."

Mastic Coating - The mastic coating used on the exposed and unexposed sides of the test assembly was manufactured by The Flamemaster Corporation, Sun Valley, CA, and designated "Flamemastic 77." The mastic coating was supplied in 5 gal (18.9 l) pails. The pails were marked with Serial No. 100078.

Ceramic Board - The ceramic board used on the exposed and unexposed surfaces of Penetration No. 5 was manufactured by Babcock & Wilcox Company, Augusta, GA, and was supplied in nominal 24 by 36 by 1 in. (610 by 914 by 25.4 mm) thick sheets having a density of 16 pcf (2513.3 n/m^3).

Concrete - The concrete used in Penetration No. 3 was "Sakrete" brand gravel mix concrete supplied in 90 lb (400.4 n) bags. Per the directions on the bag, one gallon of water was added for each bag of gravel mix concrete. The compressive strength and unit weight of the concrete at 28 days, as determined from two standard 6 by 12 in. (152 by 305 mm) cylinders, averaged 4120 psi (2.84×10^7 n/m^2) and 149.4 pcf (2.35×10^4 n/m^3) respectively.

Anchors - The anchors used in Penetration No. 3 to mechanically secure the concrete fill in the pipe sleeve were No. 3 deformed steel bars (ASTM A36 steel). The anchors were 11 in. (279 mm) long with a 2 in. (51 mm) long, 90 deg bend at one end. The other end of each anchor was bent into a hook, in the opposing direction, to engage the lip of the wall sleeve.

Cementitious Mixture - The cementitious mixture applied to the concrete blocks on the exposed surface consisted of a mixture of MK-5 cementitious mixture (manufactured by Zonolite Construction Products, Cambridge, MA) and hydrated lime mixed with water.

5.I.4 WALL ASSEMBLY NO. 2

Concrete Slabs - The nominal 12 in. (305 mm) thick reinforced concrete slabs containing various size and type penetrations were constructed as described in Appendix B. The concrete slab used for Penetration No. 4 was the same slab previously used in Wall Assembly No. 1. No concrete slab was used with the nominal 18 in. (457 mm) diameter wall sleeve (Penetration No. 3). Instead, the steel sleeve was "bricked" in.

Concrete Blocks - The concrete blocks were nominally 8 by 16 by 8 in. (203 by 406 by 203 mm) thick, formed with two core holes and having a minimum 1-1/4 in. (31.8 mm) face shell and a 1-1/16 in. (27.0 mm) minimum web thickness.

Brick - The common clay bricks were nominally 2-1/2 by 8 by 4 in. (63.5 by 203 by 102 mm) thick.

Mortar - The mortar consisted of three parts of clean sharp sand to one part Portland cement (proportioned by volume) and 15 percent hydrated lime (by cement volume) mixed with water.

Split Sleeve - The same split-sleeve previously used for Penetration No. 7 in Wall Assembly No. 1 was used in the test assembly.

Pipe - The 18 in. (457 mm) steel Schedule ST pipe used as a mechanical service penetration in Penetration No. 7 was 60 in. (1.52 m) long with an outside diameter of 18 in. (457 mm) and a wall thickness of 0.375 in. (9.53 mm). One end of the pipe was sealed by an 18 in. (457 mm) diameter by 1/4 in. (6.4 mm) thick steel plate welded to the pipe.

The 4 in. (102 mm) steel Schedule ST pipe used as a mechanical service penetration in Penetration No. 3 was 60 in. (1.52 m) long with an outside diameter of 4.500 in. (114 mm) and a wall thickness of 0.237 in. (6.02 mm). One end of the pipe was sealed by a 6 by 6 by 1/4 in. (152 by 152 by 6.4 mm) thi steel plate welded to the pipe.

The 2 in. (51 mm) steel Schedule ST pipe used as a mechanical service penetration in Penetration No. 3 was 60 in. (1.52 m) long with an outside diameter of 2.375 in. (60 mm) and a wall thickness of 0.154 in. (3.9 mm). One end of the pipe was sealed by a 3 by 3 by 4 in. (76 by 76 by 6.4 mm) thick steel plate welded to the pipe.

The 1-1/4 in. (32 mm) steel Schedule ST pipe used as a mechanical service penetration in Penetration No. 3 was 60 in. (1.52 m) long with an outside diameter of 1.660 in. (42 mm) and a wall thickness of 0.140 in. (3.6 mm). One end of the pipe was sealed by a 2 by 2 by 1/4 in. (51 by 51 by 6.4 mm) thick steel plate welded to the pipe.

Cable Trays - The nominal 24 in. (610 mm) wide open-ladder cable trays used in Penetration No. 4 consisted of 4-1/4 in. (108 mm) deep side rail members formed from 0.105 in. (2.67 mm) thick galvanized steel with 1.000 in. (25.4 mm) diameter flattened-tubing rungs formed from galvanized steel and spaced 9 in. (229 mm) on center. The inside width of each cable tray, between side rail members, was 24 in. (610 mm). The loading depth of each cable tray was 3 in. (76.2 mm). The cable trays, manufactured by T. J. Cope Inc. of Collegeville, PA and designated No. 3237-24SL-12-09 were supplied in nominal 12 ft (3.66 m) lengths.

Cables - The cable used in the various penetrations was manufactured by General Electric Company, Bridgeport, CT and designated Vulkene Control Cable, 600 v. The cable had twelve No. 19/25 AWG copper conductors, each of which consisted of nineteen 0.018 in. (0.46 mm) diameter strands. The conductor insulation was cross-linked polyethylene, the conductor wrap was mylar, the cable jacket was polyvinyl chloride, and the outside diameter of the cable was 0.765 in. (19.4 mm). The cable jacket was marked "GENERAL ELECTRIC VULKENE CONTROL CABLE 12 COND 19/25 AWG 600 V."

Cable, Cable Tray, And Pipe Support Racks - The racks used on the exposed sides of Penetration Nos. 1, 3, 5, and 6 and on the unexposed sides of Penetration Nos. 1, 2, 3, 5, and 6 to support the cables, cable trays, and pipes consisted of 2 by 2 by 1/4 in. (51 by 51 by 6.4 mm) thick steel angles, 12 and 36 in. (305 and 914 mm) long, welded to nominal 4 by 5 by 1/4 in. (102 by 127 by 6.4 mm) thick steel base plates and with 3 in. (76 mm) wide by 1/4 in. (6.4 mm) thick steel plate cross members welded to the steel angles.

The pipe support on the unexposed side of Penetration No. 7 consisted of two 2 by 2 by 1/4 in. (51 by 51 by 6.4 mm) thick steel angles used as struts between the end of the pipe and the sill of the test frame. No support was provided for the pipe on the exposed surface of Penetration No. 7 other than two small steel shims welded between the pipe and the split sleeve to maintain concentricity of the pipe in the sleeve.

The cable tray support on the exposed surface of Penetration No. 4 was designed to direct the longitudinal thermal expansion force exerted by the cable tray side rails toward the fire stop during the fire exposure. Nominal 3/4 in. (19.1 mm) diameter galvanized steel pipe with 90 deg elbows, collars, and hose adaptors was assembled to form a yoke around the ends of both cable trays. Steel angles, 3 by 5 by 1/4 in. (76.2 by 127 by 6.4 mm) thick by 3 in. (76.2 mm) long were welded to the pipe at the intersection of the pipe and the cable tray side rails such that no clearance was present between the restraining yoke and the cable tray side rails and such that the cable tray side rails were supported. The galvanized steel pipe was additionally stiffened to resist thrust by clamping a 1 by 1 by 1/8 in. (25.4 by 25.4 by 3.2 mm) thick steel angle to the pipe with the "V" of the angle pointing toward the cable trays. The short runs of pipe intersecting the wall were wrapped with two wraps of ceramic fiber blanket. During the fire exposure, cold water flowed through the pipe to prevent the restraining yoke from heating and expanding.

Ceramic Fiber - The loose alumina silica fiber material used in Penetration Nos. 1 through 6, inclusive, was manufactured by Babcock & Wilcox Company, Augusta, GA, and designated Kaowool Bulk A. The fiber was supplied in cardboard cartons containing approximately 50 lb (222.4 n) of product. The cartons were marked "P.R. 7122-C-B.B."

Ceramic Fiber Blanket - The unfaced ceramic fiber blanket used in Penetration No. 7 was manufactured by Babcock & Wilcox Company, Augusta, GA, and designated "Kaowool Needled Blanket," 8 pcf (1.26×10^3 n/m^3) density. The blanket was 1 in. (25.4 mm) thick, 24 in. (610 mm) wide, and was supplied in a 25 ft (7.62 m) long roll.

Mastic Coating - The mastic coating used on the exposed and unexposed sides of Penetration Nos. 1 and 6 was manufactured by The Flamemaster Corporation, Sun Valley, CA, and designated "Flamemastic F71-A." The mastic coating was supplied in 5 gal (18.9 l) pails. The pails were marked with Serial No. 050170.

The mastic coating used on the exposed and unexposed sides of Penetration Nos. 2, 3, 4, and 5 was manufactured by The Flamemaster Corporation, Sun Valley, CA, and designated "Flamemastic F77." The mastic coating was supplied in 5 gal (18.9 l) pails. The pails were marked with Serial No. 100068.

Ceramic Board - The ceramic board used on the exposed and unexposed surfaces of Penetration No. 5 was manufactured by Babcock & Wilcox Company, Augusta, GA, and was supplied in nominal 24 by 36 by 1 in. (610 by 914 by 25.4 mm) thick sheets having a density of 16 pcf (2513.3 n/m^3).

[redacted] Page 12 Issued: 11-17-80

5.2 ASSEMBLY CONSTRUCTION:

5.2.1 FLOOR ASSEMBLY NO. 1

The test assembly was constructed in a test frame in accordance with the methods specified by the submitter and as shown in ILL. 1. The test assembly was constructed by members of the technical staff of Underwriters Laboratories Inc. under the supervision of the engineering staff of Underwriters Laboratories Inc.

The reinforced concrete slab was constructed as described in Appendix A. Because the concrete slab was cast on the floor, it was necessary to cut a 4 in. (102 mm) section from the sleeve for Penetration No. 10 in order to install the sleeve with its top lip flush with the top surface of the concrete slab.

On the same day the reinforced concrete slab was cast, gravel mix concrete and anchors were placed in Penetration No. 12. The anchors were hooked over the top lip of the steel sleeve such that a 3 in. (76 mm) clearance was maintained between the bottom plane of the 2 in. (51 mm) horizontal leg of the anchor and the bottom plane of the sleeve. Four anchors were installed in the sleeve, equally spaced around the perimeter. An 8 in. (203 mm) thickness of gravel mix concrete was placed in the lower portion of the sleeve and the concrete was tamped and finished to a smooth, flat surface. The top plane of the concrete was 4 in. (102 mm) below the top plane of the concrete floor and 8 in. (203 mm) below the top lip of the sleeve, as shown in ILL. 14.

The steel support angles were placed along the east and west walls of the test frame such that the top of the horizontal leg was 12 in. (305 mm) below the top edges of the test frame. Eleven days after it was cast, the reinforced concrete slab was moved from the construction area and centered in the test frame with the ends of the slab bearing 4-1/2 in. (114 mm) on the steel support angles. On the same day that the slab was placed in the test frame, the gravel mix concrete was installed in Penetration Nos. 10 and 11.

In Penetration No. 10, the 4 in. (102 mm) section of sleeve was continuous-welded to the cast-in-place sleeve in its original location. The anchors were hooked under the bottom lip of the sleeve such that a 3 in. (76 mm) clearance was maintained between the top plane of the 2 in. horizontal leg and the top plane of the sleeve and concrete slab. Four anchors were installed in the sleeve, equally spaced around the perimter, and tack-welded to the bottom lip and interior of the sleeve. A removable plywood form was inserted in the sleeve with its top plane 8 in. (203 mm) below the top plane of the sleeve. Gravel mix concrete was placed in the opening, tamped, and finished to a smooth, flat surface flush with the top plane of the sleeve and concrete slab as shown in ILL. 12. The plywood form was removed from the sleeve two days after the gravel mix concrete was placed.

In Penetration No. 11, the anchors were hooked over the top lip of the sleeve such that a 3 in. (76 mm) clearance was maintained between the bottom plane of the 2 in. (51 mm) horizontal leg and the bottom plane of the sleeve. Four anchors were installed in the sleeve, equally spaced around the perimeter. The nominal 4 in. (102 mm) diameter pipe was installed in the center of the sleeve opening with the bottom plane of its capped end located 12 in. (305 mm) below the bottom plane of the floor slab. The pipe was secured in place by two steel bars spanning the sleeve opening and tack-welded to two sides of the pipe and to the top lip of the sleeve. The pipe was wrapped with two wraps of ceramic fiber blanket, 12 in. (305 mm) wide, with the bottom plane of the ceramic fiber blanket 4 in. below the bottom plane of the floor slab. The blanket was held in position by two wraps of No. 18 SWG galvanized steel wire. A removable plywood form was placed under the penetration, with its top plane flush with the underside of the concrete slab, and gravel mix concrete was placed in the sleeve opening to a depth of 8 in. (203 mm), as shown in ILL. 13. The plywood form was removed from beneath the sleeve two days after the gravel mix concrete was placed.

Reinforced vermiculite concrete filler slabs were installed along the north and south sides of the concrete slab to fill the remainder of the test frame opening. Mineral wool batts were used to fill the joints between the concrete slab and the filler slabs and to fill the openings between the slabs and the test frame walls around the periphery. Vermiculite concrete grout was applied over the batt-filled joints on the unexposed surface.

The cable and ~~cable~~ tray supports were secured to the unexposed surface using 1/2 in. (12.7 mm) diameter expansion-type masonry fasteners through the base plates. The supports were centered over Penetration Nos. 1 through 9, inclusive, and Penetration Nos. 13, 15, and 16. The cable tray support for Penetration No. 14 was offset from the longitudinal centerline of the penetration to allow for centering of the cable trays in the penetration.

Two 60 in. (1.52 m) lengths of cable tray were installed in Penetration No. 14, centered in the penetration, and secured to the cable tray supports with 1/4 in. (6.4 mm) diameter by 1 in. (25.4 mm) long steel bolts, with washers and nuts, through the side rail flanges. The cable trays were positioned with 12 in. (305 mm) of the ladder protruding below the bottom plane of the floor slab.

Cables were installed in Penetration Nos. 1 through 9, inclusive, and in Penetration Nos. 13 through 16, inclusive. The cables were secured to the cable tray rungs and cable supports with cable ties. In Penetration No. 13, the cables were secured to the cable support in groups of eighteen to twenty-one. In the remainder of the penetrations, the cables were secured to the cable tray rungs or cable supports in groups of three of four. Each cable was 60 in. (1.52 m) long and was installed such that 12 in. (305 mm) of the cable protruded beneath the bottom surface of the floor and 36 in. (914 mm) extended above the top surface of the floor. The number of cables used in each penetration varied with the size of the penetration, as shown in ILLS. 3 through 11, inclusive, ILLS. 15 through 18, inclusive, and as summarized in the following table:

Penetration No.	ILL. No.	Number Of Cables	Cable Diameter, In. (mm)	Percent Fill*
1	3	16	0.705 (17.9)	31.2
2	4	16	0.705 (17.9)	31.2
3	5	16	0.705 (17.9)	31.2
4	6	16	0.705 (17.9)	31.2
5	7	16	0.705 (17.9)	31.2
6	8	16	0.705 (17.9)	31.2
7	9	16	0.705 (17.9)	31.2
8	10	16	0.705 (17.9)	31.2
9	11	16	0.705 (17.9)	31.2
13	15	495	0.450 (11.4)	43.7
14	16	99/Tray	0.705 (17.9)	40.3/Tray
15	17	138	0.705 (17.9)	8.6
16	18	138	0.705 (17.9)	8.6

* - For Penetration No. 14, the percent fill was based on the loading volume of the cable trays. For the remaining penetrations, the percent fill was based on the volume of the floor slab penetration. Penetration Nos. 13, 15, and 16 were intended to simulate the termination of cable trays above and below the floor with continuation of cables through the floor penetration. Based on the submitter's proposed use of cable trays with a loading depth of 3 in. (76.2 mm), the following cable tray percent fills were simulated:

Penetration No.	Simulated Cable Tray Configuration	Simulated Percent Fill
13	One 30 in. (762 mm) wide tray	87.5/tray
15	Two 24 in. (610 mm) wide trays	37.4/tray
16	Two 24 in. (610 mm) wide trays	37.4/tray

After the cables were installed, loose ceramic fiber was installed in all penetrations except Penetration Nos. 10, 11, and 12. First the cables in each penetration were spread apart and ceramic fiber was inserted between cables such that the cables were separated from each other within the 12 in. depth of the penetration. Next, ceramic fiber was placed in the penetration to completely fill the 12 in. (305 mm) depth at the density shown in the following table. For Penetration Nos. 14, 15, and 16, it was necessary to place removable plywood forms against the underside of the floor to prevent the ceramic fiber from falling through when the penetrations were filled from the top surface of the floor. For Penetration Nos. 1 through 9, inclusive, and Penetration 13, no forming was required on the underside of the floor. The ceramic fiber was first pushed into the penetration from the underside such that the bottom portion of the penetration was filled. The remainder of the ceramic fiber for the penetrations was installed from the top surface of the floor. The amount of ceramic fiber used in each penetration varied with the volume of the penetration and the volume displaced by the penetrating cables, as shown in ILLS. 3 through 11, inclusive, ILLS. 15 through 18, inclusive, and as summarized in the following table:

Penetration No.	Ill. No.	Penetration Volume Less Cable Volume, In.^{3} (m^3)	Amount Of Ceramic Fiber, Lb(n)	Ceramic Fiber Density, pcf (n/m^3)
1	3	165.2 (2.71×10^{-3})	0.65 (2.89)	6.8 (1068.1)
2	4	165.2 (2.71×10^{-3})	0.65 (2.89)	6.8 (1068.1)
3	5	165.2 (2.71×10^{-3})	0.65 (2.89)	6.8 (1068.1)
4	6	165.2 (2.71×10^{-3})	0.65 (2.89)	6.8 (1068.1)
5	7	165.2 (2.71×10^{-3})	0.99 (4.40)	10.4 (1633.6)
6	8	165.2 (2.71×10^{-3})	0.99 (4.40)	10.4 (1633.6)
7	9	165.2 (2.71×10^{-3})	0.99 (4.40)	10.4 (1633.6)
8	10	165.2 (2.71×10^{-3})	0.99 (4.40)	10.4 (1633.6)
9	11	165.2 (2.71×10^{-3})	0.65 (2.89)	6.8 (1068.1)
13	15	1215.6 (1.99×10^{-2})	5.35 (23.80)	7.6 (1193.8)
14	16	6560.4 (1.08×10^{-1})	29.15 (129.66)	7.7 (1209.5)
15	17	6841.6 (1.12×10^{-1})	30.75 (136.78)	7.8 (1225.2)
16	18	6841.6 (1.12×10^{-1})	46.12 (205.14)	11.6 (1822.1)

After the ceramic fiber was installed, the mastic coating was brush-applied to the ceramic fiber and cables on the exposed and unexposed surfaces of all penetrations except Penetration Nos. 10, 11, and 12. Several coats of mastic coating were applied to build-up to the final dry thickness. The cables were spread apart in order to coat each individual cable with mastic coating. Because of the close proximity of the cables in the bundles, it was not possible to coat all of the cables in the interior of the bundles to the desired thickness. However, each cable was coated on all sides with mastic coating to an elevation of 12 in. (305 mm) above and below the unexposed and exposed surfaces of the floor slab, respectively. The exterior of each cable bundle was coated to the desired thickness at its interface with the plane of the exposed and unexposed surfaces of the ceramic fiber fill. From the interface, the mastic coating was tapered from full thickness to a thickness of approximately 1/8 to 1/4 in. (3.2 to 6.4 mm) at its termination at approximately the 12 in. (305 mm) elevation above and below the unexposed and exposed surfaces of the assembly. The mastic coating on the thirteen penetrations with cables lapped approximately 1 in. (25.4 mm) on the concrete surface around the periphery of each penetration on the exposed and unexposed surfaces of the floor slab. The cut end of each cable at the 36 in. (914 mm) elevation above the floor was capped with a brush coat of mastic coating.

The mastic coating type and average dry mastic coating thickness for each penetration with cables are shown on ILLS. 3 through 11, inclusive, ILLS. 15 through 18, inclusive, and are summarized in the following table:

Penetration No.	ILL. No.	Flamemastic Coating Type	Average Dry Thickness On Exposed Surface, In. (mm)	Average Dry Thickness On Unexposed Surface, In. (mm)
1	3	F77	0.500 (12.7)	0.458 (11.6)
2	4	F77	0.500 (12.7)	0.479 (12.2)
3	5	F77	0.396 (10.1)	0.521 (13.2)
4	6	F77	0.396 (10.1)	0.500 (12.7)
5	7	F77	0.646 (16.4)	0.771 (19.6)
6	8	F77	0.542 (13.8)	0.688 (17.5)
7	9	F77	0.729 (18.5)	0.688 (17.5)
8	10	F77	0.667 (16.9)	0.667 (16.9)
9	11	F77	0.453 (11.5)	0.563 (14.3)
13	15	F77	0.583 (14.8)	0.844 (21.4)
14	16	F77	0.516 (13.1)	0.656 (16.7)
15	17	F77	0.547 (13.9)	0.550 (14.0)
16	18	F77	0.672 (17.1)	0.800 (20.3)

The typical cable penetration fire stop installation technique is depicted in ILL. 2. The appearance of the exposed and unexposed sufaces before the fire test is shown in ILLS. 19 and 20, respectively.

5.2.2 FLOOR ASSEMBLY NO. 2

The test assembly was constructed in a test frame in accordance with the methods specified by the submitter and as shown in ILL. 22. The test assembly was constructed by members of the technical staff of Underwriters Laboratories Inc. under the supervision of the engineering staff of Underwriters Laboratories Inc.

The same floor assembly used for Floor Test No. 1 was used for Floor Test No. 2. To prepare for the construction, the underside of the floor slab was wire-brushed to remove loose concrete from around the periphery of the floor penetrations. On the top surface, the cable supports were removed from Penetration Nos. 9 and 13, the cable tray supports for Penetration No. 14 were moved to allow for centering of the shallower cable trays in the penetration, and the anchors in Penetration No. 12 were cut and removed from the sleeve. With the exception of Penetration No. 12, all of the penetrations were cleaned to remove all material from the first fire test.

Removable plywood forms were placed against the underside of the floor slab beneath Penetration Nos. 9 and 13 and both penetrations were completely filled with vermiculite concrete. The plywood forms were removed two days after the vermiculite concrete was placed.

In Penetration No. 11, a full roll [24 in. (610 mm) wide by 25 ft (7.62 m) long] of ceramic fiber blanket was compressed in an aluminum foil/vinyl scrim wrap and the compressed roll was inserted in the floor sleeve. After the roll was inserted, the aluminum foil/vinyl scrim wrap was pulled from the sleeve, allowing the ceramic fiber blanket to lock itself inside the sleeve by friction. The excess blanket above and below the floor was cut flush with the lips of the sleeve, as shown in ILL. 33. Loose ceramic fiber was stuffed into the center of the rolled blanket and at the end of the blanket at the sleeve wall to completely fill all voids in the sleeve opening. A total of 16.2 lb (72.06 n) of ceramic fiber blanket and 0.1 lb (0.44 n) of loose ceramic fiber was used in the sleeve opening to provide an average fill density of 7.53 pcf (1182.8 n/m^3). The ceramic fiber blanket was coated with Flamemastic F77 mastic coating at the exposed and unexposed surfaces of the assembly. The average dry coating thickness on both the exposed and unexposed sides was 0.250 in. (6.4 mm).

For Penetration No. 10, the nominal 4 in. (102 mm) pipe was wrapped with four wraps of the 24 in. (610 mm) wide ceramic fiber blanket, with the wraps secured by short pieces of paper masking tape, and the pipe was suspended in the sleeve opening with the bottom plane of its capped end located 12 in. (305 mm) below the bottom plane of the sleeve. The pipe centerline was offset 2-3/8 in. (60.3 mm) from the sleeve centerline such that the ceramic fiber blanket wrap was in contact with the inside of the sleeve wall. The pipe was suspended in the sleeve opening by a nominal 1 in. (25.4 mm) diameter steel rod inserted through holes drilled near the top of the pipe such that the pipe was free to pivot. The remainder of the sleeve opening was filled with ceramic fiber blanket, inserted vertically, as shown in ILL. 32. All voids in the penetration not filled by the ceramic fiber blanket were stuffed with loose ceramic fiber. The ceramic fiber blanket was cut flush with the top and bottom lips of the sleeve. A total of 17.7 lb (78.73 n) of ceramic fiber blanket and 1.8 lb (8.01 n) of loose ceramic fiber was used in the sleeve opening to provide an average fill density of 9.67 pcf (1519.0 n/m^3). The ceramic fiber blanket was coated with Flamemastic F77 mastic coating at the exposed and unexposed surfaces of the assembly. A 1 in. (25.4 mm) clearance was maintained between the mastic coating and the 4 in. (102 mm) pipe to allow lateral movement of the pipe within the sleeve. The average dry coating thickness on both the exposed and unexposed surfaces was 0.250 in. (6.4 mm).

Two 60 in. (1.52 m) lengths of cable tray were installed in Penetration No. 14, centered in the penetration, and secured to the cable tray supports with 1/4 in. (6.4 mm) diameter by 1 in. (25.4 mm) long steel bolts, with washers and nuts, through the side rail flanges. The cable trays were positioned with 12 in. (305 mm) of the ladder protruding below the bottom plane of the floor slab.

Cables were installed in Penetration Nos. 1 through 8, inclusive, and in Penetration Nos. 14 through 16, inclusive. The cables were secured to the cable tray rungs and cable supports, in groups of three of four cables, with cable ties. Each cable was 60 in. (1.52 m) long and was installed such that 12 in. (305 mm) of the cable protruded beneath the bottom surface of the floor and 36 in. (914 mm) extended above the top surface of the floor. The number of cables used in each penetration varied with the size of the penetration, as shown in ILLS. 23 through 30, inclusive, ILLS. 36 through 38, inclusive, and as summarized in the following table:

Penetration No.	ILL. No.	Number Of Cables	Cable Diameter, In. (mm)	Percent Fill*
1	23	1	0.705 (17.9)	2.0
2	24	1	0.705 (17.9)	2.0
3	25	16	0.705 (17.9)	31.2
4	26	16	0.705 (17.9)	31.2
5	27	1	0.705 (17.9)	2.0
6	28	1	0.705 (17.9)	2.0
7	29	16	0.705 (17.9)	31.2
8	30	16	0.705 (17.9)	31.2
14	36	55/Tray	0.705 (17.9)	29.8/Tray
15	37	113	0.705 (17.9)	7.1
16	38	113	0.705 (17.9)	7.1

* - For Penetration No. 14, the percent fill was based on the loading volume of the cable trays. For the remaining penetrations, the percent fill was based on the volume of the floor slab penetration. Penetration Nos. 15, and 16 were intended to simulate the termination of cable trays above and below the floor with continuation of cables through the floor penetration. Based on the submitter's proposed use of cable trays with a loading depth of 3 in. (76.2 mm), the following cable tray percent fills were simulated:

Penetration No.	Simulated Cable Tray Configuration	Simulated Percent Fill
15	Two 24 in. (610 mm) wide trays	30.6/tray
16	Two 24 in. (610 mm) wide trays	30.6/tray

After the cables were installed, loose ceramic fiber was installed in all penetrations except Penetration Nos. 9, 10, 11, 12, and 13. First the cables in each penetration were spread apart and ceramic fiber was inserted between cables such that the cables were separated from each other within the 12 in. (305 mm) depth of the penetration. Next, ceramic fiber was placed in the penetration to completely fill the 12 in. (305 mm) depth at the target density shown in the following table. For Penetration Nos. 14, 15, and 16, it was necessary to place removable plywood forms against the underside of the floor to prevent the ceramic fiber from falling through when the penetrations were filled from the top surface of the floor. For Penetration Nos. 1 through 8, inclusive, no forming was required on the underside of the floor. The ceramic fiber was first pushed into the penetration from the underside such that the bottom portion of the penetration was filled. The remainder of the ceramic fiber for the penetrations was installed from the top surface of the floor. The amount of ceramic fiber used in each penetration varied with the volume of the penetration and the volume displaced by the penetrating cables, as shown in ILLS. 23 through 30, inclusive, ILLS. 36 through 38, inclusive, and as summarized in the following table:

Penetration No.	ILL. No.	Penetration Volume Less Cable Volume, $In.^3$ (m^3)	Amount Of Ceramic Fiber, Lb(n)	Ceramic Fiber Density, pcf (n/m^3)
1	23	235.4 (3.86×10^{-3})	0.80 (3.56)	5.9 (926.8)
2	24	235.4 (3.86×10^{-3})	0.80 (3.56)	5.9 (926.8)
3	25	165.2 (2.71×10^{-3})	0.49 (2.18)	5.1 (801.1)
4	26	165.2 (2.71×10^{-3})	0.49 (2.18)	5.1 (801.1)
5	27	235.4 (3.86×10^{-3})	0.53 (2.36)	3.9 (612.6)
6	28	235.4 (3.86×10^{-3})	0.53 (2.36)	3.9 (612.6)
7	29	165.2 (2.71×10^{-3})	0.33 (1.47)	3.5 (549.8)
8	30	165.2 (2.71×10^{-3})	0.33 (1.47)	3.5 (549.8)
14	36	6972.7 (1.14×10^{-1})	23.77 (105.73)	5.9 (926.8)
15	37	6958.7 (1.14×10^{-1})	23.71 (105.46)	5.9 (926.8)
16	38	6958.7 (1.14×10^{-1})	15.80 (70.28)	3.9 (612.6)

After the ceramic fiber was installed, the mastic coating was brush-applied to the ceramic fiber and cables on the exposed and unexposed sides of all penetrations except Penetration Nos. 9, 12, and 13. Several light coats of mastic coating were applied to build-up to the final dry thickness. The cables were spread apart in order to coat each individual cable with mastic coating. Because of the close proximity of the cables in the bundles, it was not possible to coat all of the cables in the interior of the bundles to the desired thickness. However, each cable was coated on all sides with mastic coating to 12 in. (305 mm) above and below the unexposed and exposed surfaces of the floor slab. The exterior of each cable bundle was coated to the desired thickness at its interface with the plane of the exposed and unexposed surfaces of the ceramic fiber fill. From the interface, the mastic coating was tapered from full thickness to a thin brush coat at its termination at approximately 12 in. (305 mm) above and below the unexposed and exposed surfaces of the assembly. The mastic coating on the penetrations with cables lapped approximately 1 in. (25.4 mm) on the concrete surface around the periphery of each penetration on the exposed and unexposed surfaces of the floor slab. The unexposed side end of each cable was capped with a brush coat of mastic coating.

The mastic coating type and average dry mastic coating thickness for each penetration with cables are shown on ILLS. 23 through 30, ILLS. 36 through 38, and are summarized in the following table:

Penetration No.	ILL. No.	Flamemastic Coating Type	Average Dry Thickness On Exposed Surface, In. (mm)	Average Dry Thickness On Unexposed Surface, In. (mm)
1	23	F77	0.271 (6.8)	0.229 (5.8)
2	24	F71-A	0.229 (5.8)	0.229 (5.8)
3	25	F77	0.250 (6.4)	0.229 (5.8)
4	26	F71-A	0.250 (6.4)	0.250 (6.4)
5	27	F77	0.229 (5.8)	0.229 (5.8)
6	28	F71-A	0.250 (6.4)	0.250 (6.4)
7	29	F77	0.271 (6.8)	0.271 (6.8)
8	30	F71-A	0.250 (6.4)	0.271 (6.8)
14	36	F77	0.307 (7.8)	0.302 (7.7)
15	37	F77	0.263 (6.7)	0.256 (6.5)
16	38	F77	0.244 (6.2)	0.288 (7.3)

The appearance of the exposed and unexposed surfaces before the fire test is shown in ILLS. 39 and 40, respectively.

5.2.3 WALL ASSEMBLY NO. 1

The test assembly was constructed in a test frame in accordance with the methods specified by the submitter and as shown in ILL. 42. The test assembly was constructed by members of the technical staff of Underwriters Laboratories Inc. under the supervision of the engineering staff of Underwriters Laboratories Inc.

The reinforced concrete wall inserts with through penetrations were constructed as described in Appendix B. On the same day the concrete wall inserts were poured, gravel mix concrete and anchors we placed in Penetration No. 3. Two anchors were installed in each end of the sleeve, with the anchors on each end of the sleeve opposed 180 deg from each other and opposed 90 deg from the anchors at the opposite end of the sleeve. The anchors were hooked over the lip of the sleeve and tack-welded to the lip and inside of the sleeve wall such that a 9 in. (229 mm) clearance was maintained between the 2 in. (51 mm) leg of the anchor and the opposite lip of the sleeve. A removable plywood form was placed inside the sleeve and the center 8 in. (203 mm) of the sleeve was filled with gravel mix concrete, tamped, and finished to a smooth, flat surface, as shown in ILL. 45.

Each course of concrete blocks was set in a bed of mortar with mortared joints. The reinforced concrete wall inserts with through penetrations were set in a bed of mortar atop courses of block. The split sleeve used for Penetration No. 7 was bricked into the wall.

For Penetration No. 7, the 18 in. (457 mm) pipe was wrapped with two wraps of 24 in. (610 mm) wide ceramic fiber blanket and the two sections of the split sleeve were placed around the ceramic fiber blanket wrap. The two sections of the split sleeve were then drawn together by tightening the four bolts, thereby compressing the nominal 2 in. (51 mm) thickness of ceramic fiber blanket to a thickness of 1-1/2 in. (38 mm), as shown in ILL. 49. The 18 in. (457 mm) pipe with ceramic fiber blanket wrap was installed in the split sleeve before the split sleeve was bricked into the wall. The capped end of the 18 in. (457 mm) diameter pipe protruded 12 in. (305 mm) from the exposed surface of the wall assembly.

The cable and cable tray support racks were secured to the exposed and unexposed surfaces of the wall using 1/2 in. (12.7 mm) diameter expansion-type masonry fasteners through the base plates. The support racks for Penetration Nos. 1, 2, 5, and 6 were oriented with their bearing surfaces even with the bottom plane of the cable penetration. The cable tray support rack for Penetration No. 4 was offset from the longitudinal centerline of the penetration to allow centering of the cable trays in the penetration.

For Penetration No. 5, two 7 by 36 in. (179 by 914 mm) and two 12 by 36 in. ~~(305~~ by 914 mm) pieces of ceramic fiber board were installed on each side of the wall. The bottom 7 by 36 in. (179 by 914 mm) piece and both 12 by 36 in. (305 by 914 mm) pieces were each provided with a 3 by 24 in. (76 by 610 mm) notch centered in their top edge. The boards were sandwiched between the concrete and 3 in. (76 mm) wide steel plates around the perimeter of the through penetration and were secured in place by 1/4 in. (6.4 mm) diameter expansion-type masonry fasteners through the steel plates, as shown in ILL. 47.

Two 60 in. (1.52 m) lengths of cable tray were installed in Penetration No. 4, centered in the penetration, and secured to the cable tray support rack, on the unexposed surface only, with tack-welds through the side rail flanges. The cable trays were positioned with 12 in. (305 mm) of the ladder protruding beyond the exposed surface of the wall.

Cables were installed in Penetration Nos. 1, 2, 4, 5, and 6. Each cable was 60 in. (1.52 m) long and was installed such that 12 in. (305 mm) of the cable protruded beyond the exposed surface of the wall. The number of cables used in each penetration varied with the size of the penetration, as shown in ILLS. 43, 44, 46, 47, and 48 and as summarized in the following table:

Penetration No.	ILL. No.	Number Of Cables	Cable Diameter, In. (mm)	Percent Fill*
1	43	59	0.705 (17.9)	39.2
2	44	59	0.705 (17.9)	39.2
4	46	99/Tray	0.705 (17.9)	40.3/Tray
5	47	59/Slot	0.705 (17.9)	32.0
6	48	16	0.705 (17.9)	31.2

* - For Penetration No. 4, the percent fill was based on the loading volume of the cable trays. For Penetration No. 5, the percent fill was based on the loading volume of the three 3 by 24 in. (76 by 610 mm) slots. For the remaining penetrations, the percent fill was based on the volume of the wall penetration.

After the cables were installed, loose ceramic fiber was installed in all penetrations except Penetration Nos. 3 and 7. First, the cables in each penetration were spread apart and ceramic fiber was inserted between cables such that the cables were separated from each other within the depth of the penetration. Next, loose ceramic fiber was placed in the penetration, from both sides of the wall, to completely fill the depth at the density shown in the following table. The amount of ceramic fiber used in each penetration varied with the volume of the penetration and the volume displaced by the penetrating cables, as shown in ILLS. 43, 44, 46, 47, and 48 and as summarized in the following table:

Penetra- No.	ILL. No.	Penetration Volume Less Cable Volume, In.^{3} (m^3)	Amount Of Ceramic Fiber, Lb(n)	Ceramic Fiber Density, pcf (n/m^3)
1	43	739.8 ($1.21x10^{-2}$)	4.07 (18.10)	9.5 (1492.2)
2	44	739.8 ($1.21x10^{-2}$)	4.07 (18.10)	9.5 (1492.2)
4	46	6560.4 ($1.08x10^{-1}$)	27.55 (122.54)	7.3 (1146.7)
5	47	9970.8 ($1.63x10^{-1}$)	44.90 (199.72)	7.8 (1225.2)
6	48	165.2 ($2.71x10^{-3}$)	0.65 (2.89)	6.8 (1068.1)

After the ceramic fiber was installed, the mastic coating was brush-applied to the ceramic fiber and cables on the exposed and unexposed surfaces of all penetrations except Penetration Nos. 3 and 7. Several coats of mastic coating were applied to build-up to the final dry thickness. The cables were spread apart in order to coat each individual cable with mastic coating. Because of the close proximity of the cables in the bundles, it was not possible to coat all of the cables in the interior of the bundles to the desired thickness. However, each cable was coated on all sides with mastic coating from the wall to approximately 12 in. (305 mm) beyond the wall on the exposed and unexposed surfaces. The exterior of each cable bundle was coated to the desired thickness at its interface with the plane of the exposed and unexposed surfaces of the ceramic fiber fill. From the interface, the mastic coating was tapered from full thickness to a thin brush coat at its termination approximately 12 in. (305 mm) beyond the unexposed and exposed surfaces of the assembly. The mastic coating on the penetrations with cables lapped approximately 1 in. (25.4 mm) on the concrete surface around the periphery of each penetration on the exposed and unexposed surfaces of the wall. The unexposed side end of each cable was capped with a brush coat of mastic coating. For Penetration Nos. 1 and 2, the 6 in. (152 mm) length of the welded wall sleeve which protruded from the unexposed and exposed surfaces of the wall, respectively, was also coated with mastic coating. For Penetration No. 5, the steel plates and bolts around the periphery of the ceramic fiber boards and the joints between the ceramic fiber boards were coated with mastic coating in addition to the mastic coating applied to the cables and exposed ceramic fiber in the three slots.

The mastic coating type and average dry mastic coating thickness for each penetration with cables are shown on ILLS. 43, 44, 46, 47, and 48 and are summarized in the following table:

Penetration No.	ILL. No.	Flamemastic Coating Type	Average Dry Thickness On Exposed Surface, In. (mm)	Average Dry Thickness On Unexposed Surface, In. (mm)
1	43	F77	0.234 (5.9)	0.219 (5.6)
2	44	F77	0.219 (5.6)	0.219 (5.6)
4	46	F77	0.234 (5.9)	0.211 (5.4)
5	47	F77	0.244 (6.2)	0.263 (6.7)
6	48	F77	0.229 (5.8)	0.250 (6.4)

Cementitious mixture was trowel-applied to the concrete blocks, to a thickness of approximately 1/4 in. (6.4 mm), on the exposed surface of the assembly only. Cementitious mixture was not applied on the concrete wall inserts.

The appearance of the exposed and unexposed surfaces before the fire test is shown in ILLS. 50 and 51, respectively.

5.2.4 WALL ASSEMBLY NO. 2

The test assembly was constructed in a test frame in accordance with the methods specified by the submitter and as shown in ILL. 53. The test assembly was constructed by members of the technical staff of Underwriters Laboratories Inc. under the supervision of the engineering staff of Underwriters Laboratories Inc.

The reinforced concrete wall inserts with through penetrations were constructed as described in Appendix B. For Penetration No. 3, the reinforced concrete wall insert containing the 18 in. (457 mm) diameter sleeve was not in a useable condition following its use in Wall Test No. 1. Instead, the sleeve was "bricked" into the wall assembly. For Penetration No. 4, the same reinforced concrete wall insert used for Wall Test No. 1 was used for Wall Test No. 2. For Penetration No. 7, the same split-sleeve used for Wall Test No. 1 was used for Wall Test No. 2. To prepare for the construction, the concrete was removed from the interior and exterior of the sleeve for Penetration No. 3 and new anchor plates were welded to the exterior of the sleeve to replace the old anchor plates. For Penetration No. 4, the exposed surface of the concrete was wire-brushed to remove loose concrete from around the periphery of the penetration and the penetration was cleaned to remove all material from the first fire test. For Penetration No. 7, the mortar was removed from the exterior of each sleeve half and the interior of each sleeve half was cleaned to remove all material from the first wall test.

Each course of bricks and concrete blocks was set in a bed of mortar with mortared joints. The wall inserts were set in a bed of mortar atop the masonry courses. The sleeve for Penetration No. 3 and the split sleeve for Penetration No. 7 were bricked into the wall.

For Penetration No. 7, the 18 in. (457 mm) pipe was wrapped with two wraps of 24 in. (610 mm) wide ceramic fiber blanket and the two sections of the split sleeve were placed around the ceramic fiber blanket wrap. The two sections of the split sleeve were then drawn together by tightening the four bolts, thereby compressing the nominal 2 in. (51 mm) thickness of ceramic fiber blanket to a thickness of 1-1/2 in. (38 mm), as shown in ILL. 60. The 18 in. (457 mm) pipe with ceramic fiber wrap was installed in the split sleeve before the split sleeve was bricked into the wall. The capped end of the pipe was 12 in. (305 mm) from the exposed surface of the wall assembly. The open end of the pipe was 36 in. (914 mm) from the unexposed surface of the wall assembly and was supported, near the end, by two struts welded to the pipe end and to the sill of the test frame.

The cable, cable tray, and pipe support racks were secured to the exposed and unexposed surfaces of the wall using 1/2 in. (12.7 mm) diameter expansion-type masonry fasteners through the base plates. The support racks for Penetration Nos. 1, 2, 5, and 6 were oriented with their bearing surfaces even with the bottom plane of the cable penetration. The cable tray support rack and the water-cooled restraining yoke for Penetration No. 4 were offset from the longitudinal centerline of the penetration to allow centering of the cable trays in the penetration. The pipe support racks for Penetration No. 3 were offset from the centerline of the sleeve to allow centering of the 4 in. (102 mm) pipe in the sleeve opening.

For Penetration No. 3, the 4 in. (102 mm) pipe was centered in the sleeve opening with its capped end 12 in. (305 mm) from the exposed surface of the wall assembly. The 1-1/4 in. (31.8 mm) and 2 in. (51 mm) pipes were installed on either side of the 4 in. (102 mm) pipe with the capped end of each pipe 12 in. (305 mm) from the exposed surface of the wall assembly. The three pipes were each secured to the unexposed surface support rack with a steel bolt passing through holes drilled through the pipe near their open end, thereby allowing each pipe to pivot laterally. Loose ceramic fiber was packed into the sleeve opening, from both sides of the wall, to fill the center 8 in. of the sleeve depth, as shown in ILL. 56. A total of 7.80 lb (34.69 n) of loose ceramic fiber was used in the sleeve opening to provide an average fill density of 7.9 pcf (1240.9 n/m^3). The ceramic fiber was coated with Flamemastic F77 mastic coating on both the exposed and unexposed surfaces. A 1 in. (25.4 mm) clearance was maintained between the mastic coating and each of the three pipes on the exposed and unexposed surfaces of the assembly to allow lateral movement of the pipe within the sleeve. The average dry coating thickness on both the exposed and unexposed surfaces was 0.250 in. (6.4 mm).

For Penetration No. 5, two 7 by 36 in. (179 by 914 mm) and two 12 by 36 in. (305 by 914 mm) pieces of ceramic fiber board were installed on each side of the wall. The bottom 7 by 36 in. (179 by 914 mm) piece and both 12 by 36 in. (305 by 914 mm) pieces were each provided with a 3 by 24 in. (76 by 610 mm) notch centered in their top edge. The boards were sandwiched between the concrete and 3 in. (76 mm) wide steel plates around the perimeter of the through penetration and were secured in place by 1/2 in. (12.7 mm) diameter expansion-type masonry fasteners through the steel plates, as shown in ILL. 58.

Two 60 in. (1.52 m) lengths of cable tray were installed in Penetration No. 4, centered in the penetration, and secured to the cable tray support rack, on the unexposed surface only, with tack-welds through the side rail flanges. The cable trays were positioned with 12 in. (305 mm) of the ladder protruding beyond the exposed surface of the wall. The end of each cable tray side rail on the exposed surface of the wall was butted against and supported by the steel angle sections on the water-cooled restraining yoke.

Cables were installed in Penetration Nos. 1, 2, 4, 5 and 6. Each cable was 60 in. (1.52 m) long and was installed such that 12 in. (305 mm) of the cable protruded beyond the exposed surface of the wall. The number of cables used in each penetration varied with the size of the penetration, as shown in ILLS. 54, 55, 57, 58, and 59 and as summarized in the following table:

Penetration No.	ILL. No.	Number of Cables	Cable Diameter, In. (mm)	Percent Fill*
1	54	50	0.765 (19.4)	39.1
2	55	50	0.765 (19.4)	39.1
4	57	57/Tray	0.765 (19.4)	36.4/Tray
5	58	56/Slot	0.765 (19.4)	35.7/Slot
6	59	17	0.765 (19.4)	39.1

* - For Penetration No. 4, the percent fill was based on the loading volume of the cable trays. For Penetration No. 5, the percent fill was based on the loading volume of the three 3 by 24 in. (76 by 610 mm) slots. For the remaining penetrations, the percent fill was based on the volume of the wall penetration.

After the cables were installed, loose ceramic fiber was installed in the five cable penetrations. First, the cables in each penetration were spread apart and ceramic fiber was inserted between cables such that the cables were separated from each other within the depth of the penetration. Next, loose ceramic fiber was placed in the penetration, from both sides of the wall, to completely fill the depth at the density shown in the following table. The amount of ceramic fiber used in each penetration varied with the volume of the penetration and the volume displaced by the penetrating cables, as shown in ILLS. 54, 55, 57, 58, and 59 and as summarized in the following table:

Penetra- No.	ILL. No.	Penetration Volume Less Cable Volume, $In.^3$ (m^3)	Amount Of Ceramic Fiber, Lb(n)	Ceramic Fiber Density, pcf (n/m^3)
1	54	740.7 (1.21×10^{-2})	2.24 (9.96)	5.2 (816.8)
2	55	740.7 (1.21×10^{-2})	2.24 (9.96)	5.2 (816.8)
4	57	6859.2 (1.12×10^{-1})	15.86 (70.55)	4.0 (628.3)
5	58	9873.3 (1.62×10^{-1})	22.83 (101.55)	4.0 (628.3)
6	59	146.3 (2.40×10^{-3})	0.56 (2.49)	6.6 (1036.7)

After the ceramic fiber was installed, the mastic coating was brush-applied to the ceramic fiber and cables on the exposed and unexposed surfaces of all penetrations except Penetration No. 7 Several coats of mastic coating were applied to build-up to the final dry thickness. The cables were spread apart in order to coat each individual cable with mastic coating. Because of the close proximity of the cables in the bundles, it was not possible to coat all of the cables in the interior of the bundles to the desired thickness. However, each cable was coated on all sides with mastic coating from the wall to approximately 12 in. (305 mm) beyond the wall on the exposed and unexposed surfaces. The exterior of each cable bundle was coated to the desired thickness at its interface with the plane of the exposed and unexposed surfaces of the ceramic fiber fill. From the interface, the mastic coating was tapered from full thickness to a thin brush coat at its termination approximately 12 in. (305 mm) beyond the unexposed and exposed surfaces of the assembly. The mastic coating on the penetrations with cables lapped approximately 1 in. (25.4 mm) on the concrete surface around the periphery of each penetration on the exposed and unexposed surfaces of the wall. The cut end of each cable at 36 in. (914 mm) beyond the unexposed surface was capped with a brush coat of mastic coating. For Penetration Nos. 1 and 2, the 6 in. (152 mm) length of the welded wall sleeve which protruded from the unexposed and exposed surfaces of the wall, respectively, were also coated with mastic coating. For Penetration No. 5, the steel plates and bolts around the periphery of the ceramic fiber boards and the joints between the ceramic fiber boards were coated with mastic coating in addition to the mastic coating applied to the cables and exposed ceramic fiber in the three slots.

The mastic coating type and average dry mastic coating thickness for each penetration with cables are shown on ILLS. 54, 55, 57, 58, and 59 and are summarized in the following table:

Penetration No.	ILL. No.	Flamemastic Coating Type	Average Dry Thickness On Exposed Surface, In. (mm)	Average Dry Thickness On Unexposed Surface, In. (mm)
1	54	F71-A	0.250 (6.4)	0.250 (6.4)
2	55	F77	0.250 (6.4)	0.234 (5.9)
4	57	F77	0.242 (6.1)	0.234 (5.9)
5	58	F77	0.250 (6.4)	0.245 (6.2)
6	59	F71-A	0.250 (6.4)	0.250 (6.4)

The appearance of the exposed and unexposed surfaces before the fire test is shown in ILLS. 61 and 62, respectively.

6. FLOOR ASSEMBLIES TEST RECORD

6.1 FIRE ENDURANCE TEST-FLOOR ASSEMBLY NO. 1:

The test was conducted in general accordance with provisions outlined for power generating stations in IEEE 634-1978 entitled "Standard Cable Penetration Fire Stop Qualification Test" and in accordance with the imposed provisions for pipe penetration fire stops.

6.1.1 SAMPLE

The fire endurance test was conducted on Floor Assembly No. 1 as described previously in this Report under "5.2 Assembly Construction," constructed as shown in ILLS. 1 through 20.

At the time of the fire test, the concrete floor slab had aged 163 days, 79 of which were at a temperature of 110-120 F (43.3-48.9 C), four of which were at brief high-temperature exposures of 550-800 F (287.8-426.7 C), and the remaining 80 of which were at room temperature. For 71 of the 79 days at 110-120 F (43.3-48.9 C) ambient temperature, the floor slab was exposed to the heating effect of industrial infrared lamps placed 12 in. (305 mm) below the undersurface of the floor slab. The lamps were periodically moved to different locations to obtain uniform drying.

At the time of the test the concrete had dried to an average relative humidity of 80.3 percent at a depth of 6 in. (152 mm) (wettest section). The humidity was measured by means of moisture-sensitive elements inserted into short lengths of galvanized steel pipe buried in the concrete and attached to a measuring instrument when measurements were taken.

The application of mastic coating on the exposed and unexposed surfaces of the test assembly was completed approximately two weeks before the fire endurance test was conducted.

6.1.2 METHOD

The standard equipment of Underwriters Laboratories Inc. for testing floor and ceiling assemblies was used for the fire endurance test.

The temperatures of the furnace chamber were measured by 16 thermocouples which ~~were~~ placed 12 in. (305 mm) below the exposed surface, located as shown in ILL. 21.

The temperatures of the fire stops, penetrating items, and floor slab on the unexposed side of the assembly were measured by 96 thermocouples located as shown in ILL. 1 and in ILLS. 3 through 18. The thermocouples were covered with dry asbestos pads.

The pressure within the furnace with respect to atmosphere was measured at two locations along the north-south centerline of the furnace, with the orifice of each stainless steel sampling tube located approximately flush with the exposed surface of the floor slab.

Throughout the fire test, observations were made of the character of the fire and its control, the conditions of the exposed and unexposed surfaces, and all developments pertaining to the performance of the fire stops with special reference to integrity and flame passage through the assembly.

6.1.3 RESULTS

Character And Distribution Of Fire - The fire was luminous and well-distributed, and the furnace temperatures followed the Standard Time-Temperature Curve as outlined in Standard IEEE 634-1978 (ASTM E119, UL 263) and as shown in ILL. 21.

Pressure Within The Furnace Chamber - During the first 15 min of fire exposure, the measured furnace pressure was slightly negative to neutral. After 15 min and for the remainder of the fire exposure, the measured furnace pressure fluctuated from neutral to a positive pressure of 0.01 in. (0.25 mm) water column.

Observation Of The Exposed Surface - The following is a chronological description of the observations made during the fire endurance test.

[redacted] Page 32 Issued: 11-17-80

Test Time, Min	Observations
2	Exposed cable insulation is flaming. Mastic coating is darkening to brown color.
8	The concrete slab is black in color. The cables are flaming and smoking profusely.
14	Profuse smoking and flaming continues. Flaming material is dripping from cables.
21	Flaming, smoking, and dripping continues.
34	Smoke is very dense, limiting observations. Blue flames issuing from cables.
43	No apparent change.
54	The flaming, smoking, and dripping have diminished somewhat.
65	Smoking continues. Flaming and dripping has subsided.
78	Flaming present at Penetration Nos. 1 through 8. Smoking continues at a much diminished rate.
105	Smoking and flaming continues. Some mastic coating is delaminating from the concrete at the feathered edge of Penetration No. 15.
124	No apparent change.
149	Flaming and smoking greatly diminished. No further delamination of mastic coating is apparent.
180	Furnace fire extinguished.

Observations Of The Unexposed Surface - The following is a chronological description of the observations made during the fire endurance test. All observed dimensions are approximate.

Test Time, Min	Observations
0.5	Smoke from cutting oil issuing from 4 in. (102 mm) pipe in Penetration No. 11.
6	Smoking from pipe ceased.
30	Smoke issuing from cables and mastic coating in Penetration No. 13.
35	Smoking has ceased.
49	Smoke once again issuing from Penetration No. 13.
75	Water is seeping from concrete slab between Penetration Nos. 10 and 11 and between Penetration Nos. 11 and 12.
128	Smoking continues from Penetration No. 13.
135	The maximum concrete slab deflection is approximately 3/4 in. (19 mm).
155	Smoking continues from Penetration No. 13.
163	Water noted at 75 min is drying up.
180	Furnace fire extinguished.

Temperatures Of The Assembly - The temperatures measured by the various thermocouples were recorded at 5 min intervals during the fire test. The temperatures (deg F) recorded immediately before the fire exposure and at 60, 120 and 180 min of fire exposure are tabulated below:

[redacted] Page 35 Issued: 11-17-80

Thermocouple No.	Penetration No.	0 Min	60 Min	120 Min	180 Min
36	13	71.3	77.0	128.2	173.5
37	13	69.4	75.4	93.0	109.2
38	13	71.0	77.5	114.8	150.3
39	13	69.5	74.7	97.1	112.3
40	13	70.4	149.2	278.5	357.3
41	13	70.1	166.8	313.4	401.1
42	9	70.7	83.7	121.3	154.2
43	9	71.1	88.5	125.7	157.4
44	9	70.9	88.4	131.6	172.2
45	9	70.6	89.1	136.7	173.1
46	9	71.1	98.4	154.7	187.6
47	9	70.9	98.2	151.4	190.4
48	9	68.8	76.7	91.2	102.1
49	9	69.0	76.4	93.3	106.9
50	9	70.2	77.9	103.5	127.1
51	9	70.9	142.7	223.6	298.5
52	9	71.0	132.1	216.2	298.9
53	9	71.2	84.0	122.6	160.8
54	14	71.8	74.6	121.9	180.7
55	14	71.7	79.0	146.7	182.3
56	14	71.8	73.4	101.4	165.6
57	14	72.1	73.7	109.0	171.0
58	14	71.7	80.1	151.7	189.3
59	14	71.3	77.0	119.9	175.5
60	14	72.1	75.8	116.5	175.1
61	14	70.4	74.5	91.3	117.8
62	14	70.5	76.1	103.6	137.3
63	14	70.8	75.0	93.4	120.4
64	14	71.2	110.4	205.1	309.1
65	14	71.1	108.4	213.3	321.2
66	14	70.4	130.2	186.7	211.5
67	14	70.0	145.6	215.1	241.6
68	14	70.0	152.2	225.9	264.7
69	14	71.9	122.4	184.3	205.2
70	15	72.8	76.4	105.5	132.2

[redacted] Page 36 Issued: [illegible]

Thermocouple No.	Penetration No.	0 Min	60 Min	120 Min	180 Min
71	15	71.3	75.5	119.3	162.6
72	15	72.7	77.0	117.8	169.4
73	15	72.5	81.7	138.0	184.0
74	15	71.2	78.1	134.5	180.4
75	15	72.2	79.8	139.8	190.8
76	15	70.9	76.7	101.1	123.0
77	15	72.6	75.5	88.2	114.4
78	15	69.9	76.0	96.4	126.5
79	15	71.7	121.1	224.3	287.1
80	15	70.8	110.5	211.5	262.5
81	15	72.5	76.5	117.8	168.3
82	15	72.4	77.0	109.4	148.8
83	16	72.2	74.4	94.0	139.6
84	16	71.7	74.0	100.1	136.7
85	16	72.6	75.1	96.1	134.8
86	16	72.5	73.9	98.0	147.5
87	16	71.6	77.2	113.6	161.5
88	16	72.8	75.5	99.6	145.0
89	16	71.7	74.6	85.0	100.9
90	16	71.3	75.5	93.1	116.4
91	16	73.0	75.5	86.3	95.5
92	16	71.9	91.2	166.2	211.4
93	16	72.0	93.4	173.9	216.2
94	16	72.7	74.5	100.0	151.1
95	16	72.3	74.5	101.3	137.0
96	Concrete	72.5	72.9	93.3	132.1

6.2 FIRE ENDURANCE TEST-FLOOR ASSEMBLY NO. 2:

The test was conducted in general accordance with provisions outlined for power generating stations in IEEE 634-1978 entitled "Standard Cable Penetration Fire Stop Qualification Test" and in accordance with the imposed provisions for pipe penetration fire stops.

6.2.1 SAMPLE

The fire endurance test was conducted on Floor Assembly No. 2 as described previously in this Report under "5.2 Assembly Construction," constructed as shown in ILLS. 22 through 40.

Floor Assembly No. 2 employed the same concrete floor slab used in the fire ~~endurance~~ and hose stream tests of Floor Assembly No. 1. No humidity measurements of the concrete floor slab were obtained immediately before the fire endurance test of Floor Assembly No. 2.

The application of mastic coating on the exposed and unexposed surfaces of the test assembly was completed approximately two weeks before the fire endurance test was conducted.

6.2.2 METHOD

The standard equipment of Underwriters Laboratories Inc. for testing floor and ceiling assemblies was used for the fire endurance test.

The temperatures of the furnace chamber were measured by 16 thermocouples which were placed 12 in. (305 mm) below the exposed surface, located as shown in ILL. 41.

The temperatures of the fire stops, penetrating items, vermiculite concrete, and floor slab on the unexposed side of the assembly were measured by 81 thermocouples, located as shown in ILLS. 22 through 38. The thermocouples were covered with dry asbestos pads.

The pressure within the furnace with respect to atmosphere was measured at two locations along the north-south centerline of the furnace, with the orifice of each stainless steel sampling tube located approximately flush with the exposed surface of the floor slab.

Throughout the fire test, observations were made of the character of the fire and its control, the conditions of the exposed and unexposed surfaces, and all developments pertaining to the performance of the fire stops with special reference to integrity and flame passage through the assembly.

6.2.3 RESULTS

Character And Distribution Of Fire - The fire was luminous and well-distributed, and the furnace temperatures followed the Standard Time-Temperature Curve as outlined in Standard IEEE 634-1978 (ASTM E119, UL 263) and as shown in ILL. 41.

Pressure Within The Furnace Chamber - During the first 15 min of fire exposure, the measured furnace pressure was slightly negative to neutral. After 15 min and for the remainder of the fire exposure, the measured furnace pressure fluctuated from neutral to a positive pressure of 0.02 in. (0.51 mm) water column.

Observation Of The Exposed Surface - The following is a chronological description of the observations made during the fire endurance test.

Test Time, Min	Observations
1	Cable ends in Penetration No. 14 are flaming.
2	Cable ends in all penetrations are flaming.
4	Cable ends are flaming profusely. Flaming droplets are falling from cable bundles.
9	Profuse flaming continues. Dense smoke present in the vicinity of Penetration No. 12, 13, and 14.
13	Heavy flame involvement of cables up to the plane of the underside of the floor slab. Dense smoke making observations difficult.
20	Heavy cable flaming and smoking continues. Flaming droplets continue to fall from cables.
30	Cable flaming continues at a diminished intensity. Smoking has greatly diminished.
49	Light cable flaming continues. Smoking is also quite light.
58	Light cable flaming and smoking continues. Mastic coating appears to be delaminating from the concrete at the east and west edges of Penetration Nos. 14, 15, and 16.
89	Cable flaming continues. Mastic coating delaminating from concrete around periphery of Penetration Nos. 1, 3, 14, 15, and 16.
105	Light cable flaming and smoking continues.
123	Light cable flaming continues.
150	Cable flaming and smoking almost ceased.
180	Furnace fire extinguished.

Observations Of The Unexposed Surface - The following is a chronological description of the observations made during the fire endurance test.

Test Time, Min	Observations
9	Smoke from cutting oil issuing from 4 in. (102 mm) pipe in Penetration No. 10.
85	Slight amount of smoke issuing from one of the cable bundles (second from west end) in Penetration No. 13.
97	Slight smoking noted at 85 min continues.
105	Slight smoking noted at 85 min continues.
180	Furnace fire extinguished.

Temperatures Of The Assembly - The temperatures measured by the various thermocouples were recorded at 5 min intervals during the fire test. The temperatures (deg F) recorded immediately before the fire exposure and at 60, 120 and 180 min of fire exposure are tabulated below:

Thermocouple No.	Penetration No.	0 Min	60 Min	120 Min	180 Min
1	1	82.9	84.8	87.2	89.8
2	2	83.0	85.8	89.0	92.8
3	5	83.4	88.1	93.5	99.8
4	6	83.2	86.6	92.4	98.1
5	1	83.9	144.4	197.6	218.6
6	2	83.8	148.7	197.8	221.5
7	5	84.3	142.4	188.6	205.9
8	6	84.1	136.5	188.8	211.4
9	1	82.9	82.8	84.8	88.7
10	2	83.9	121.6	169.4	191.6
11	5	84.4	110.6	151.3	165.4
12	6	84.2	114.7	162.5	185.0
13	1	83.9	105.9	157.4	169.0
14	2	83.4	103.1	154.3	203.3
15	5	84.0	98.9	138.1	154.8

[redacted] Page 40 Issued: 11-17-80

Thermocouple No.	Penetration No.	0 Min	60 Min	120 Min	180 Min
16	6	83.9	98.6	144.1	171.5
17	3	83.9	92.6	126.4	143.1
18	4	83.8	90.5	113.9	129.6
19	7	83.9	93.2	123.9	144.0
20	8	83.5	90.5	111.4	128.7
21	3	83.2	124.4	202.0	261.1
22	4	83.2	133.5	223.4	284.4
23	7	83.2	97.7	121.9	145.0
24	8	83.5	128.6	204.1	264.6
25	3	83.0	106.3	166.1	219.0
26	4	83.1	118.2	194.8	262.0
27	7	83.2	105.5	129.3	160.1
28	8	83.3	110.5	176.1	239.3
29	3	83.0	110.0	175.9	230.1
30	4	84.1	117.8	192.8	256.1
31	7	84.4	128.3	187.[illegible]	238.4
32	8	84.3	117.0	186.6	250.3
33	10	84.9	320.2	492.2	591.1
34	10	84.8	208.8	331.2	413.3
35	10	84.7	132.7	207.1	269.8
36	10	85.3	90.9	111.1	121.0
37	11	85.8	85.4	88.7	97.7
38	11	84.7	95.8	127.7	157.0
39	12	84.4	94.2	196.1	249.3
40	14	83.4	139.7	175.7	207.1
41	14	83.7	175.3	234.0	275.1
42	14	84.4	131.5	226.0	294.3
43	14	84.1	133.0	216.8	261.3
44	14	84.2	123.8	207.8	269.9
45	14	83.9	118.2	177.2	222.7
46	14	63.9	134.7	229.9	288.8
47	14	82.9	89.4	104.8	118.1
48	14	82.5	85.8	93.4	102.3
49	14	82.9	89.8	109.0	125.7
50	14	84.7	93.8	126.6	164.7

[redacted] Page 41 Issued: 11-17-80

Thermocouple No.	Penetration No.	0 Min	60 Min	120 Min	180 Min
51	14	84.4	95.6	134.2	170.3
52	14	84.2	107.5	150.8	181.5
53	15	83.6	87.9	111.1	134.4
54	15	84.8	107.7	150.6	176.9
55	15	84.0	95.6	131.2	158.9
56	15	84.5	127.8	224.9	289.2
57	15	84.5	158.9	272.4	351.4
58	15	84.6	136.3	236.4	298.0
59	15	84.1	91.1	109.7	122.7
60	15	83.8	92.6	125.1	147.7
61	15	83.6	92.1	123.0	145.8
62	15	84.0	103.0	154.2	196.7
63	15	84.3	120.0	189.7	232.3
64	16	83.3	93.0	123.6	152.2
65	16	84.0	110.0	140.8	171.0
66	16	83.7	100.2	136.8	167.8
67	16	83.9	128.0	199.4	232.5
68	16	84.0	171.3	259.2	337.5
69	16	83.9	130.2	173.1	202.6
70	16	84.5	94.8	116.1	125.5
71	16	84.0	95.7	126.9	143.4
72	16	83.4	90.7	104.8	117.6
73	16	84.0	131.8	187.3	220.2
74	16	83.8	104.8	149.7	187.6
75	13	83.4	83.5	84.9	94.7
76	13	83.5	83.7	84.9	92.0
77	9	83.6	86.7	111.4	182.3
78	Concrete	83.7	84.0	93.8	125.8
79	11	83.5	117.2	185.9	249.8
80	11	83.5	101.9	158.1	222.5
81	11	83.4	90.1	130.3	194.2

6.3 HOSE STREAM TEST-FLOOR ASSEMBLY NO. 1:

6.3.1 SAMPLE

The hose stream was applied to the exposed surface of Floor Assembly No. 1. The hose stream test commenced 4 min, 35 sec after the fire endurance test.

6.3.2 METHOD

The test was conducted in accordance with the provisions outlined for power-generating stations in the Standard IEEE, 634-1978. The assembly was subjected to the action of a 75 psi (5.17 x 10^5 n/m^2) (at the nozzle base) 75 gpm (4.73 l/s) water stream applied with a 1-1/2 in. (38.1 mm) spray nozzle (set at a 30 deg included angle) at a distance of 10 ft (3.05 m) from the center of the concrete slab. The water stream was applied for 163 sec and traversed the concrete slab and all penetrations.

6.3.3 RESULTS

The penetration fire stops withstood the water hose stream test without developing any openings that would permit the penetration of the water stream.

6.4 HOSE STREAM TEST-FLOOR ASSEMBLY NO. 2:

6.4.1 SAMPLE

The hose stream was applied to the exposed surface of Floor Assembly No. 2. The hose stream test commenced 4 min, 36 sec after the fire endurance test.

6.4.2 METHOD

The test was conducted in accordance with the provisions outlined for power-generating stations in the Standard, IEEE 634-1978. The assembly was subjected to the action of a 75 psi (5.17 x 10^5 n/m^2) (at the nozzle base) 75 gpm (4.73 l/s) water stream applied with a 1-1/2 in. (38.1 mm) spray nozzle (set at a 30 deg included angle) at a distance of 10 ft (3.05 m) from the center of the concrete slab. The water stream was applied for 163 sec and traversed the concrete slab and all penetrations. The appearance of the assembly before and during the hose stream test is shown in ILL. 64.

6.4.3 RESULTS

The penetration fire stops withstood the water hose stream test without developing any openings that would permit the penetration of the water stream.

6.5 OBSERVATIONS AFTER TEST:

6.5.1 FLOOR ASSEMBLY NO. 1

The appearance of the exposed and unexposed surfaces of Floor Assembly No. 1 after the fire endurance and hose stream tests is shown in ILLS. 65 through 67.

On the exposed surface, the concrete within Penetration Nos. 10, 11, and 12 and the concrete slab were powdery with the gravel aggregate exposed. The mastic coating was off-white to gray in color with several small black areas. All of the mastic coating remained in place, but was brittle. The cables protruding from the mastic coating were devoid of insulation, and the copper conductors were blackened.

Within the various penetrations, the ceramic fiber ranged in color from black on the exposed surface to the original white color on the unexposed surface. The depth of unaffected ceramic fiber varied from penetration to penetration. Within the ceramic fiber, the cable damage also varied from penetration to penetration. The average depths of unaffected ceramic fiber, solid cable jacket material, and solid conductor insulation for each penetration, as measured from the top surface of the concrete, are shown in the following table:

Penetration No.	Unaffected Ceramic Fiber Depth, In. (mm)	Solid Cable Jacket, In. (mm)	Solid Conductor Insulation, In. (mm)
1, 2, 3, 4	4 (102)	5 (127)	8 (203)
5, 6, 7, 8 Q	4-1/2 (114)	6-1/ (165)	9 (229)
9	4 (102)	6 (152)	8 (203)
11	12 (305)	Not Applicable	Not Applicable
13	2 (51)	9 (229)	9 (229)
14	7 (178)	3 (76)	6-1/2 (165)
15	9 (229)	2-1/2 (64)	5-1/2 (140)
16	10 (254)	4 (102)	8 (203)

On the unexposed surface, the cables and mastic coating appeared unchanged.

6.5.2 FLOOR ASSEMBLY NO. 2

The appearance of the exposed and unexposed surfaces of Floor Assembly No. 2fter the fire endurance and hose stream tests is shown in ILLS. 68 through 71.

[redacted] Page 44 Issued: 11-17-80

On the exposed surface, the concrete within Penetration No. 12 and the concrete slab were powdery with the gravel aggregate exposed. The mastic coating was off-white to yellowish in color, with the Flamemastic 77 mastic coating having a bluish tint turning to black around the cables and with the Flamemastic 71-A mastic coating having a brownish tint turning to black around the cables. All of the mastic coating on the exposed surface was brittle and all of the exposed cables were devoid of insulation with blackened copper conductors.

Within the various penetrations, the ceramic fiber ranged in color from black on the exposed surface to the original white color on the unexposed surface. The depth of unaffected ceramic fiber varied from penetration to penetration. Within the ceramic fiber and, for some penetrations, within the "cone" of mastic coating above the unexposed surface, the cable damage also varied from penetration to penetration. The average depths of unaffected ceramic fiber, solid cable jacket material, and solid conductor insulation for each penetration, as measured from the top surface of the concrete, are shown in the following table:

Penetration No.	Unaffected Ceramic Fiber Depth, In. (mm)	Solid Cable Jacket, In. (mm)*	Solid Conductor Insulation, In. (mm)*
1	1 (25.4)	-2 (-50.8)	-5 (-127)
2	1 (25.4)	-2-1/2 (-63.5)	-5-3/4 (-146)
3	3 (76.2)	0	-5 (-127)
4	3-1/2 (88.9)	1-3/4 (44.5)	-5 (-127)
5	2 (50.8)	-2 (-50.8)	-5-1/4 (-133)
6	1-1/2 (38.1)	-2 (-50.8)	-5-1/4 (-133)
7	3-1/2 (88.9)	1/2 (12.7)	-5 (-127)
8	8 (203)	1/2 (12.7)	-5-1/2 (-140)
10	16 (406)	Not Applicable	Not Applicable
11	16 (406)	Not Applicable	Not Applicable
14	1-1/2 (38.1)	4 (102)	-3-1/4 (-82.6)
15	2-1/2 (63.5)	-1-1/2 (-38.1)	-3 (-76.2)
16	3 (76.2)	1/2 (12.7)	-3 (-76.2)

* - Measurements prefaced with (-) indicate damage height extending into "cone" of mastic coating above unexposed surface.

On the unexposed surface, the cables and mastic coating appeared unchanged.

7. WALL ASSEMBLIES TEST RECORD

7.1 FIRE ENDURANCE TEST-WALL ASSEMBLY NO. 1:

The test was conducted in general accordance with provisions outlined for power generating stations in IEEE 634-1978 entitled "Standard Cable Penetration Fire Stop Qualification Test" and in accordance with the imposed provisions for pipe penetration fire stops.

7.1.1 SAMPLE

The fire endurance test was conducted on Wall Assembly No. 1 as described previously in this Report under "5.2 Assembly Construction," constructed as shown in ILLS. 42 through 51.

At the time of the fire test, the concrete wall inserts had aged 199 days, 96 of which were at a temperature of 110-120 F (43.3-48.9 C), and the remaining 103 of which were at room temperature.

At the time of the test the wettest of the five concrete wall inserts had dried to a relative humidity of 76 percent at a depth of 6 in. (152 mm). The humidity was measured by means of moisture-sensitive elements inserted into short lengths of galvanized steel pipe buried in the concrete and attached to a measuring instrument when measurements were taken.

The application of mastic coating on the exposed and unexposed surfaces of the test assembly was completed approximately two weeks before the fire endurance tets was conducted.

7.1.2 METHOD

The standard equipment of Underwriters Laboratories Inc. for testing wall assemblies was used for the fire endurance test.

The temperatures of the furnace chamber were measured by 12 thermocouples which were placed 6 in. (152 mm) from the exposed surface, located as shown in ILL. 52.

The temperatures of the fire stops, penetrating items, concrete wall inserts and concrete blocks on the unexposed side of the assembly were measured by 45 thermocouples located as shown in ILLS. 42 through 49. The thermocouples were covered with dry asbestos pads.

The pressure within the furnace with respect to atmosphere was measured at four elevations along the vertical centerline of the assembly, with the orifice of each stainless steel sampling tube located approximately 12 in. (305 mm) from the exposed surface of the wall assembly.

Throughout the fire test, observations were made of the character of the fire and its control, the conditions of the exposed and unexposed surfaces, and all developments pertaining to the performance of the fire stops with special reference to integrity and flame passage through the assembly.

7.1.3 RESULTS

Character And Distribution Of Fire - The fire was luminous and well-distributed, and the furnace temperatures followed the Standard Time-Temperature Curve as outlined in Standard IEEE 634-1978 (ASTM E119, UL 263) and as shown in ILL. 52.

Pressure Within The Furnace Chamber - The observed air pressure within the furnace chamber approximately 12 in. (305 mm) away from the exposed surface of the wall assembly and along the vertical centerline of the assembly ranged from a positive pressure of 0.015 in. (0.38 mm) water column at the top of the assembly to a negative pressure of 0.035 in. (0.89 mm) at the center of the assembly to a negative pressure of 0.07 in. (1.78 mm) at the bottom of the assembly. The neutral pressure zone was located approximately 12 in. (305 mm) below the welded wall sleeves of Penetration Nos. 1 and 2.

Observation Of The Exposed Surface - The following is a chronological description of the observations made during the fire endurance test. All observed dimensions are approximate.

Test Time, Min	Observations
3	Flames issuing from ends of cables in Penetration Nos. 5 and 6.
13	Flames issuing from ends of cables in all penetrations.
55	Flaming of cables in Penetration Nos. 5 and 6 engulfing cables to within 6 in. (152 mm) of wall surface.
56-179	Cable flaming continues.
180	Furnace fire extinguished.

Observations Of The Unexposed Surface - The following is a chronological description of the observations made during the fire endurance test. All observed dimensions are approximate.

Test Time, Min	Observations
56	The concrete wall insert for Penetration No. 3. has a hairline crack, with moisture present on the concrete surface at the crack location. The cap plate and pipe protruding into the furnace chamber in Penetration No. 7 is glowing red.
102	A hairline crack is present in the top south corner of the concrete wall insert for Penetration No. 1. Moisture is present on the surface of the concrete wall insert for Penetration No. 1 and on the surface of the concrete blocks along the top of the wall.
112	A 3 by 6 in. (76.2 by 152 mm) piece of concrete appears to be breaking away from the concrete wall insert for Penetration No. 1.
120	Steam is issuing from mortar bed beneath the concrete wall insert for Penetration No. 1.
134	The piece of concrete noted at 112 min fell from the concrete wall insert. Steam is issuing from the mortar bed above the concrete wall insert for Penetration No. 1.
180	Furnace fire extinguished.

Temperatures Of The Assembly - The temperatures measured by the various thermocouples were recorded at 5 min intervals during the fire test. The temperatures (deg F) recorded immediately before the fire exposure and at 60, 120 and 180 min of fire exposure are tabulated below:

[redacted] Page 48 Issued: 11-17-80

Thermocouple No.	Penetration No.	0 Min	60 Min	120 Min	180 Min
1	4	77.4	87.1	119.8	152.9
2	4	77.1	100.7	144.3	172.2
3	4	76.4	103.8	148.5	185.0
4	4	75.9	162.9	248.6	302.1
5	4	74.2	164.6	254.2	313.7
6	4	74.4	83.2	127.4	172.9
7	4	76.4	89.8	151.1	195.3
8	4	75.2	145.2	242.4	306.4
9	4	73.7	103.2	170.8	210.4
10	2	78.3	89.1	116.4	138.2
11	2	79.0	93.0	117.6	132.2
12	2	78.3	88.0	119.8	139.4
13	2	73.0	107.8	196.8	218.7
14	2	78.5	96.0	116.1	126.6
15	2	74.0	95.3	189.7	214.8
16	5	76.1	82.1	111.4	138.7
17	5	74.0	79.9	111.9	145.9
18	5	73.0	79.2	109.7	138.5
19	5	74.9	84.6	140.9	187.0
20	5	75.3	80.0	116.7	142.1
21	5	72.9	83.0	146.7	207.0
22	5	72.5	83.7	143.9	204.0
23	5	75.8	77.9	89.5	108.9
24	5	73.3	74.7	88.9	116.5
25	1	78.0	84.8	113.4	138.2
26	1	77.8	85.3	115.1	140.2
27	1	78.1	85.2	114.9	134.0
28	1	74.4	87.4	144.0	189.6
29	1	75.0	86.2	130.8	167.1
30	1	73.1	94.8	169.3	220.1
31	6	74.2	82.1	104.7	121.5
32	6	74.3	85.6	118.5	143.7
33	6	74.3	83.6	107.9	125.3
34	6	70.6	90.9	140.4	186.5
35	6	70.3	82.5	127.1	170.7

Thermocouple No.	Penetration No.	0 Min	60 Min	120 Min	180 Min
36	6	70.8	89.8	146.7	193.2
37	3	72.5	97.9	209.2	214.1
38	3	72.3	98.2	208.9	217.7
39	3	72.5	128.7	215.1	268.4
40	3	72.1	164.0	235.5	308.8
41	7	70.7	168.4	301.7	388.6
42	7	72.2	184.4	314.0	382.9
43	7	74.0	544.8	763.6	825.2
44	Concrete	71.7	81.0	115.7	153.3
45	Conc. Block	73.3	97.0	181.1	192.0

7.2 FIRE ENDURANCE TEST-WALL ASSEMBLY NO. 2:

The test was conducted in general accordance with provisions outlined for power generating stations in IEEE 634-1978 entitled "Standard Cable Penetration Fire Stop Qualification Test" and in accordance with the imposed provisions for pipe penetration fire stops.

7.2.1 SAMPLE

The fire endurance test was conducted on Wall Assembly No. 2 as described previously in this Report under "5.2 Assembly Construction," constructed as shown in ILLS. 53 through 62.

At the time of the fire test, the concrete wall inserts for Penetration Nos. 1, 2, 5, and 6 had aged 358 days, 256 of which were at a temperature of 110-120 F (43.3-48.9 C) and the remaining 102 of which were at room temperature. No humidity measurements were made of the concrete wall inserts immediately before the fire endurance test of Wall Assembly No. 2. However, it was felt that the relative humidity of the concrete wall inserts was well below 75 percent at the time of the test. The concrete wall insert for Penetration No. 4 was the same concrete wall insert used in the fire endurance and hose stream tests of Wall Assembly No. 1.

The application of mastic coating on the exposed and unexposed surfaces of the test assembly was completed approximately two weeks before the fire endurance test was conducted.

7.2.2 METHOD

The standard equipment of Underwriters Laboratories Inc. for testing wall assemblies was used for the fire endurance test.

The temperatures of the furnace chamber were measured by 12 thermocouples which were placed 6 in. (152 mm) from the exposed surface, located as shown in ILL. 63.

The temperatures of the fire stops, penetrating items, concrete wall inserts, and concrete blocks on the unexposed side of the assembly were measured by 49 thermocouples, located as shown in ILLS. 53 through 60. The thermocouples were covered with dry asbestos pads.

The pressure within the furnace with respect to atmosphere was measured at four elevations along the vertical centerline of the assembly, with the orifice of each stainless steel sampling tube located approximately 12 in. (305 mm) from the exposed surface of the floor slab.

Throughout the fire test, observations were made of the character of the fire and its control, the conditions of the exposed and unexposed surfaces, and all developments pertaining to the performance of the fire stops with special reference to integrity and flame passage through the assembly.

7.2.3 RESULTS

Character And Distribution Of Fire - The fire was luminous and well-distributed, and the furnace temperatures followed the Standard Time-Temperature Curve as outlined in Standard IEEE 634-1978 (ASTM E119, UL 263) and as shown in ILL. 63.

Pressure Within The Furnace Chamber - The observed air pressure ithin the furnace chamber approximately 12 in. (305 mm) away from the exposed surface of the wall assembly and along the vertical centerline of the assembly ranged from a positive pressure of 0.04 in. (1.02 mm) water column at the top of the assembly to a positive pressure of 0.01 in. (0.25 mm) at the center of the assembly to a negative pressure of 0.015 in. (0.38 mm) at the bottom of the assembly. The neutral pressure zone was located approximately even with top plane of the wall sleeve of Penetration No. 7.

Observation Of The Exposed Surface - The following is a chronological description of the observations made during the fire endurance test.

Test Time, Min	Observations
3	Cable ends in Penetration Nos. 1 and 2 are flaming.
5	All cable ends are flaming.
8	Cables well-involved in flaming. The cable flaming appears to have engulfed the entire cable protrusion up to its interface with the wall and/or sleeve.
15	All cables well-involved in flaming.
105	Cable flaming greatly diminished.
120	Cable flaming almost ceased.
180	Furnace fire extinguished.

Observations Of The Unexposed Surface - The following is a chronological description of the observations made during the fire endurance test.

Test Time, Min	Observations
8	Smoke from cutting oil issuing from the pipe in Penetration No. 7.
10	Smoke issuing from ends of cables in Penetration Nos. 1 and 2.
15	Smoking noted at 8 min ceased. Smoking noted at 10 min continues. Smoke issuing from ends of cables in Penetration No. 4.
20	Smoke issuing from all cable ends except for the cables in Penetration No. 6. The cap on the pipe in Penetration No. 7 is glowing red.
25	Smoke issuing from cable ends in Penetration Nos. 1, 2, and 4 only.

Test Time, Min	Observations
45	Smoking noted at 25 min continues. A yellowish residue is present on the concrete at its interface with the mastic coating beneath the sleeve in Penetration No. 2.
68	Smoking noted at 25 min continues. No distress is evident in the restrained cable trays in Penetration No. 4.
85	Smoking greatly diminished.
120	Smoking almost ceased.
121-179	No apparent damage.
180	Furnace fire extinguished.

Temperatures Of The Assembly - The temperatures measured by the various thermocouples were recorded at 5 min intervals during the fire test. The temperatures (deg F) recorded immediately before the fire exposure and at 60, 120 and 180 min of fire exposure are tabulated below:

Thermocouple No.	Penetration No.	0 Min	60 Min	120 Min	180 Min
1	4	70.5	95.0	153.8	194.9
2	4	70.5	107.0	148.4	193.7
3	4	70.2	86.1	113.5	129.3
4	4	70.7	211.5	217.7	258.4
5	4	70.7	208.5	231.0	246.2
6	4	70.4	175.7	176.4	182.7
7	4	70.5	147.5	203.3	212.7
8	4	71.2	207.2	353.1	416.1
9	4	70.6	134.3	201.5	224.5
10	2	68.7	95.3	139.8	161.9
11	2	68.5	95.7	134.2	166.4
12	2	68.7	87.3	129.8	154.8
13	2	69.6	113.6	193.0	249.9
14	2	69.6	129.5	207.2	240.6
15	2	69.3	125.7	216.0	265.2

[redacted] Page 53 Issued: 11-17-80

Thermocouple No.	Penetration No.	0 Min	60 Min	120 Min	130 Min
16	5	68.0	86.5	145.5	189.9
17	5	67.6	88.4	162.0	219.6
18	5	67.8	86.6	142.2	180.3
19	5	68.2	100.6	205.5	280.0
20	5	68.3	87.3	155.3	347.7
21	5	68.4	94.8	174.7	276.6
22	5	68.8	100.9	206.4	294.8
23	5	68.3	74.3	97.7	123.0
24	5	68.5	70.5	84.7	116.2
25	1	69.5	95.2	155.1	187.5
26	1	69.5	92.0	153.6	189.5
27	1	69.4	89.4	146.6	173.1
28	1	69.8	100.2	185.5	229.2
29	1	69.6	94.7	160.6	192.2
30	1	69.1	119.7	201.2	255.8
31	6	67.8	85.5	130.5	159.9
32	6	67.9	88.7	142.8	180.8
33	6	67.7	87.6	127.4	161.1
34	6	68.3	111.7	195.8	251.7
35	6	68.3	86.4	149.4	205.9
36	6	68.3	113.2	203.6	263.6
37	3	68.7	192.5	310.4	379.1
38	3	68.9	226.7	366.1	448.4
39	3	68.0	144.9	256.5	363.9
40	3	67.2	129.9	218.7	330.8
41	3	68.2	601.8	793.6	874.0
42	3	68.1	366.8	512.2	577.0
43	3	68.1	426.7	598.6	669.7
44	3	67.4	211.2	381.4	481.4
45	7	67.6	140.1	262.4	354.9
46	7	67.5	146.3	273.1	348.2
47	7	67.7	440.7	687.9	763.2
48	Concrete	67.4	73.7	115.6	157.0
49	Conc. Block	66.7	70.7	112.4	168.3

7.3 HOSE STREAM TEST-WALL ASSEMBLY NO. 1:

7.3.1 SAMPLE

The hose stream was applied to the exposed surface of Wall Assembly No. 1. The hose stream test commenced 2 min, 35 sec after the fire endurance test.

7.3.2 METHOD

The test was conducted in accordance with the provisions outlined for power-generating stations in the Standard, IEEE 634-1978. The assembly was subjected to the action of a 75 psi (5.17 x 10^5 n/m^2) (at the nozzle base) 75 gpm (4.73 l/s) water stream applied with a 1-1/2 in. (38.1 mm) spray nozzle (set at a 30 deg included angle) at a distance of 10 ft (3.05 m) from the center of the wall assembly. The water stream was applied for 198 sec and traversed the wall assembly and all penetrations. The appearance of the assembly during the hose stream test is shown in ILL. 64.

Immediately following the water spray stream hose stream test, a second hose stream was applied to the exposed surface. The second hose stream test was conducted in accordance with the provisions outlined for industrial and commercial establishments in the Standard, IEEE 634-1978. The assembly was subjected to the action of a 30 psi (2.07 x 10^5 n/m^2) (at the nozzle base) water stream delivered through a 2-1/2 in. (63.5 mm) national standard playpipe equipped with a 1-1/8 in. (28.6 mm) discharge tip of the standard-taper, smooth-bore pattern without a shoulder at the orifice. The orifice of the nozzle was located 20 ft (6.1 m) from the center of the wall assembly. The water stream was applied for 198 sec and traversed the wall assembly and all penetrations.

7.3.3 RESULTS

The penetration fire stops withstood both water hose stream tests without developing any openings that would permit the penetration of the water stream.

7.4 HOSE STREAM TEST-WALL ASSEMBLY NO. 2:

7.4.1 SAMPLE

The hose stream was applied to the exposed surface of Wall Assembly No. 2. The hose stream test commenced 2 min, 25 sec after the fire endurance test.

7.4.2 METHOD

The test was conducted in accordance with the provisions outlined for power-generating stations in the Standard, IEEE 634-1978. The assembly was subjected to the action of a 75 psi (5.17 x 10^5 n/m^2) (at the nozzle base) 75 gpm (4.73 l/s) water stream applied with a 1-1/2 in. (38.1 mm) spray nozzle (set at a 30 deg included angle) at a distance of 10 ft (3.05 m) from the center of the wall assembly. The water stream was applied for 163 sec and traversed the wall assembly and all penetrations.

7.4.3 RESULTS

The penetration fire stops withstood the water hose stream test without developing any openings that would permit the penetration of the water stream.

7.5 OBSERVATIONS AFTER TEST:

7.5.1 WALL ASSEMBLY NO. 1

The appearance of the exposed and unexposed surfaces of Wall Assembly No. 1 after the fire endurance and hose stream tests is shown in ILLS. 72 through 75.

On the exposed surface, the concrete within Penetration No. 3 and each of the six concrete wall inserts were powdery with the gravel aggregate exposed. Most of the mastic coating was dislodged during the hose streams, as was the cementitious mixture on the concrete blocks. The cables protruding from the ceramic fiber were devoid of insulation, and the copper conductors were blackened.

Within the various penetrations, the ceramic fiber ranged in color from black on the exposed surface to the original white color on the unexposed surface. The depth of unaffected ceramic fiber varied from penetration to penetration. Within the ceramic fiber, the cable damage also varied from penetration to penetration. The average depths of unaffected ceramic fiber, solid cable jacket material, and solid conductor insulation for each penetration, as measured from the unexposed surface of the wall assembly, are shown in the following table:

Penetration No.	Ceramic Fiber Depth, In. (mm)	Cable Jacket, In. (mm)	Insulation, In. (mm)
1	0	2 (50.8)	8 (203)
2	7 (178)	9 (229)	13 (330)
4 (south)	5 (127)	0	5 (127)
4 (north)	5 (127)	0	5 (127)
5 (top)	3 (76.2)	0	4 (102)
5 (center)	3-1/2 (88.9)	0	4-1/2 (114)
5 (bottom)	4 (102)	0	4-1/2 (114)
6	6 (152)	3-3/4 (95.3)	6-1/2 (165)
7	15 (381)	Not Applicable	Not Applicable

On the unexposed surface, the cables and mastic coating appeared unchanged.

7.5.2 WALL ASSEMBLY NO. 2

The appearance of the exposed and unexposed surfaces of Wall Assembly No. 2 after the fire endurance and hose stream tests is shown in ILLS. 76 through 81.

On the exposed surface, each of the five concrete wall inserts were powdery with the gravel aggregate exposed. Much of the mastic coating fell away during the fire and hose stream tests. The remaining mastic coating was off-white to yellowish in color. All of the mastic coating remaining on the exposed surface was brittle and all of the exposed cables were devoid of insulation with blackened copper conductors.

Within the various penetrations, the ceramic fiber ranged in color from black on the exposed surface to the original white color on the unexposed surface. The depth of unaffected ceramic fiber varied from penetration to penetration. Within the ceramic fiber and, for some penetrations, within the "cone" of mastic coating beyond the unexposed surface, the cable damage also varied from penetration to penetration. The average depths of unaffected ceramic fiber, solid cable jacket material, and solid conductor insulation for each penetration, as measured from the plane of the unexposed surface of the wall assembly, are shown in the following table:

Penetration No.	Unaffected Ceramic Fiber Depth, In. (mm)	Solid Cable Jacket, In. (mm)*	Solid Conductor Insulation, In. (mm)*
1	0	-9 (-229)	5 (127)
2	-1-1/2 (-38.1)	-3-1/2 (-88.9)	6 (152)
3	8 (203)	Not Applicable	Not Applicable
4 (south)	3 (76.2)	-4 (-102)	2 (50.8)
4 (north)	2 (50.8)	-5 (-127)	2-1/2 (63.5)
5 (top)	3 (76.2)	-6-1/2 (-165)	2 (50.8)
5 (center)	2 (50.8)	-6 (-152)	2 (50.8)
5 (bottom)	2 (50.8)	-3 (-76.2)	3 (76.2)
6	4 (102)	-5 (-127)	5 (127)
7	15 (381)	Not Applicable	Not Applicable

* - Measurements prefaced with (-) indicate damage height extending into "cone" of mastic coating beyond unexposed surface.

On the unexposed surface, the cables and mastic coating appeared unchanged except for some discoloration of the mastic coating.

[redacted] Page 59 Issued: [illegible]

In Wall Assembly No. 2, a ceramic fiber fill density in the neighborhood of 4 pcf (628.3 n/m^3) was desired for Penetration Nos. 1, 2, 4, 5, and 6. For Penetration Nos. 4 and 5, the desired ceramic fiber fill density was achieved, although for Penetration No. 4 the low fill density made application of the mastic coating a slow process. For Penetration Nos. 1, 2, and 6, it was not possible to achieve the desired ceramic fiber fill density because the weight of the cables compressed the ceramic fiber between the sleeve and the cables and between successive layers of cables. The ceramic fiber fill densities achieved for Penetration Nos. 1, 2, and 6 in Wall Assembly No. 2 were the lowest practical fill densities achievable by the installers with the cable fill employed for the three penetrations.

Report by:
C. J. JOHNSON
Senior Engineering Assistant
Fire Protection Department

Reviewed by:
L. J. Przybyla
L. J. PRZYBYLA
Senior Project Engineer
Fire Protection Department

K. W. Howell
K. W. HOWELL
Associate Managing Engineer
Fire Protection Department

LJP/KWH:sas

NOT FOR COMMERCIAL USE

TABLE A
SUMMARY - FLOOR ASSEMBLY NO. 1
(NC601-1 Tested March 4, 1980)

ration o.	Penetrating Item	Ceramic Fiber Density pcf (n/m³)	Flamemastic Coating Type	Average Dry Coating Thickness, In. (mm) Exposed Surface	Unexposed Surface	Maximum Individual Temperature At 180 Min, Deg F
	16 cables (31.2% fill)	6.8 (1068.1)	F77	0.500 (12.7)	0.458 (11.6)	-
	16 cables (31.2% fill)	6.8 (1068.1)	F77	0.500 (12.7)	0.479 (12.2)	194.2
	16 cables (31.2% fill)	6.8 (1068.1)	F77	0.396 (10.1)	0.521 (13.2)	288.1
	16 cables (31.2% fill)	6.8 (1068.1)	F77	0.396 (10.1)	0.500 (12.7)	262.0
	16 cables (31.2% fill)	10.4 (1633.6)	F77	0.646 (16.4)	0.771 (19.6)	285.5
	16 cables (31.2% fill)	10.4 (1633.6)	F77	0.542 (13.8)	0.688 (17.5)	-
	16 cables (31.2% fill)	10.4 (1633.6)	F77	0.729 (18.5)	0.608 (17.5)	301.7
	16 cables (31.2% fill)	10.4 (1633.6)	F77	0.667 (16.9)	0.667 (16.9)	172.4
	16 cables (31.2% fill)	6.8 (1068.1)	F77	0.453 (11.5)	0.563 (14.3)	298.9
	None (conc. fill)	N.A.	N.A.	N.A.	N.A.	215.0
	Pipe	N.A.	N.A.	N.A.	N.A.	653.6
	None (conc. fill)	N.A.	N.A.	N.A.	N.A.	211.2
3*	495 cables (43.7% fill)	7.6 (1193.8)	F77	0.583 (14.8)	0.844 (21.4)	401.1
	99 Cables/Tray (40.3% fill/tray)	7.7 (1209.5)	F77	0.516 (13.1)	0.656 (16.7)	321.2
5*	138 cables (8.6% fill)	7.8 (1225.2)	F77	0.547 (13.9)	0.550 (14.0)	207.1
6*	138 cables (8.6% fill)	11.6 (1822.1)	F77	0.672 (17.1)	0.800 (20.3)	216.2
ete slab	N.A.	N.A.	N.A.	N.A.	N.A.	132.1

* - Penetration Nos. 13, 15, and 16 were intended to simulate the termination of cable trays above and below the floor with continuation of cables through the floor penetration. Based on the submitter's proposed use of cable trays with a loading depth of 3 in. (76.2 mm), the following cable tray percent fills were simulated.

Penetration No.	Simulated Cable Tray Configuration	Simulated Percent Fill
13	One 30 in. (762 mm) wide tray	87.5/tray
15	Two 24 in. (610 mm) wide trays	37.4/tray
16	Two 24 in. (610 mm) wide trays	37.4/tray

[redacted]

Page 60

Issued:

TABLE B
SUMMARY - FLOOR ASSEMBLY NO. 2
(NC601-3 Tested July 17, 1980)

ation	Penetrating Item	Ceramic Fiber Density, pcf (n/m^3)	Flamemastic Coating Type	Average Dry Coating Thickness, In. (mm) Exposed Surface	Unexposed Surface	Maximum Individual Temperature At 180 Min, Deg F
	1 cable (2% fill)	5.9 (926.8)	F77	0.271 (6.8)	0.229 (5.8)	218.6
	1 cable (2% fill)	5.9 (926.8)	F71-A	0.229 (5.8)	0.229 (5.8)	221.5
	16 cables (31.2% fill)	5.1 (801.1)	F77	0.250 (6.4)	0.229 (5.8)	261.1
	16 cables (31.2% fill)	5.1 (801.1)	F71-A	0.250 (6.4)	0.250 (6.4)	284.4
	1 cable (2% fill)	3.9 (612.6)	F77	0.229 (5.8)	0.229 (5.8)	205.9
	1 cable (2% fill)	3.9 (612.6)	F71-A	0.250 (6.4)	0.250 (6.4)	211.4
	16 cables (31.2% fill)	3.5 (549.8)	F77	0.271 (6.8)	0.271 (6.8)	238.4
	16 cables (31.2% fill)	3.5 (549.8)	F71-A	0.250 (6.4)	0.271 (6.8)	264.6
	None (verm. conc. fill)	N.A.	N.A.	N.A.	N.A.	182.3
	Pipe	9.7 (1519.0)	F77	0.250 (6.4)	0.250 (6.4)	591.1
	None (cer. fiber fill)	7.5 (1182.8)	F77	0.250 (6.4)	0.250 (6.4)	249.8
	None (conc. fill)	N.A.	N.A.	N.A.	N.A.	249.3
	None (verm. conc. fill)	N.A.	N.A.	N.A.	N.A.	94.7
	55 cables/tray (29.8% fill/tray)	5.9 (926.8)	F77	0.307 (7.8)	0.302 (7.7)	294.3
*	113 cables (7.1% fill)	5.9 (926.8)	F77	0.263 (6.7)	0.256 (6.5)	351.4
*	113 cables (7.1% fill)	3.9 (612.6)	F77	0.244 (6.2)	0.228 (7.3)	337.5
te slab	N.A.	N.A.	N.A.	N.A.	N.A.	222.5

* - Penetration Nos. 13, 15, and 16 were intended to simulate the termination of cable trays above and below the floor with continuation of cables through the floor penetration. Based on the submitter's proposed use of cable trays with a loading depth of 3 in. (76.2 mm), the following cable tray percent fills were simulated.

Penetration No.	Simulated Cable Tray Configuration	Simulated Percent Fill
15	Two 24 in. (610 mm) wide trays	30.6/tray
16	Two 24 in. (610 mm) wide trays	30.6/tray

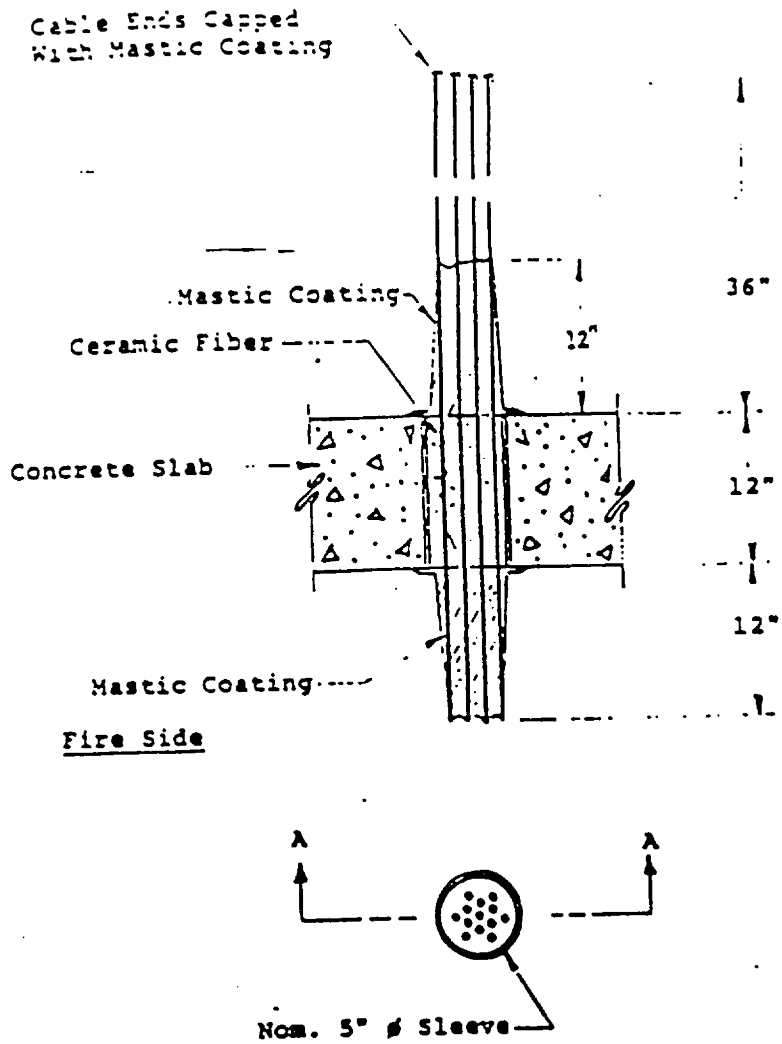
[redacted] Page 62 Issued: 11-17-80

TABLE C
SUMMARY - WALL ASSEMBLY NO. 1
(NC601-2 Tested April 10, 1980)

...ration ...o.	Penetrating Item	Ceramic Fiber Density pcf (n/m^3)	Flamemastic Coating Type	Average Dry Coating Thickness, In. (mm) Exposed Surface	Unexposed Surface	Maximum Individual Temperature At 180 Min, Deg F
	59 cables (39.2% fill)	9.5 (1492.2)	F77	0.234 (5.9)	0.219 (5.6)	220.1
	59 cables (39.2% fill)	9.5 (1492.2)	F77	0.219 (5.6)	0.219 (5.6)	218.7
	None (conc. fill)	N.A.	N.A.	N.A.	N.A.	308.8
	99/cables/tray (40.3% fill/tray)	7.3 (1146.7)	F77	0.234 (5.9)	0.211 (5.4)	313.7
	59 cables/slot (32% fill/slot)	7.8 (1225.2)	F77	0.244 (6.2)	0.263 (6.7)	207.0
	16 cables (31.2% fill)	6.8 (1068.1)	F77	0.229 (5.8)	0.250 (6.4)	193.2
	Pipe	N.A.	N.A.	N.A.	N.A.	825.2
...crete ...ert	N.A.	N.A.	N.A.	N.A.	N.A.	153.1
...crete ...ck	N.A.	N.A.	N.A.	N.A.	N.A.	192.0

TABLE D
SUMMARY - WALL ASSEMBLY NO. 2
(NC601-4 Tested September 16, 1980)

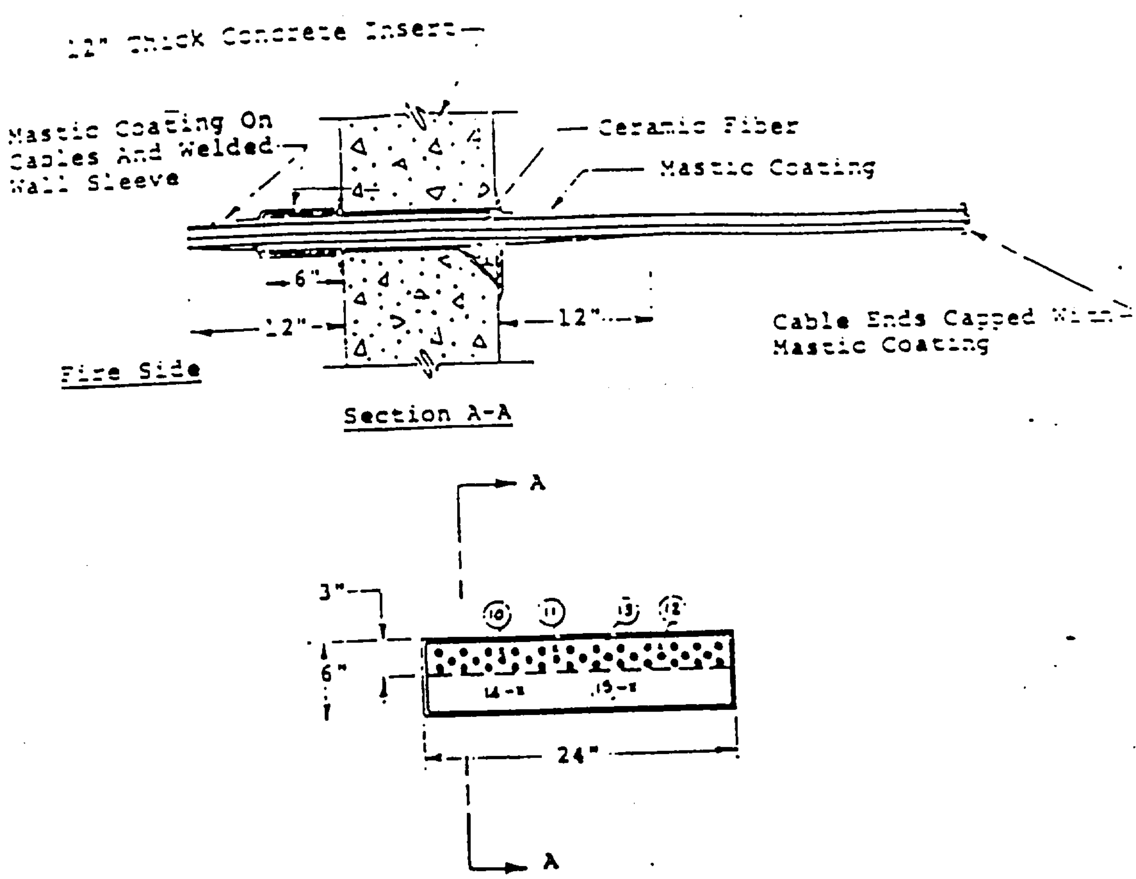
etration No.	Penetrating Item	Ceramic Fiber Density pcf (n/m^3)	Flamemastic Coating Type	Average Dry Coating Thickness, In. (mm) Exposed Surface	Average Dry Coating Thickness, In. (mm) Unexposed Surface	Maximum Individual Temperature At 180 Min, Deg F
1	50 cables (39.1% fill)	5.2 (816.8)	F71-A	0.250 (6.4)	0.250 (6.4)	255.8
2	50 cables (39.1% fill)	5.2 (816.8)		0.250 (6.4)	0.250 (6.4)	265.2
3	3 pipes	7.9 (1240.9)	F77	0.250 (6.4)	0.250 (6.4)	874.0
4	57/cables/tray (36.4% fill/tray)	4.0 (628.3)	F77	0.242 (6.1)	0.234 (5.9)	416.1
5	56 cables/slot (35.7% fill/slot)	4.0 (628.3)	F77	0.250 (6.4)	0.245 (6.2)	347.7
6	17 cables (39.1% fill)	6.6 (1036.7)	F71-A	0.250 (6.4)	0.250 (6.4)	261.6
7	Pipe	N.A.	N.A.	N.A.	N.A.	763.2
oncrete insert	N.A.	N.A.	N.A.	N.A.	N.A.	157.0
oncrete block	N.A.	N.A.	N.A.	N.A.	N.A.	168.3



PENETRATION VOLUME - 240 in^3
CABLE DIAMETER - .705 in.
NUMBER OF CABLES - 16 (31.2% fill)
CERAMIC FIBER AMOUNT - .65 lb.
CERAMIC FIBER DENSITY - 6.8 pcf
MASTIC COATING TYPE - FLAMEMASTIC F77
[illegible] THKNS EXP SURF - .500 in (3 readings)

FLOOR TEST NO. 1
PENETRATION
NO. 1

[redacted] III.2.G-248

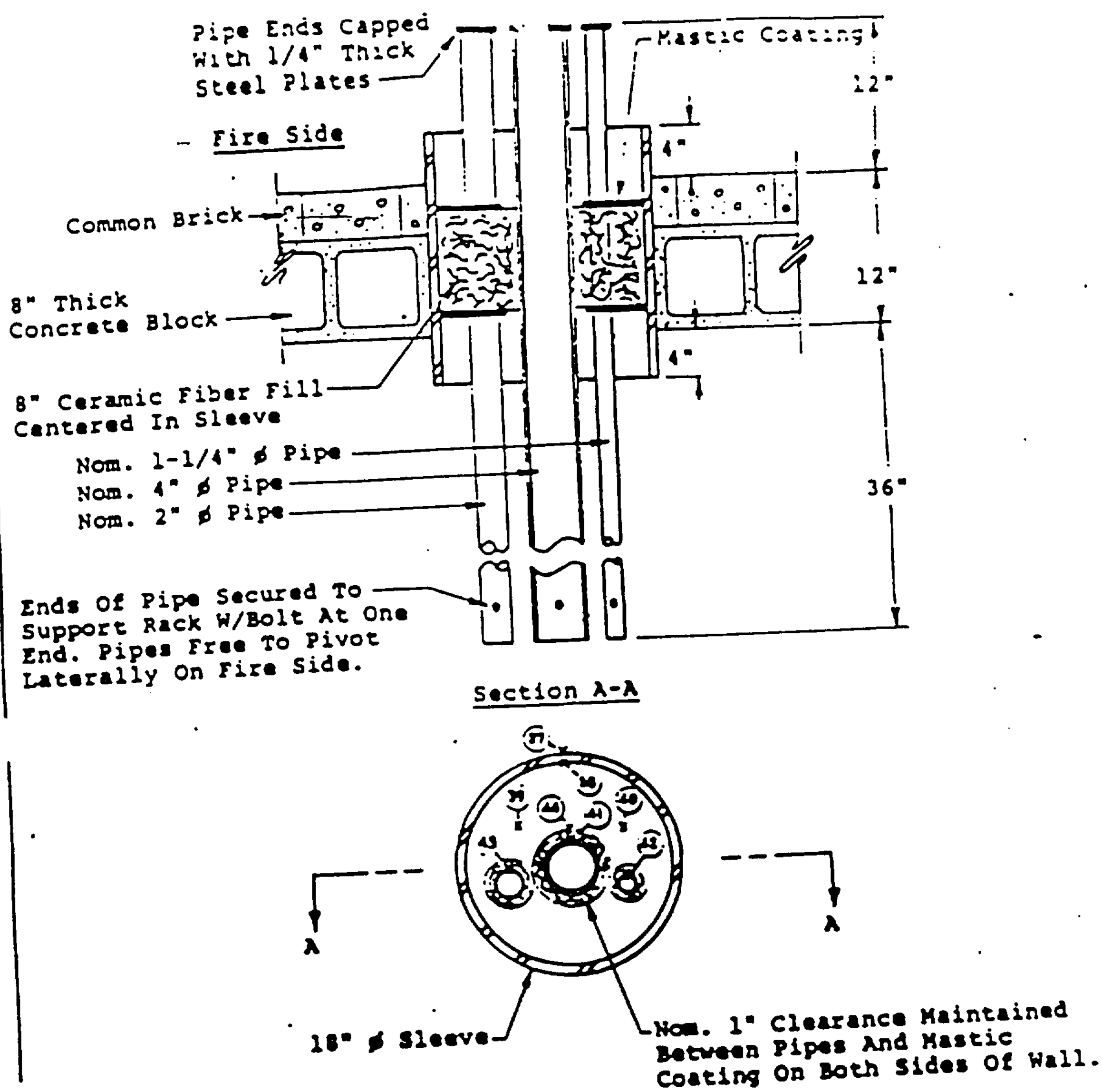


T.C.#10,11,12 - ON CABLE JACKET/MASTIC COATING INTERFACE
T.C.#13 - ON MASTIC COATING AT EDGE OF OPENING
T.C.#14,15 - ON MASTIC COATING BETWEEN CABLES AND EDGE OF OPENING

PENETRATION VOLUME - 1154 in³.
CABLE DIAMETER - .765 in.
NUMBER OF CABLES - 50 (32.1 % fill)
CERAMIC FIBER AMOUNT - 2.24 lb.
CERAMIC FIBER DENSITY - 5.2 pcf
MASTIC COATING TYPE - FLAMEMASTIC F77

WALL TEST NO. 2
PENETRATION NO. 2

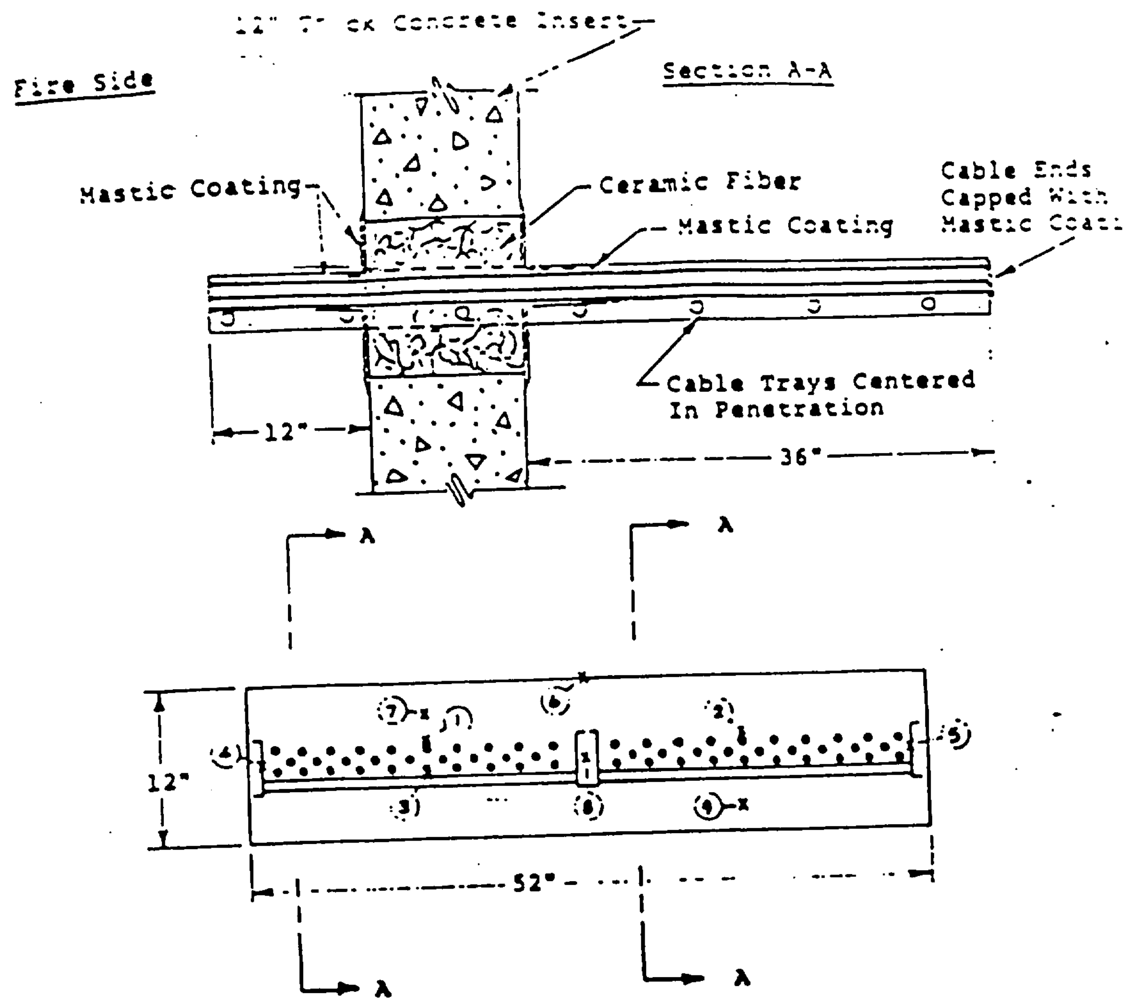
[redacted]



T.C.#37 - ON SLEEVE/MASONRY INTERFACE
T.C.#38 - ON SLEEVE/MASTIC COATING INTERFACE
T.C.#39,40 - ON MASTIC COATING MIDWAY BETWEEN 4"ø PIPE AND SLEEVE WALL
T.C.#41,42,43 - ON PIPE/CERAMIC FIBER INTERFACE
T.C.#44 - ON MASTIC COATING/CERAMIC FIBER INTERFACE

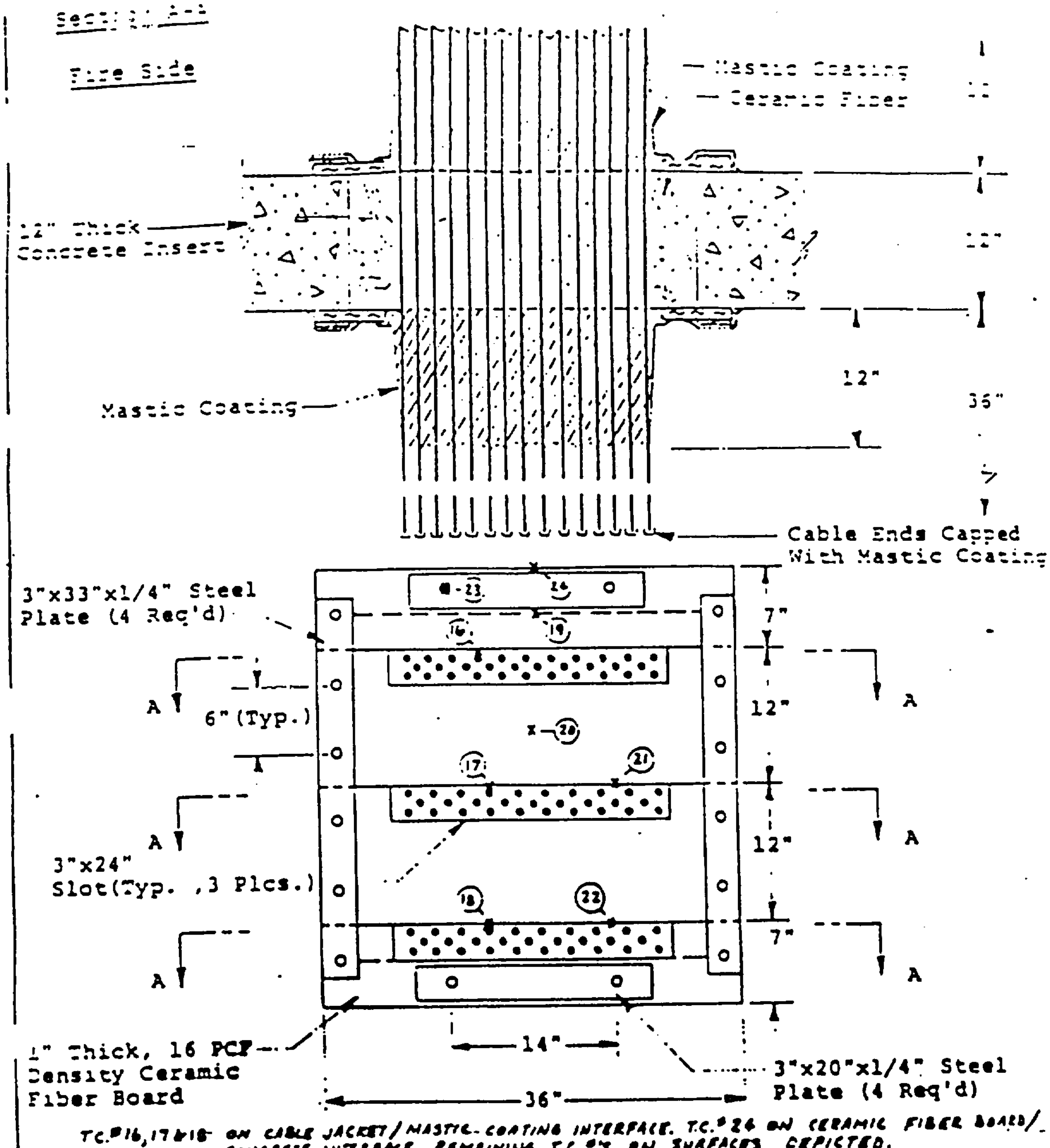
PENETRATION VOLUME - 1870 in^3 (Center 8" section)
CABLE DIAMETER - N.A. in
NUMBER OF CABLES - 0 (0 % fill)
CERAMIC FIBER AMOUNT - 7.80 lb
CERAMIC FIBER DENSITY - 7.9 pcf
... COATING TYPE - FLAMEMASTIC F77

WALL TEST NO.
PENETRATION
NO. 3



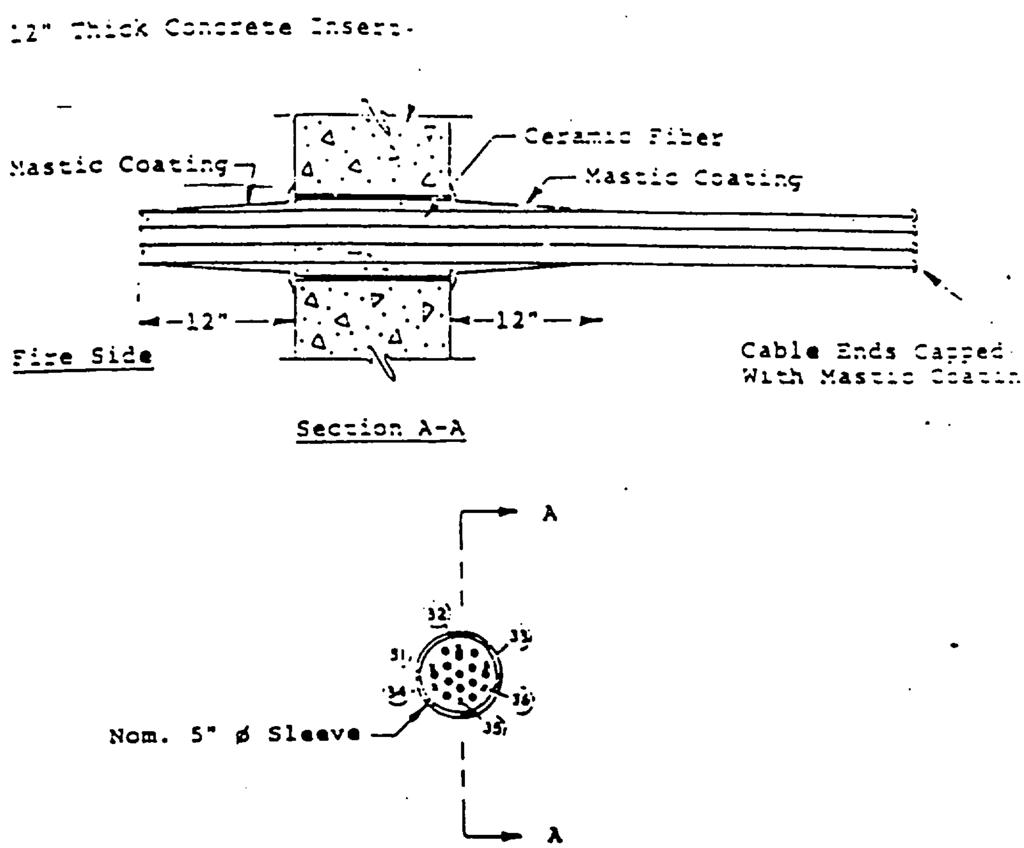
T.C.# 1,2,3 - ON CABLE JACKET/MASTIC COATING INTERFACE
T.C.# 4,5 - ON CABLE TRAY/MASTIC COATING INTERFACE
T.C.# 6 - ON MASTIC COATING AT EDGE OF OPENING
T.C.# 7,9 - ON MASTIC COATING BETWEEN CABLES AND EDGE OF OPENING
T.C.# 8 - ON MASTIC COATING BETWEEN CABLE TRAYS

PENETRATION VOLUME - 7488 in^3 CABLE DIAMETER - .765 in NUMBER OF CABLES - 114 (36.4% fill/tray) CERAMIC FIBER AMOUNT - 15.86 lb CERAMIC FIBER DENSITY - 4.0 pcf MASTIC COATING TYPE - FLAMEMASTIC F77 in (8 readings)	WALL TEST NO. 2 PENETRATION NO. 4 [redacted]



PENETRATION VOLUME - 10,800 in^3
CABLE DIAMETER - .765 in.
NUMBER OF CABLES - 168 (35.7% fill/slot)
CERAMIC FIBER AMOUNT - 22.83 lb.
CERAMIC FIBER DENSITY - 4.0 pcf
MASTIC COATING TYPE - FLAMEMASTIC F77

WALL TEST NO. 2
PENETRATION NO. 5

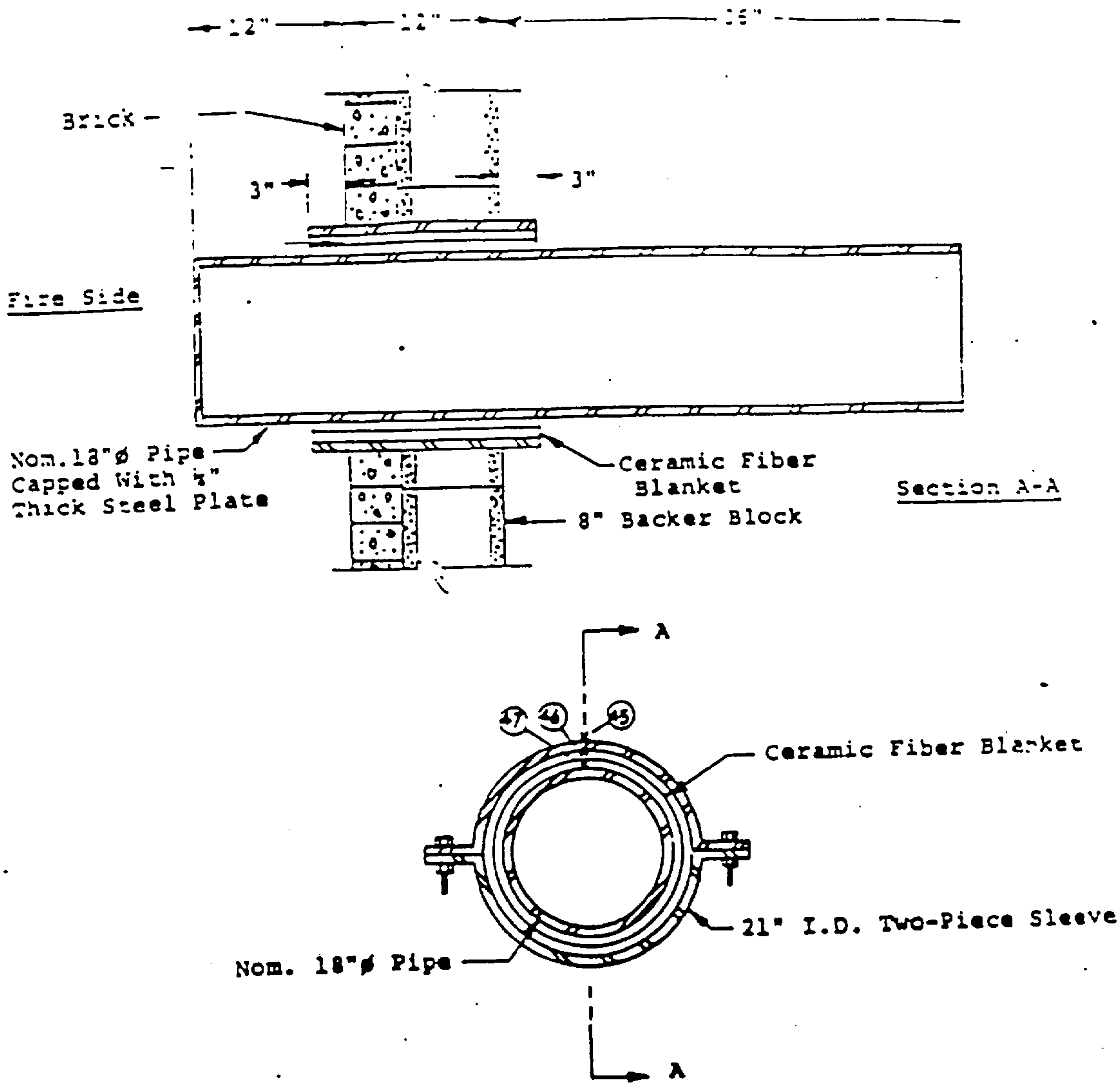


T.C.# 31,32,33 - ON CABLE JACKET/MASTIC COATING INTERFACE

T.C.# 34,35,36 - ON MASTIC COATING MIDWAY BETWEEN CABLES AND OPENING

PENETRATION VOLUME - 240 in^3 CABLE DIAMETER - .765 in. NUMBER OF CABLES - 17 (39.1 % fill) CERAMIC FIBER AMOUNT - .56 lb. CERAMIC FIBER DENSITY - 6.6 pcf MASTIC COATING TYPE - FLAMEMASTIC F71-A	WALL TEST NO. 2 PENETRATION NO. 6

[redacted]

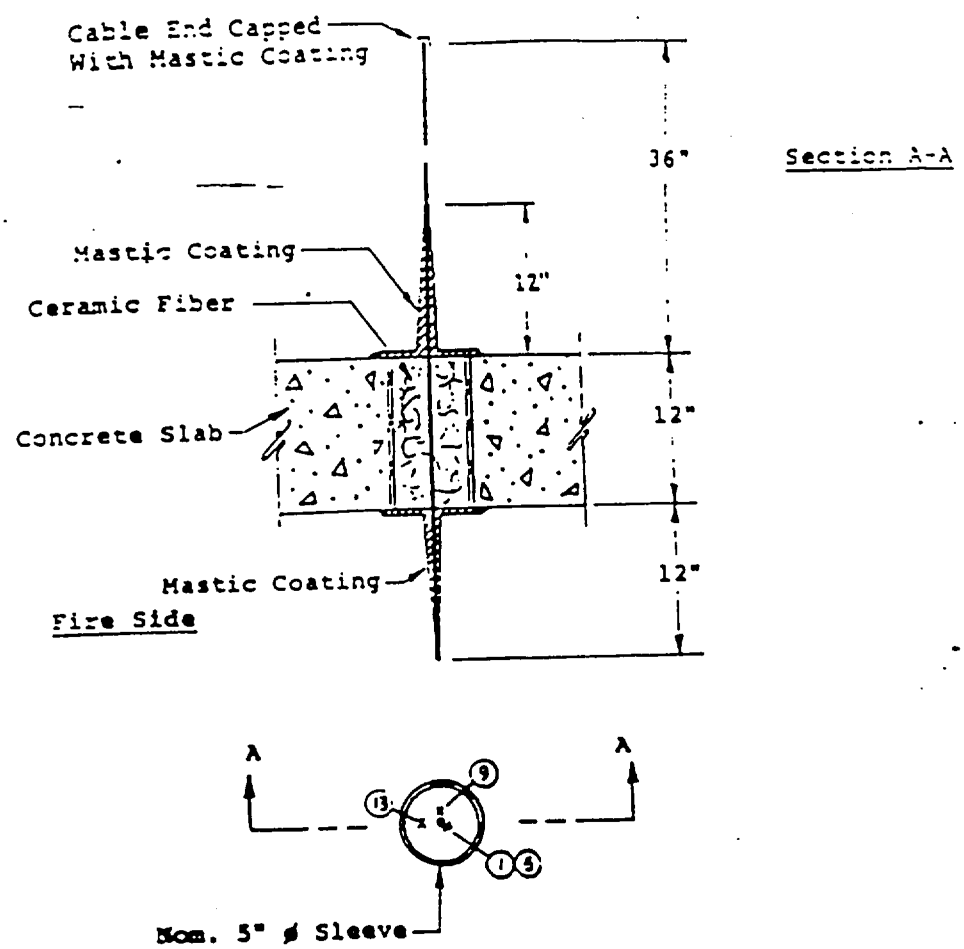


T.C.#45 - ON SLEEVE/CONCRETE BLOCK INTERFACE

T.C.#46 - ON SLEEVE/CERAMIC FIBER BLANKET INTERFACE

T.C.#47 - ON PIPE/CERAMIC FIBER BLANKET INTERFACE

~~PENETRATION VOLUME - in.^{3}~~ ~~CABLE DIAMETER - in.~~ ~~NUMBER OF CABLES - (% fill)~~ ~~CERAMIC FIBER AMOUNT - lb.~~ ~~CERAMIC FIBER DENSITY - pcf~~ MASTIC COATING TYPE - FLAMEMASTIC MIC DRY COATING THKNS. EXP. SURF. - in.(readings)	WALL TEST NO. 2 PENETRATION NO. 7



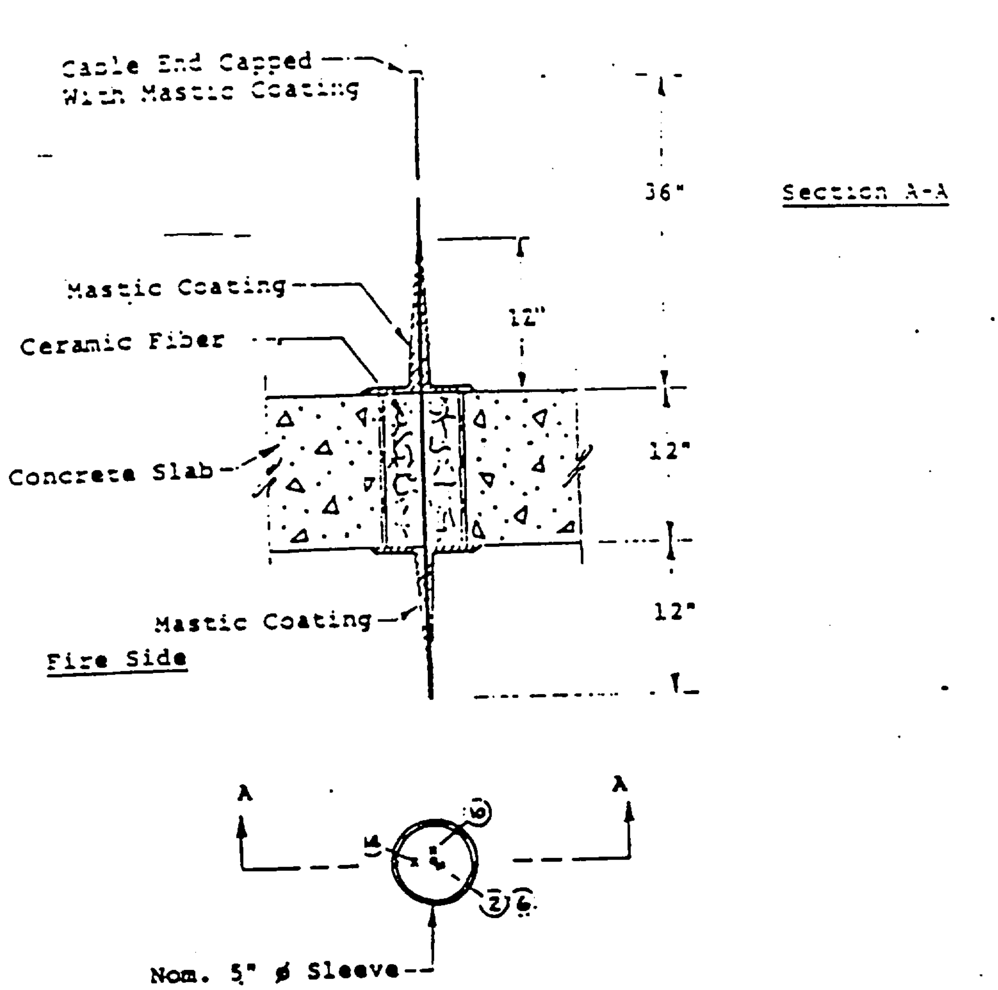
T.C.#1 - ON CABLE JACKET/MASTIC COATING INTERFACE

T.C.#5 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"

T.C.#9 - ON MASTIC COATING ½" FROM BASE OF MASTIC COATING "CONE"

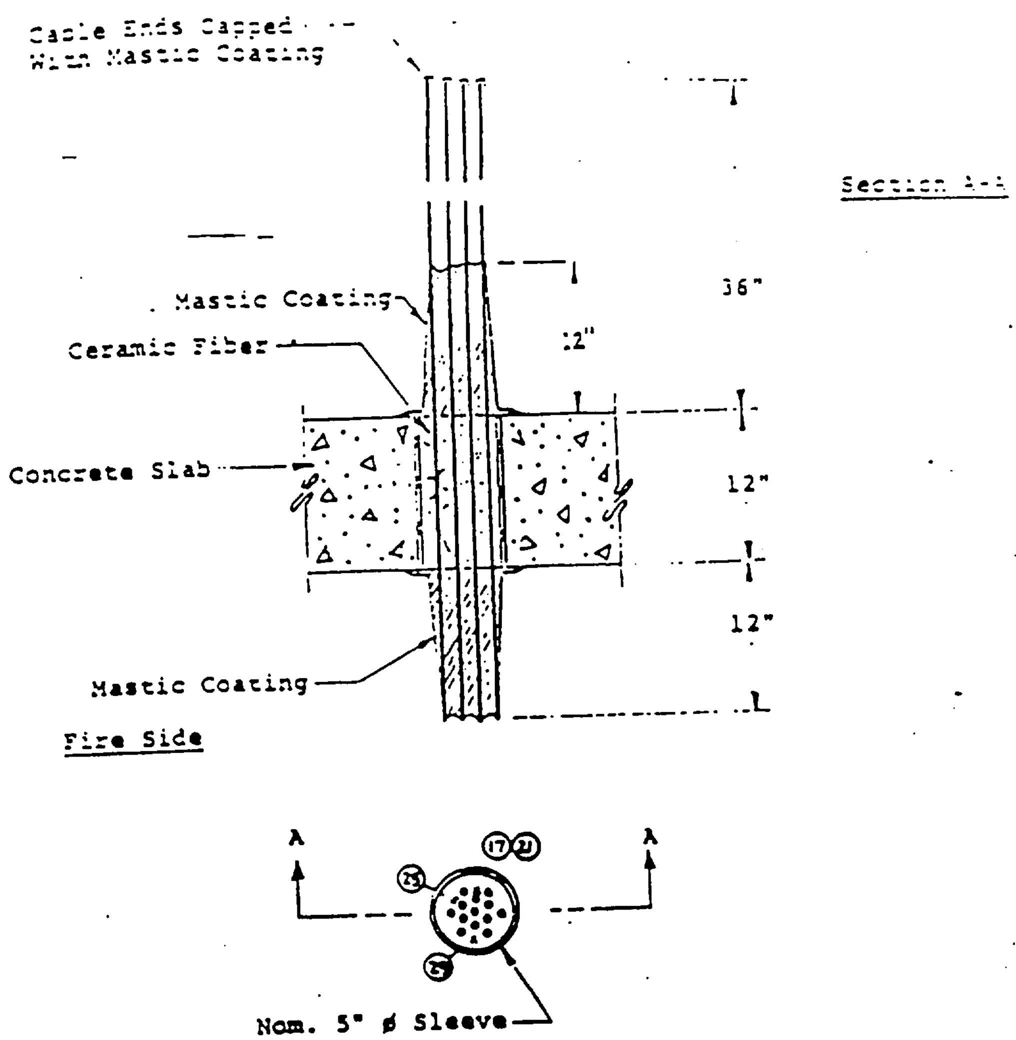
T.C.#13 - ON MASTIC COATING IN FIELD OF FIRE STOP

PENETRATION VOLUME - 240 in^3 CABLE DIAMETER - .705 in NUMBER OF CABLES - 1 (2 % fill) CERAMIC FIBER AMOUNT - .80 lb CERAMIC FIBER DENSITY - 5.9 pcf MASTIC COATING TYPE - FLAMEMASTIC F77	FLOOR TEST NO. 2 PENETRATION NO. 1



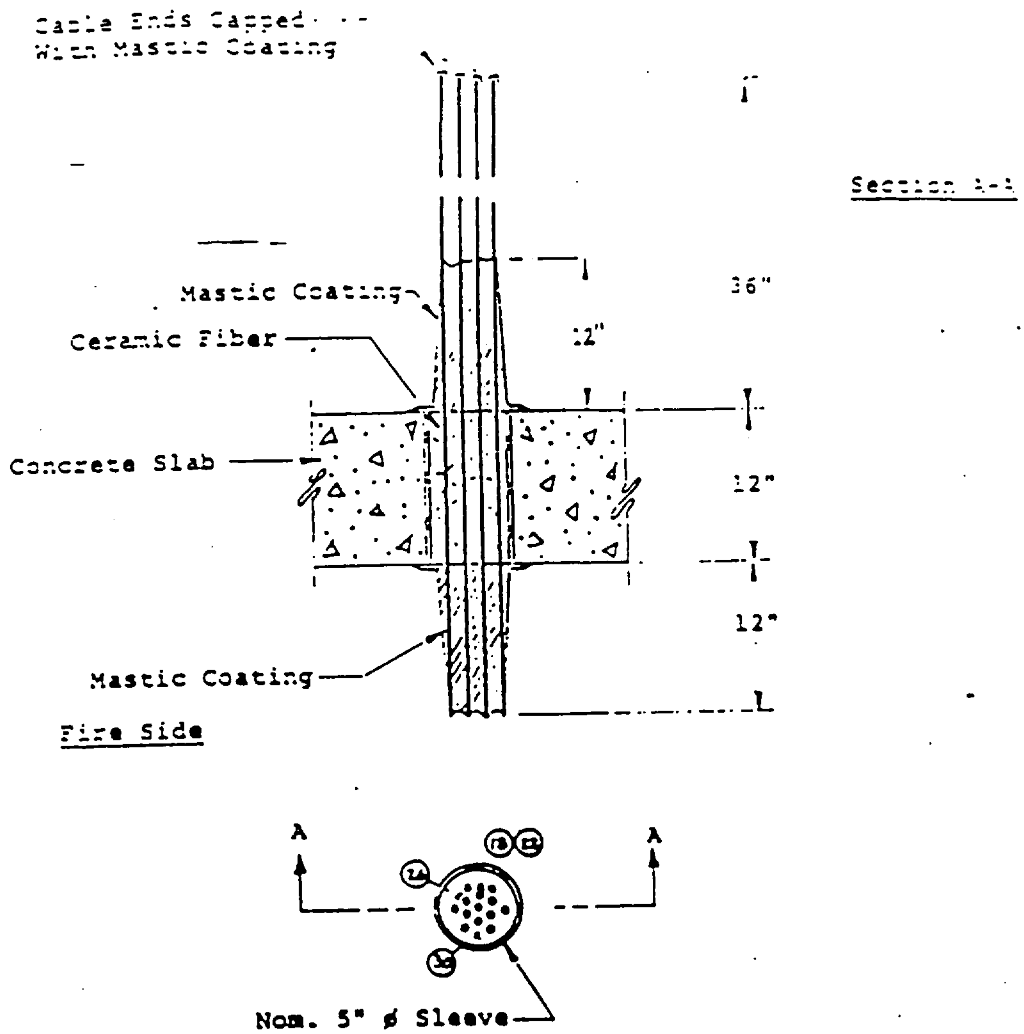
T.C.#2 - ON CABLE JACKET/MASTIC COATING INTERFACE
T.C.#6 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"
T.C.#10 - ON MASTIC COATING ½" FROM BASE OF MASTIC COATING "CONE"
T.C.#14 - ON MASTIC COATING IN FIELD OF FIRE STOP

PENETRATION VOLUME - 240 in^3 CABLE DIAMETER - .705 in. NUMBER OF CABLES - 1 (2 % fill) CERAMIC FIBER AMOUNT - .80 lb. CERAMIC FIBER DENSITY - 5.9 pcf MASTIC COATING TYPE - FLAMEMASTIC F71-A	FLOOR TEST NO. PENETRATION NO. 2



T.C.#17 - ON CABLE JACKET/MASTIC COATING INTERFACE
T.C.#21 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"
T.C.#25 - ON MASTIC COATING ½ IN. FROM BASE OF MASTIC COATING "CONE"
T.C.#29 - ON MASTIC COATING IN FIELD OF FIRE STOP.

PENETRATION VOLUME - 240 in^3 CABLE DIAMETER - .705 in. NUMBER OF CABLES - 16 (31.2% fill) CERAMIC FIBER AMOUNT - .49 lb. CERAMIC FIBER DENSITY - 5.1 pcf MASTIC COATING TYPE - FLAMEMASTIC F77	FLOOR TEST NO. PENETRATION NO. 3



T.C.#18 - ON CABLE JACKET/MASTIC COATING INTERFACE

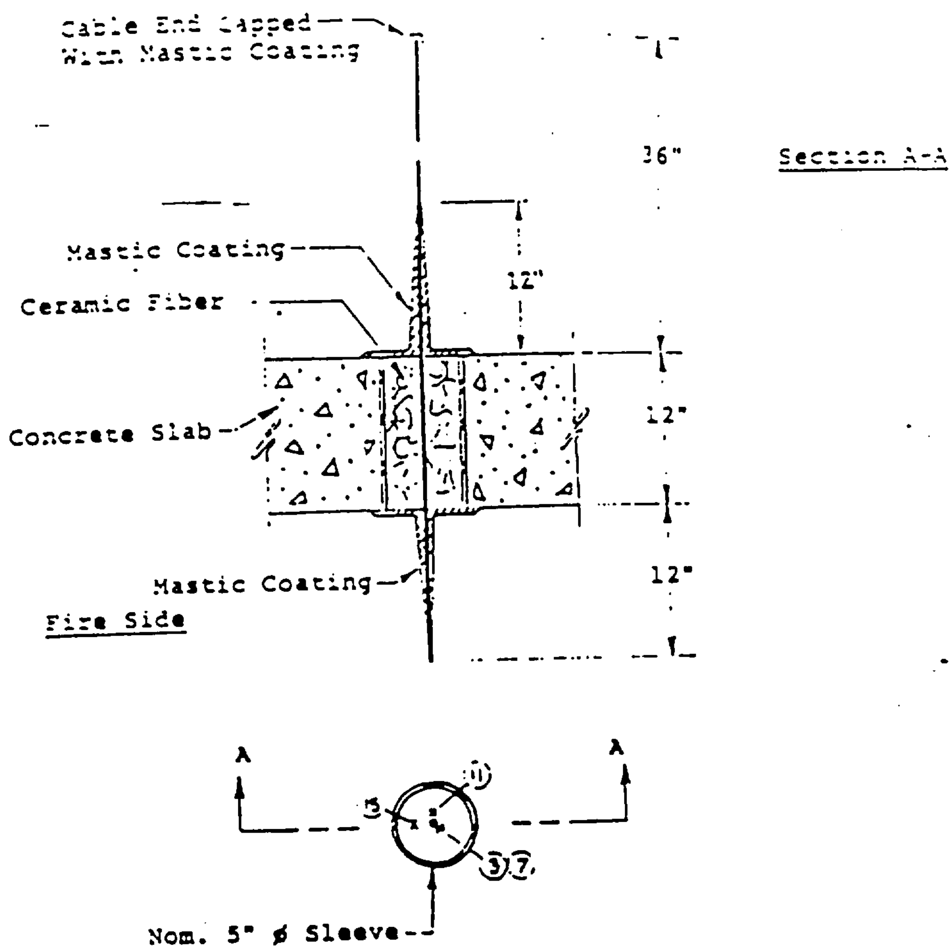
T.C.#22 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"

T.C.#26 - ON MASTIC COATING ½ IN. FROM BASE OF MASTIC COATING "CONE"

T.C.#30 - ON MASTIC COATING IN FIELD OF FIRE STOP

PENETRATION VOLUME - 240 in^3 CABLE DIAMETER - .705 in. NUMBER OF CABLES - 16 (31.2% fill) CERAMIC FIBER AMOUNT - .49 lb. CERAMIC FIBER DENSITY - 5.1 pcf MASTIC COATING TYPE - FLAMEMASTIC F71-A	FLOOR TEST NO. 2 PENETRATION NO. 4

[redacted]II.2.G-258



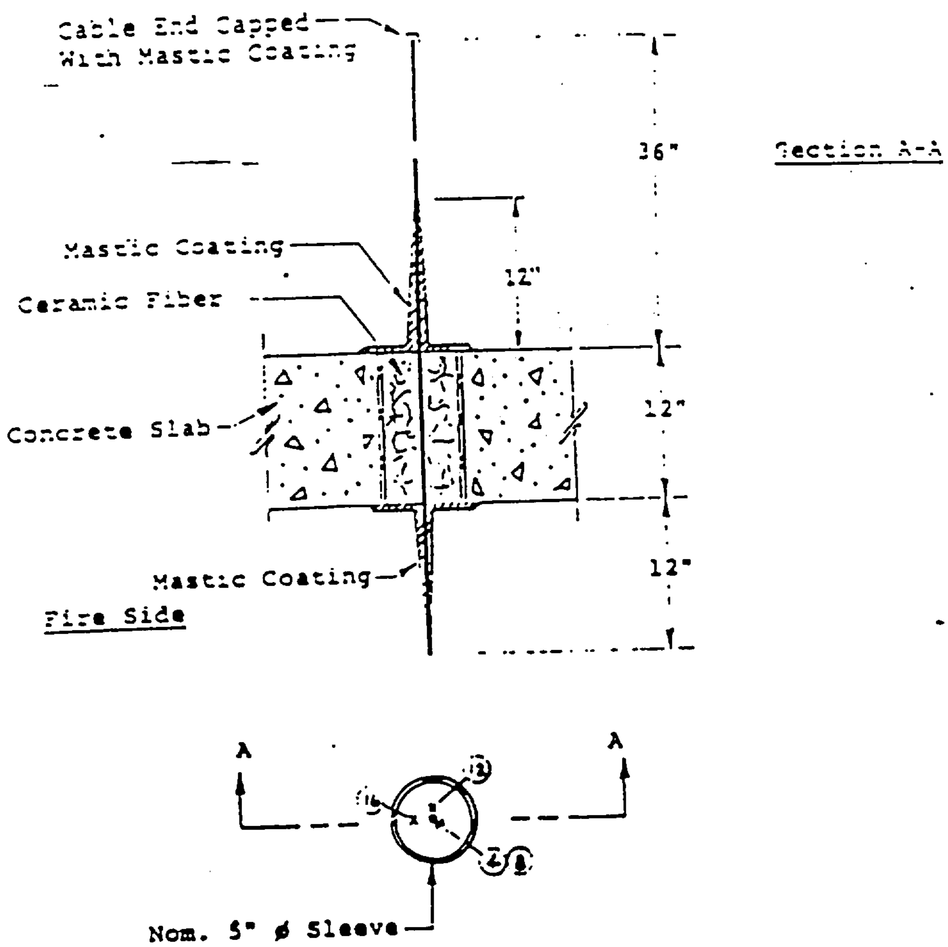
T.C.# 3 - ON CABLE JACKET/MASTIC COATING INTERFACE

T.C.# 7 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"

T.C.# 11 - ON MASTIC COATING ½" FROM BASE OF MASTIC COATING "CONE"

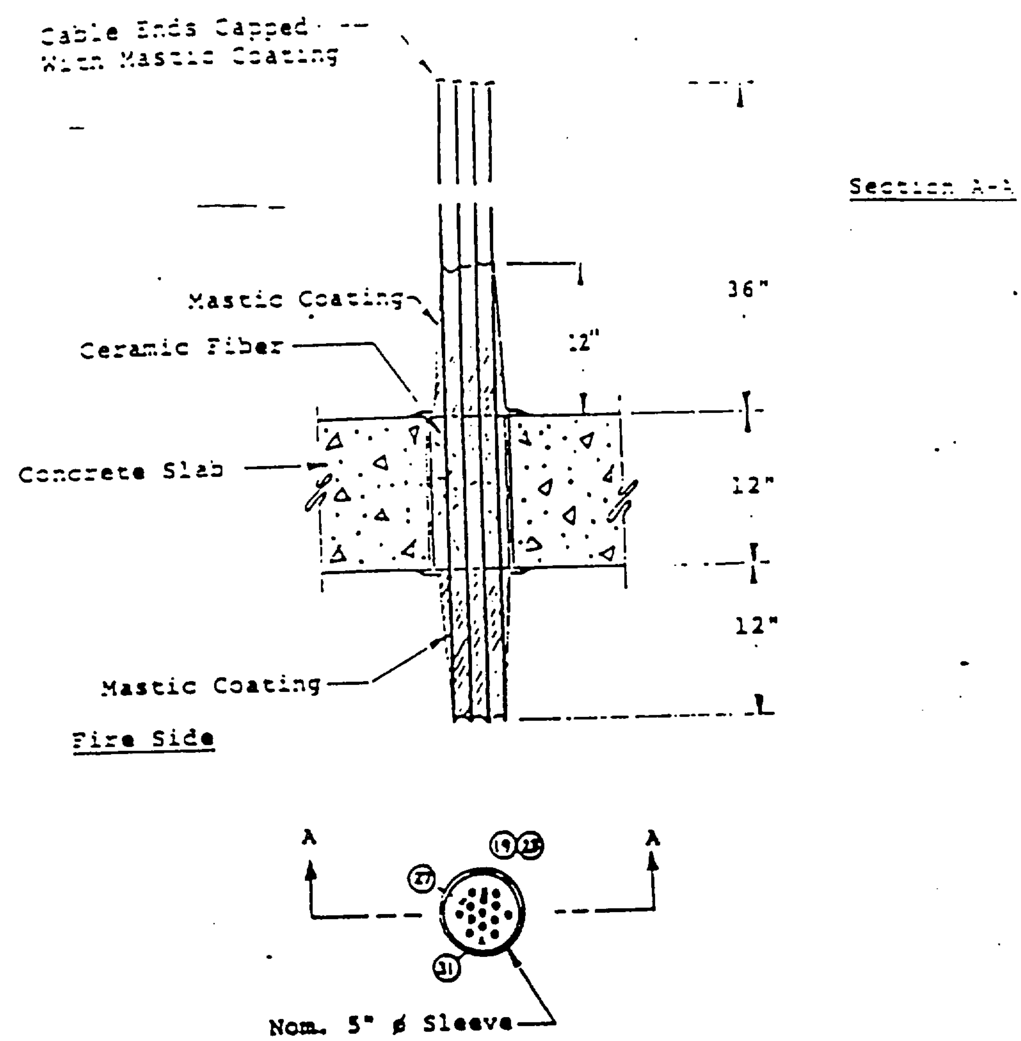
T.C.# 15 - ON MASTIC COATING IN FIELD OF FIRE STOP

PENETRATION VOLUME - 240 in^3 CABLE DIAMETER ≈ .705 in. NUMBER OF CABLES - 1 (2 % fill) CERAMIC FIBER AMOUNT - .53 lb. CERAMIC FIBER DENSITY - 3.9 pcf MASTIC COATING TYPE - FLAMEMASTIC F77	FLOOR TEST NO. _ PENETRATION NO. 5



T.C.#4 - ON CABLE JACKET/MASTIC COATING INTERFACE
T.C.#8 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"
T.C.#12 - ON MASTIC COATING ½" FROM BASE OF MASTIC COATING "CONE"
T.C.#16 - ON MASTIC COATING IN FIELD OF FIRE STOP

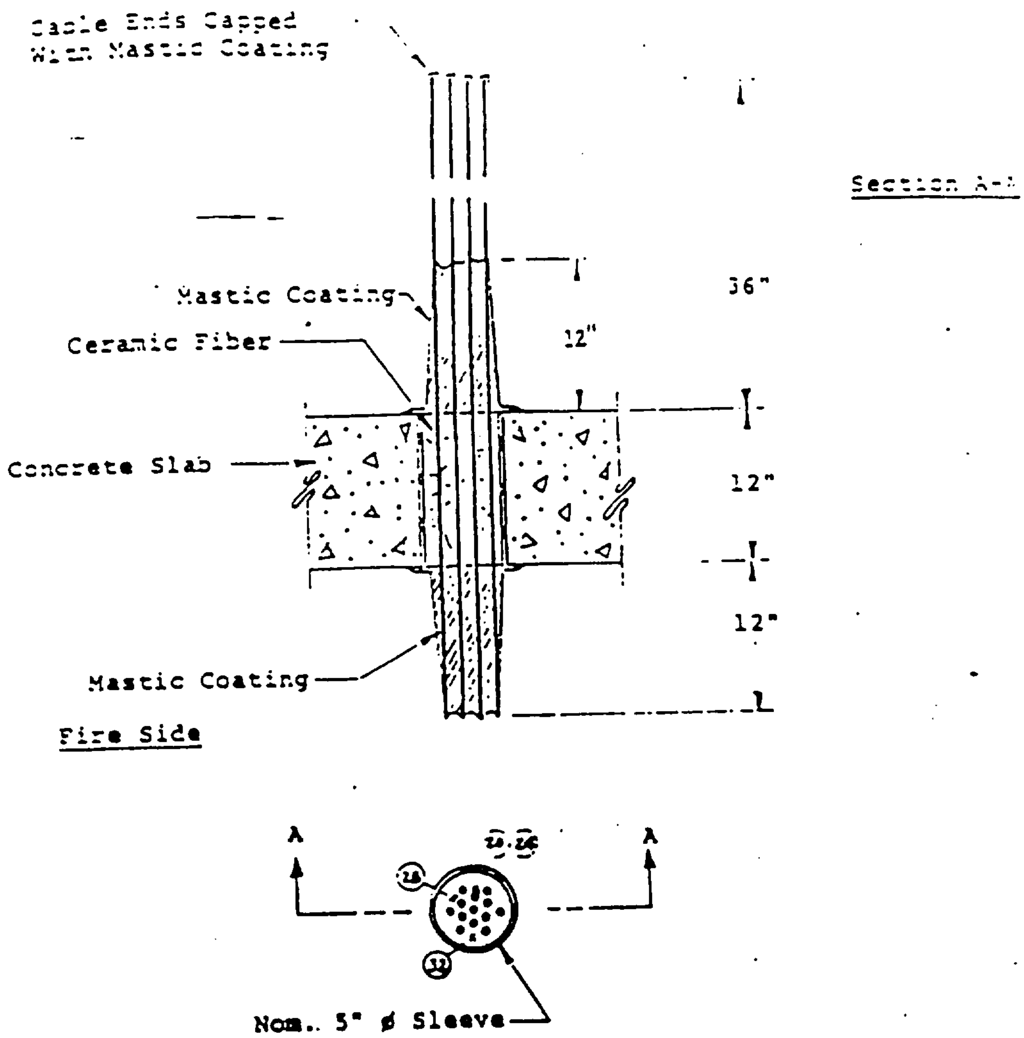
PENETRATION VOLUME - 240 in³ CABLE DIAMETER - .705 in. NUMBER OF CABLES - 1 (2 % fill) CERAMIC FIBER AMOUNT - .53 lb.	FLOOR TEST NO. 2 PENETRATION NO. 6



T.C.#19 - ON CABLE JACKET/MASTIC COATING INTERFACE
T.C.#23 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"
T.C.#27 - ON MASTIC COATING ½ IN. FROM BASE OF MASTIC COATING "CONE"
T.C.#31 - ON MASTIC COATING IN FIELD OF FIRE STOP

PENETRATION VOLUME - 240 in³
CABLE DIAMETER - .705 in.
NUMBER OF CABLES - 16 (31.2% fill)
CERAMIC FIBER AMOUNT - .33 lb.
CERAMIC FIBER DENSITY - 3.5 pcf

FLOOR TEST NO.
PENETRATION
NO. 7



T.C.#20 - ON CABLE JACKET/MASTIC COATING INTERFACE

T.C.#24 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"

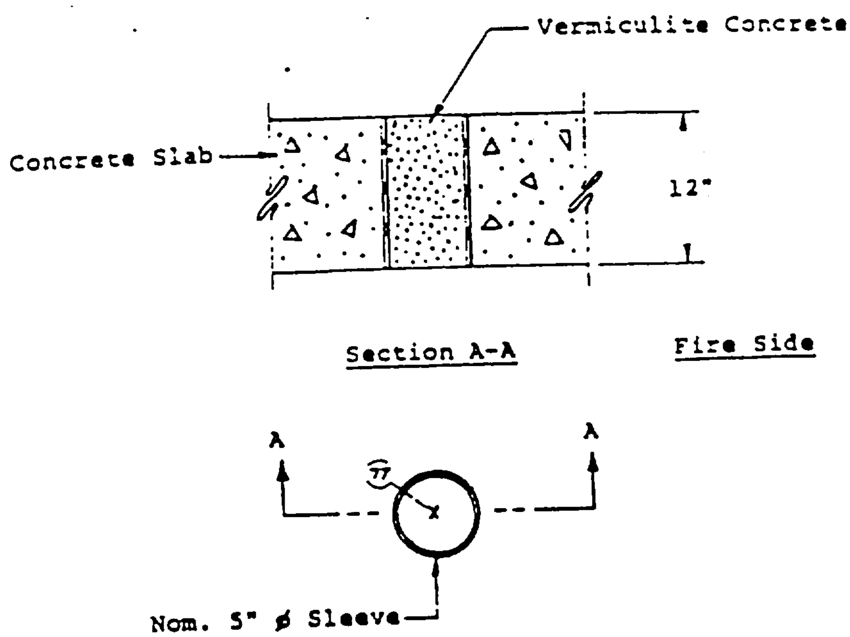
T.C.#28 - ON MASTIC COATING ½ IN. FROM BASE OF MASTIC COATING "CONE"

T.C.#32 - ON MASTIC COATING IN FIELD OF FIRE STOP

PENETRATION VOLUME - 240 in^3 CABLE DIAMETER - .705 in. NUMBER OF CABLES - 16 (31.2% fill) CERAMIC FIBER AMOUNT - .33 lb. CERAMIC FIBER DENSITY - 3.5 pcf	FLOOR TEST NO. 2 PENETRATION NO. 3

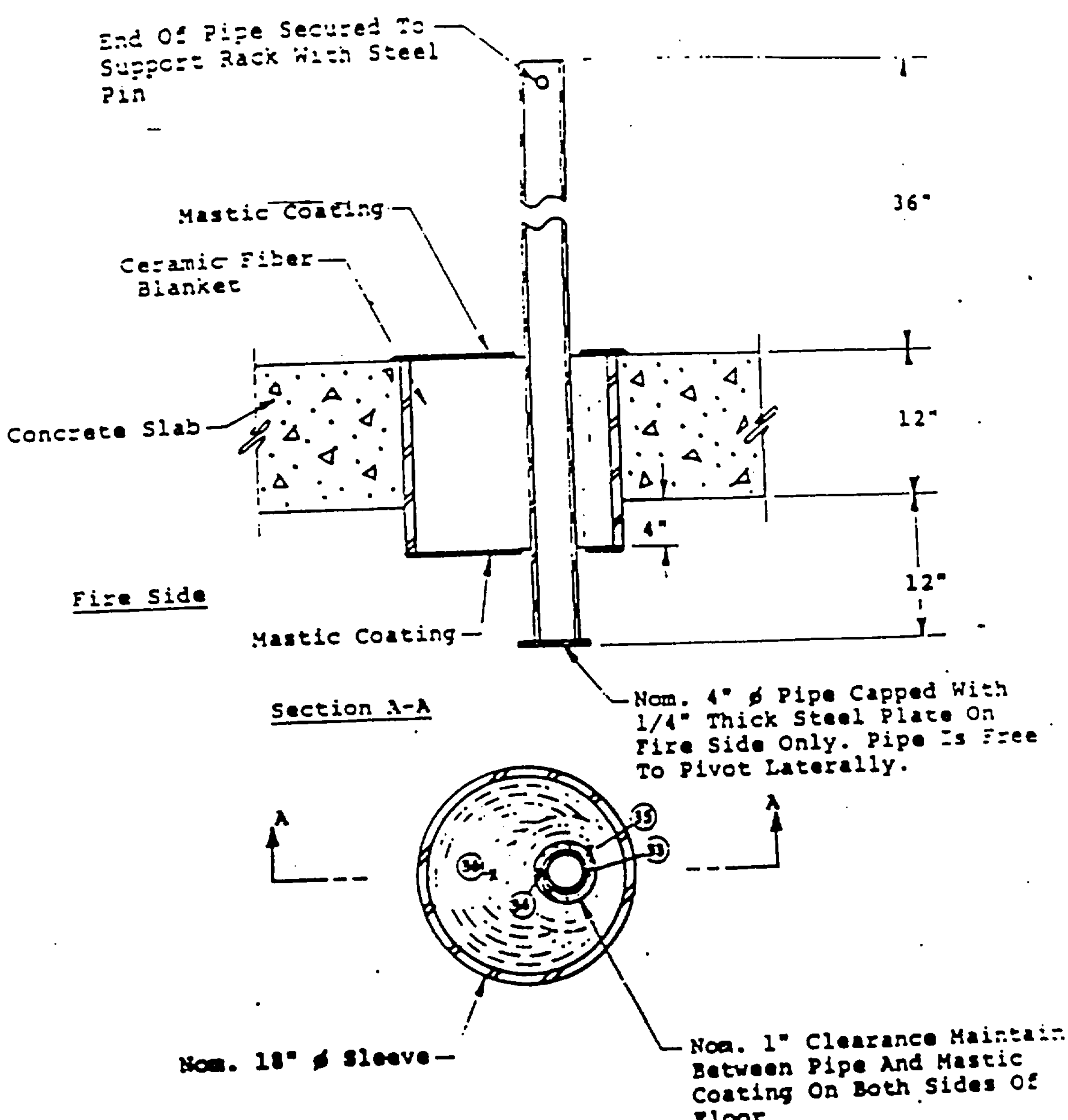
HI.2.G-262

[redacted]



PENETRATION VOLUME - in³ -
CABLE DIAMETER - in.
NUMBER OF CABLES - (% fill)
CERAMIC FIBER AMOUNT - lb
CERAMIC FIBER DENSITY - pcf

FLOOR TEST NO. 2
PENETRATION
NO. 9

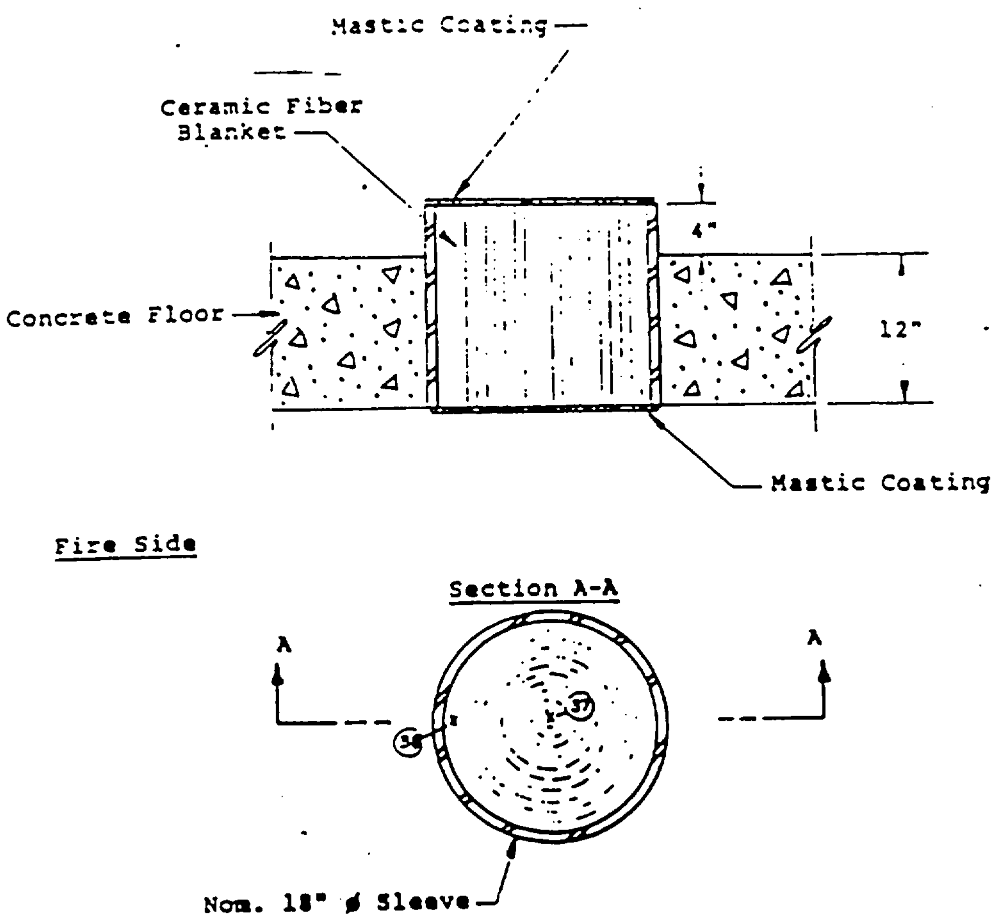


T.C.#33 - ON PIPE/CERAMIC FIBER BLANKET INTERFACE
T.C.#34 - ON CERAMIC FIBER BLANKET 1" FROM PIPE
T.C.#35 - ON CERAMIC FIBER BLANKET/MASTIC COATING INTERFACE
T.C.#36 - ON MASTIC COATING IN FIELD OF FIRE STOP

PENETRATION VOLUME - 3739 in³
CABLE DIAMETER - N.A. in.
NUMBER OF CABLES - 0 (0 % fill)
CERAMIC FIBER AMOUNT - 19.5 lb.
CERAMIC FIBER DENSITY - 9.67 pcf
MASTIC COATING TYPE - FLAMEMASTIC 77

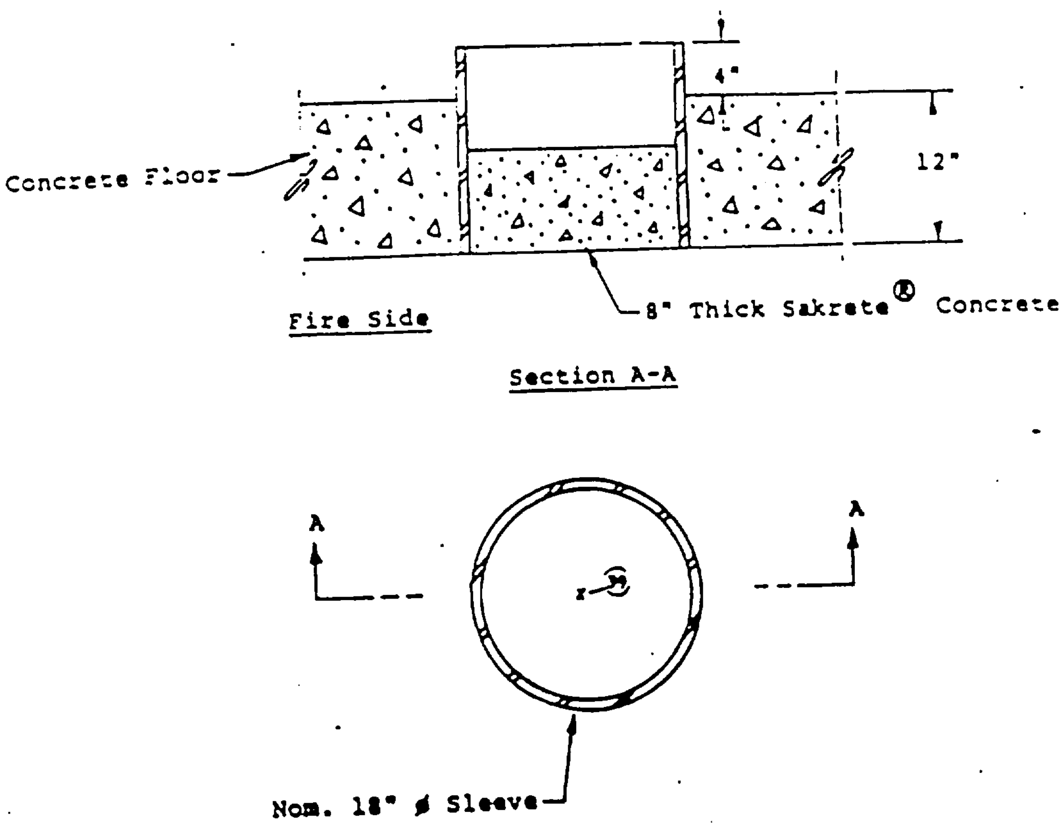
FLOOR TEST NO. 2
PENETRATION
NO. 10

[redacted]

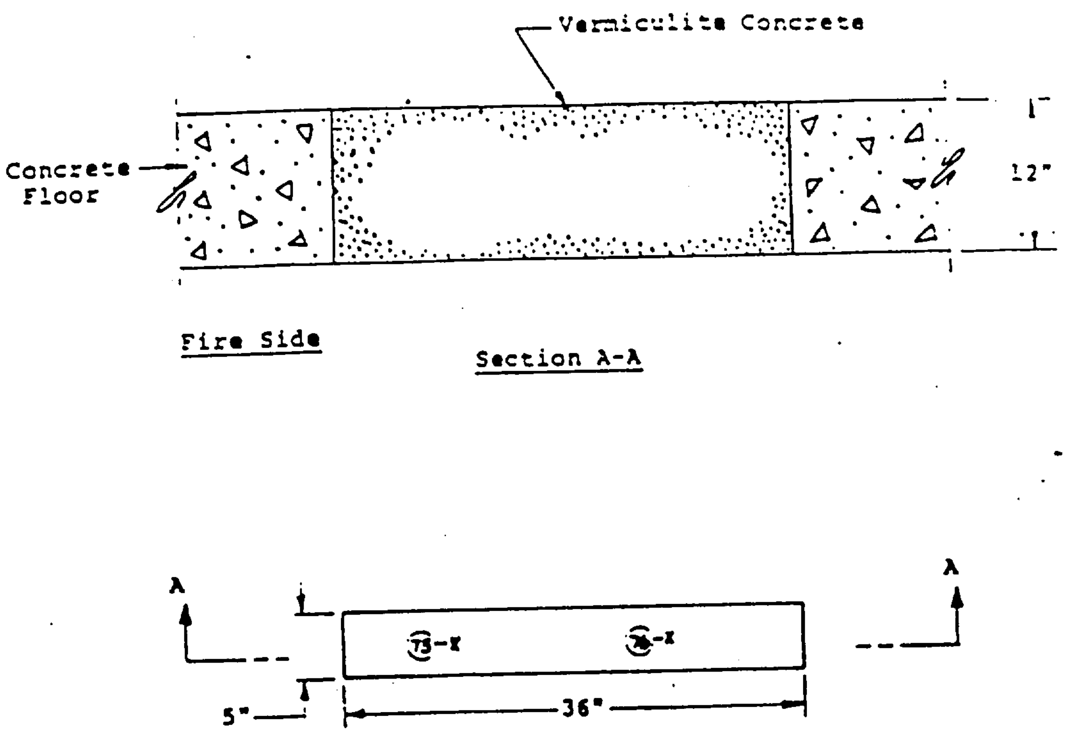


PENETRATION VOLUME - 3739 in³
CABLE DIAMETER - N.A. in.
NUMBER OF CABLES - 0 (0 % fill)
CERAMIC FIBER AMOUNT - 16.3 lb.
CERAMIC FIBER DENSITY - 7.53 pcf

FLOOR TEST NO. 2
PENETRATION
NO. 11

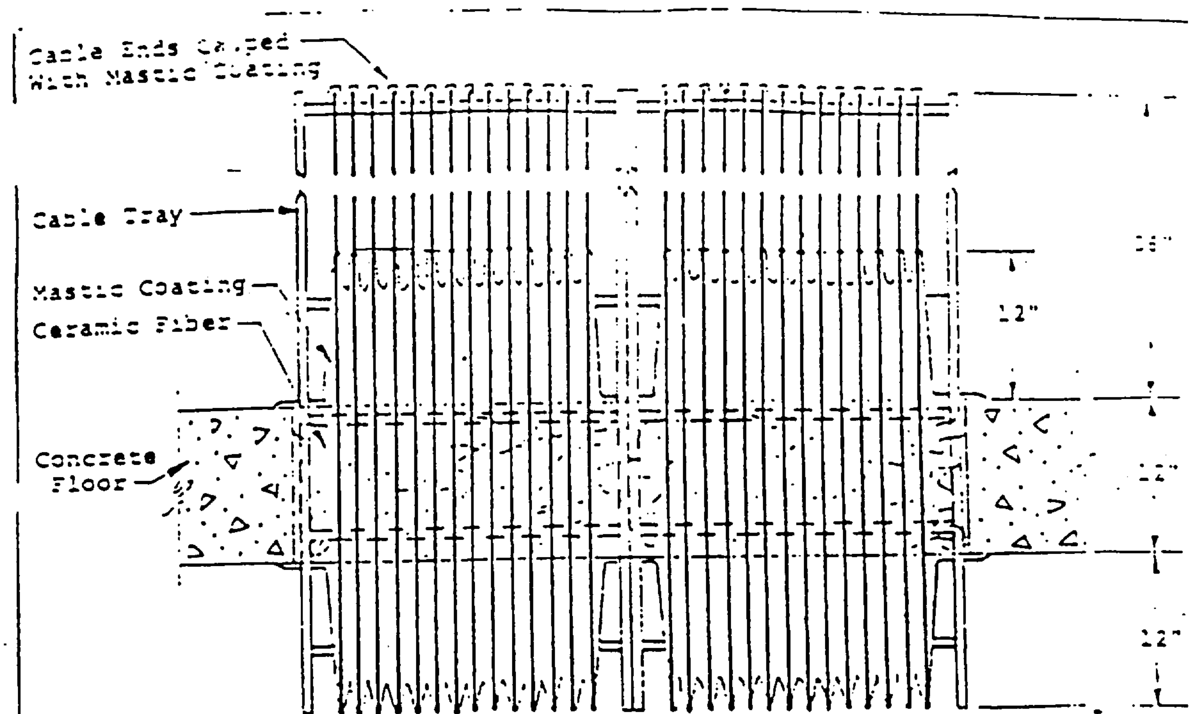


PENETRATION VOLUME - in^3 CABLE DIAMETER - in. NUMBER OF CABLES - (%fill) CERAMIC FIBER AMOUNT - lb CERAMIC FIBER DENSITY - pcf		FLOOR TEST NO. PENETRATION NO. 12 [redacted]

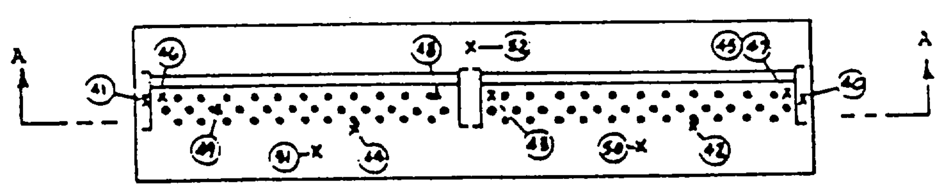


PENETRATION VOLUME - in³
CABLE DIAMETER - in.
NUMBER OF CABLES - (% fill)
CERAMIC FIBER AMOUNT - lb

FLOOR TEST NO. 2
PENETRATION NO. 13

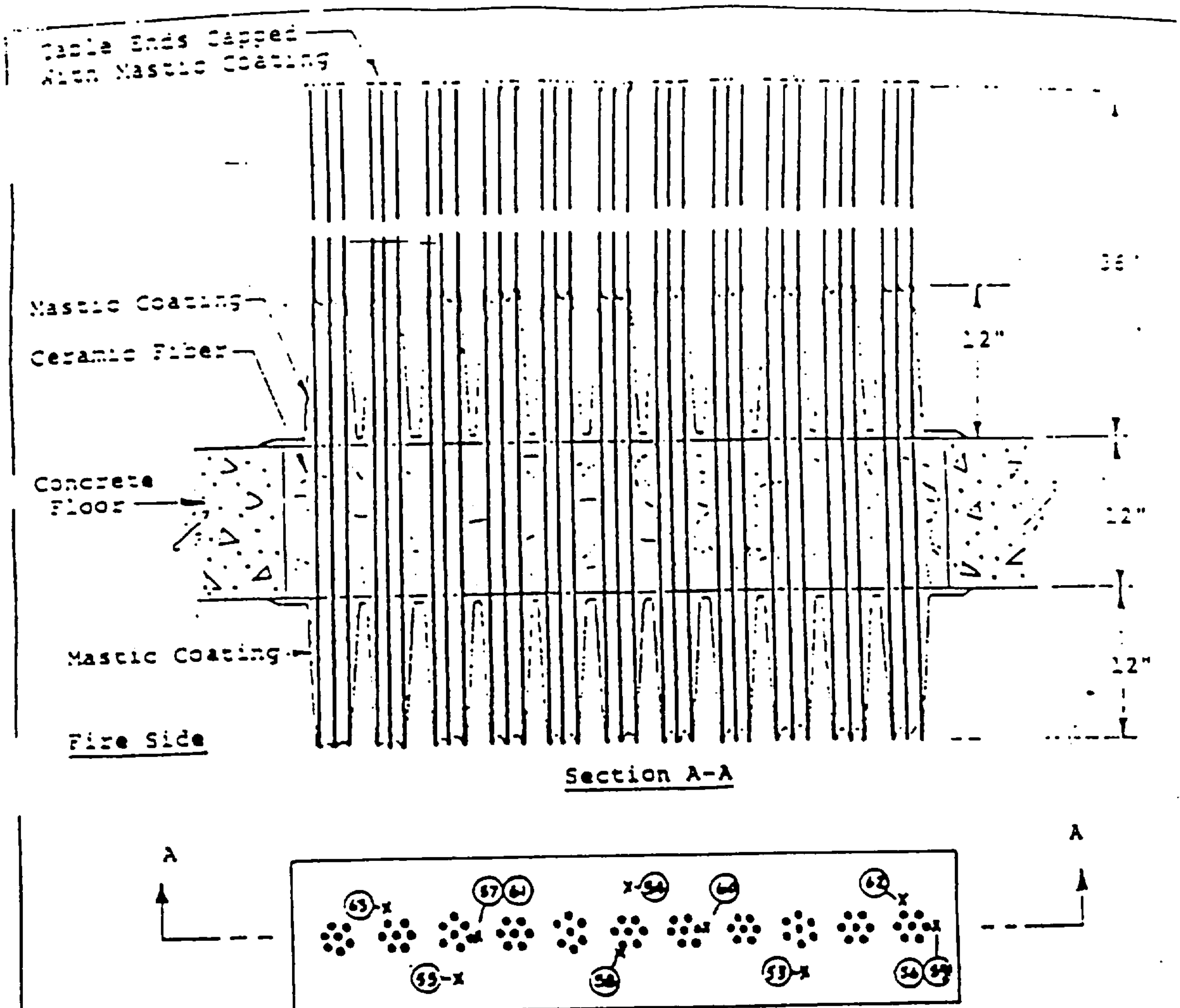


Section A-A



T.C.# 40,41 - ON MASTIC COATING/CABLE TRAY INTERFACE
T.C.# 42,43,44 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"
T.C.# 45,46 - ON MASTIC COATING ½" FROM BASE OF MASTIC COATING "CONE"
T.C.# 47,48,49 - ON CABLE JACKET/ MASTIC COATING INTERFACE
T.C.# 50,51,52 - ON MASTIC COATING IN FIELD OF FIRESTOP

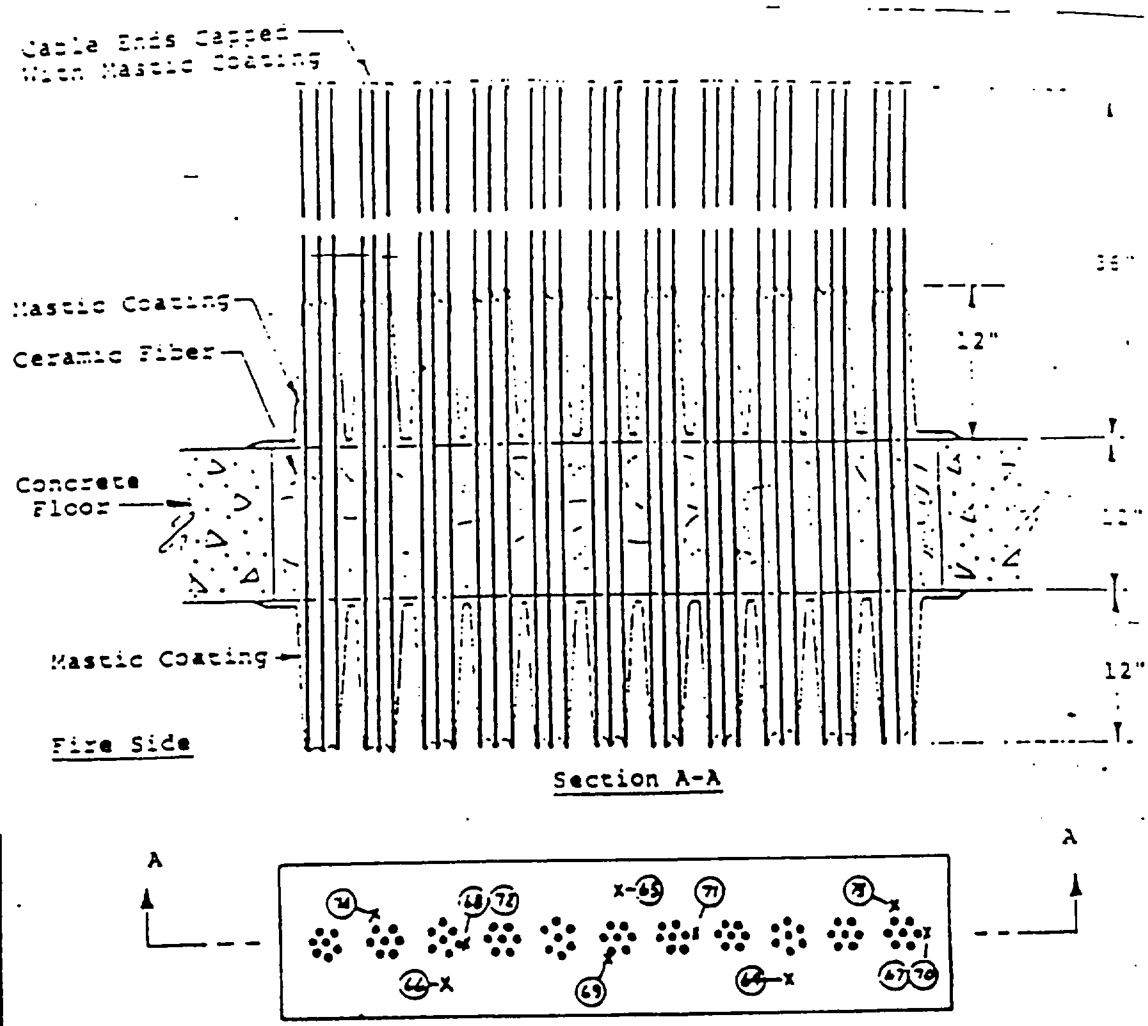
PENETRATION VOLUME - 7488 in^3 - CABLE DIAMETER - .705 in. NUMBER OF CABLES - 110 (29.8% fill/tray) CERAMIC FIBER AMOUNT - 23.77 lb. CERAMIC FIBER DENSITY - 5.9 pcf	FLOOR TEST NO. 2 PENETRATION NO. 14



T.C.# 53,54,55 - ON MASTIC COATING IN FIELD OF FIRESTOP
T.C.# 56,57,58 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"
T.C.# 59,60,61 -- ON CABLE JACKET/MASTIC COATING INTERFACE
T.C.# 62,63 - ON MASTIC COATING 1" FROM BASE OF MASTIC COATING "CONE"

PENETRATION VOLUME - 7488 in^3
CABLE DIAMETER - .705 in.
NUMBER OF CABLES - 113 (7.1 % fill)
CERAMIC FIBER AMOUNT - 23.71 lb.
CERAMIC FIBER DENSITY - 5.9 pcf

FLOOR TEST NO. 2
PENETRATION
NO. 15



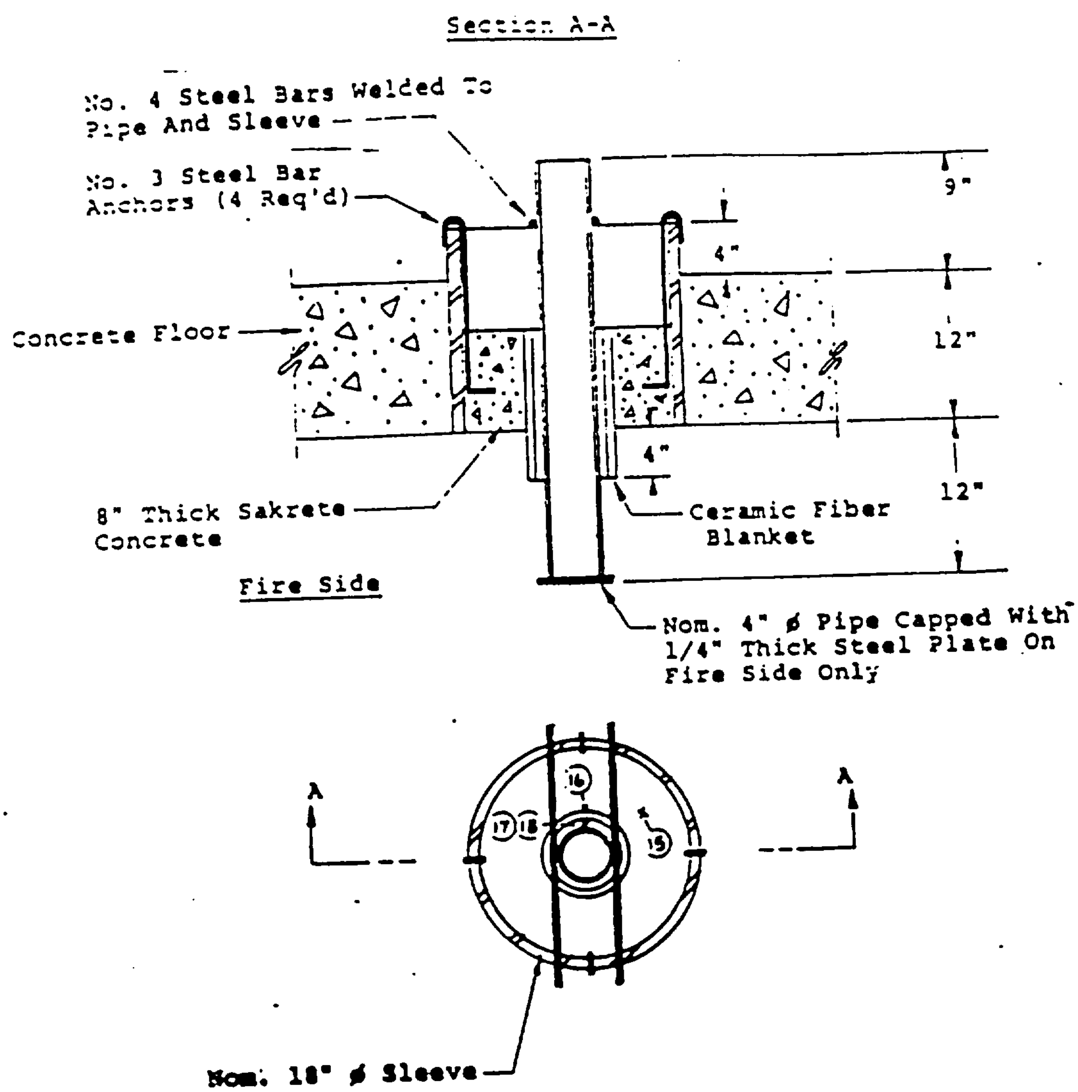
T.C.# 64, 65, 66 - ON MASTIC COATING IN FIELD OF FIRE STOP

T.C.# 67, 68, 69 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"

T.C.# 70, 71, 72 - ON CABLE JACKET/MASTIC COATING INTERFACE

T.C.# 73, 74 - ON MASTIC COATING 1" FROM BASE OF MASTIC COATING "CONE"

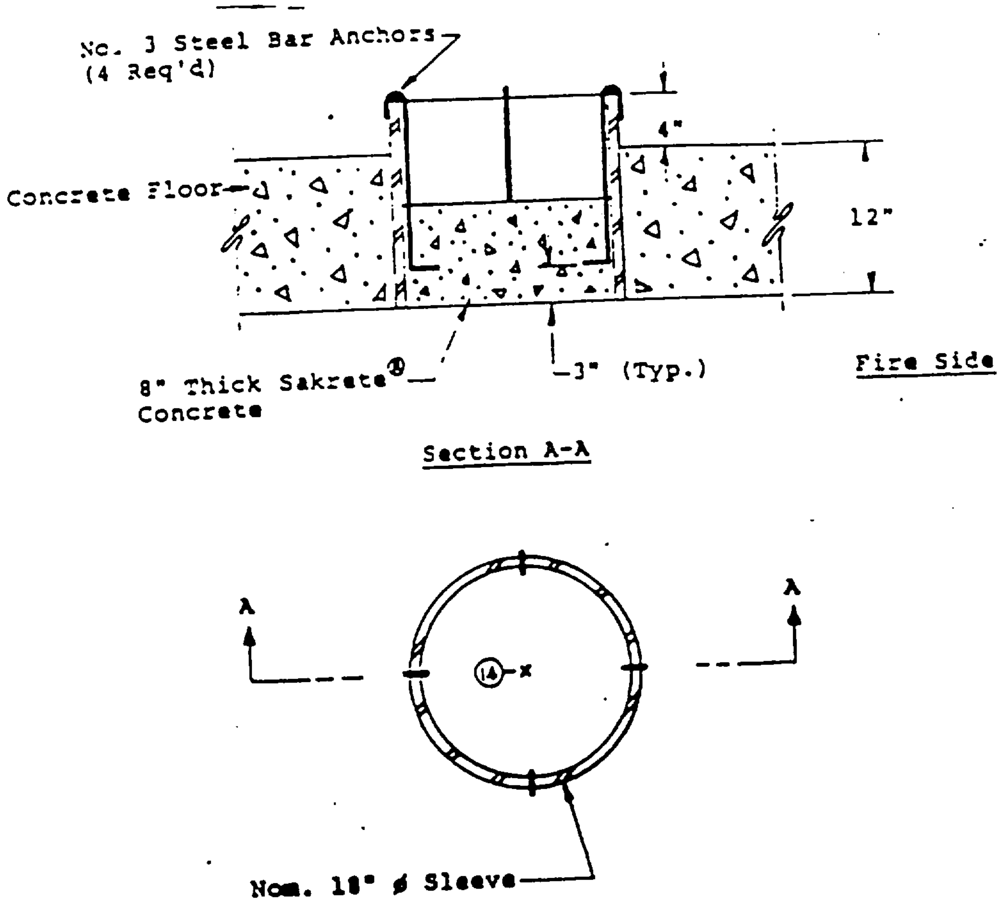
PENETRATION VOLUME - 7488 in³ CABLE DIAMETER - .705 in. NUMBER OF CABLES - 113 (7.1 % fill) CERAMIC FIBER AMOUNT - 15.80 lb.	FLOOR TEST NO. 2 PENETRATION NO. 16



T.C.#15 - ON CONCRETE IN FIELD OF FIRE STOP
T.C.#16 - ON CONCRETE/CERAMIC FIBER BLANKET INTERFACE
T.C.#17 - ON PIPE/CERAMIC FIBER BLANKET INTERFACE
T.C.#18 - ON PIPE 1" ABOVE CERAMIC FIBER BLANKET

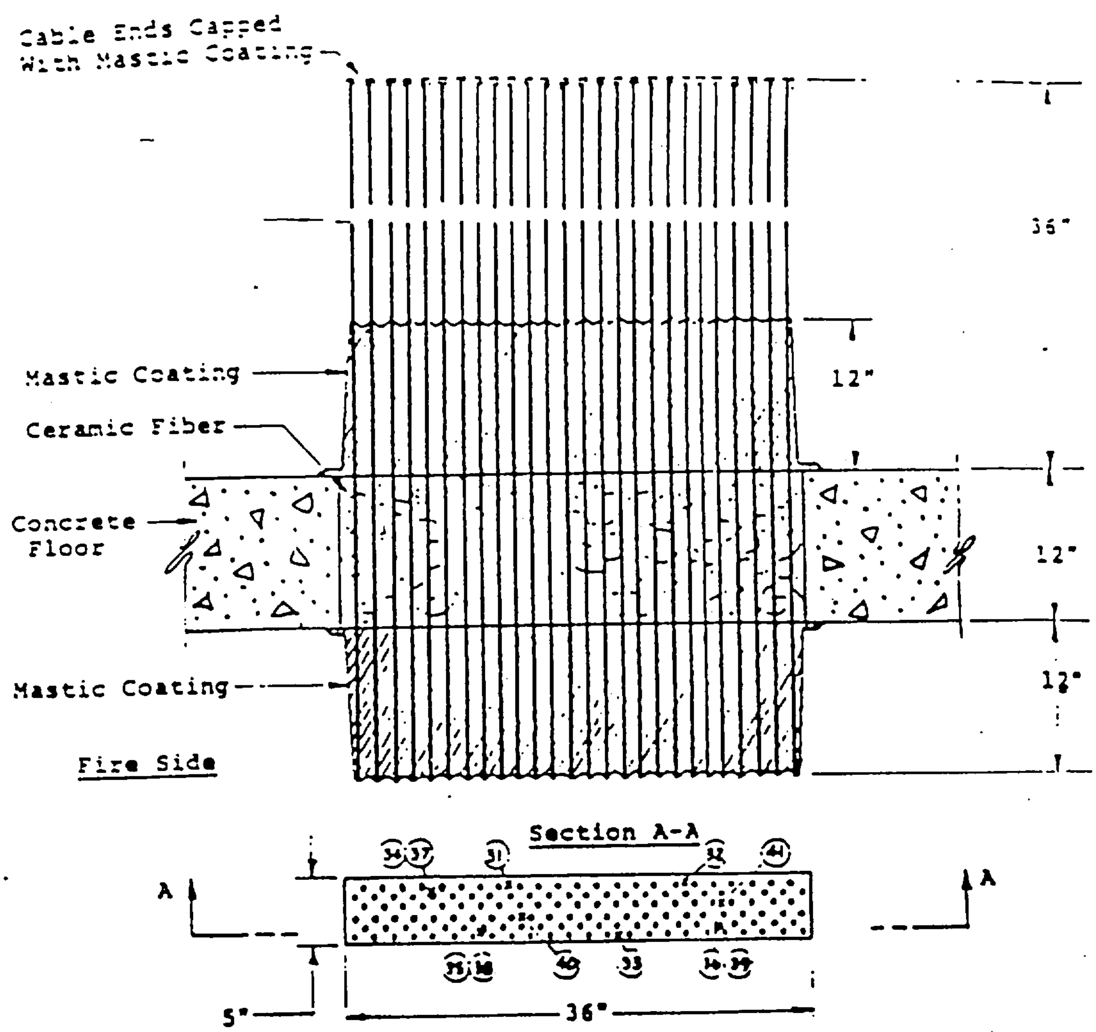
PENETRATION VOLUME - in^3 CABLE DIAMETER - in NUMBER OF CABLES - (%FILL) CERAMIC FIBER AMOUNT - lb CERAMIC FIBER DENSITY - pcf	FLOOR TEST NO. 1 PENETRATION NO. 11	

[redacted]



PENETRATION VOLUME - in^3
CABLE DIAMETER - in.
NUMBER OF CABLES - (%FILL)
CERAMIC FIBER AMOUNT - lb
CERAMIC FIBER DENSITY - pcf

FLOOR TEST NO
PENETRATIOI
NO. 12



T.C.# 31,32,33 - ON MASTIC COATING IN FIELD OF FIRE STOP

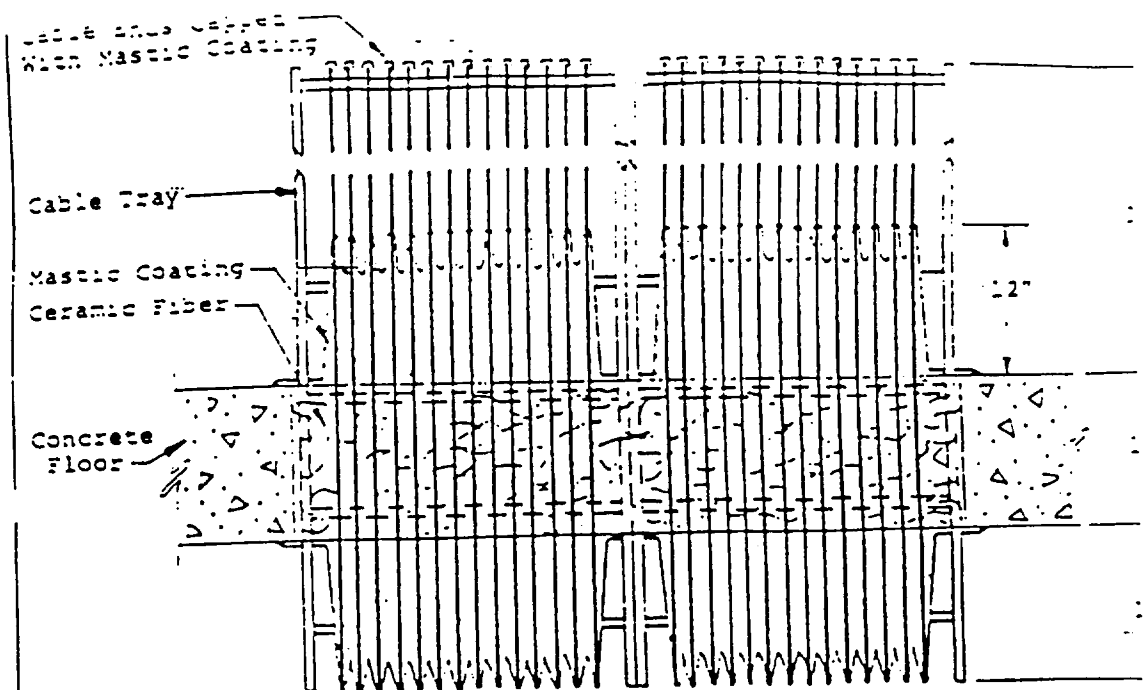
T.C.# 34,35,36 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"

T.C.# 37,38,39 - ON CABLE JACKET/MASTIC COATING INTERFACE

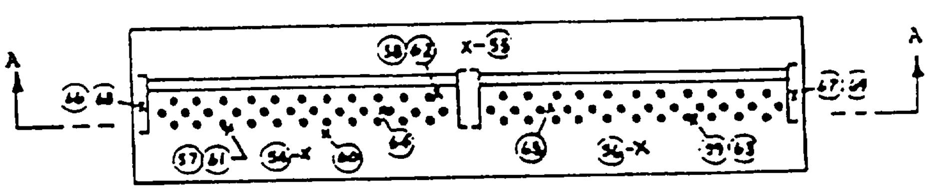
T.C.# 40,41 . - ON MASTIC COATING AT INTERFACE WITH BASE OF CABLE IN THE INTERIOR OF CABLE BUNDLE

PENETRATION VOLUME - 2160 in^3
CABLE DIAMETER - .450 in.
NUMBER OF CABLES - 495 (43.7 % fill)
CERAMIC FIBER AMOUNT - 5.35 lb.
CERAMIC FIBER DENSITY - 7.6 pcf

FLOOR TEST NO
PENETRATION
NO. 13

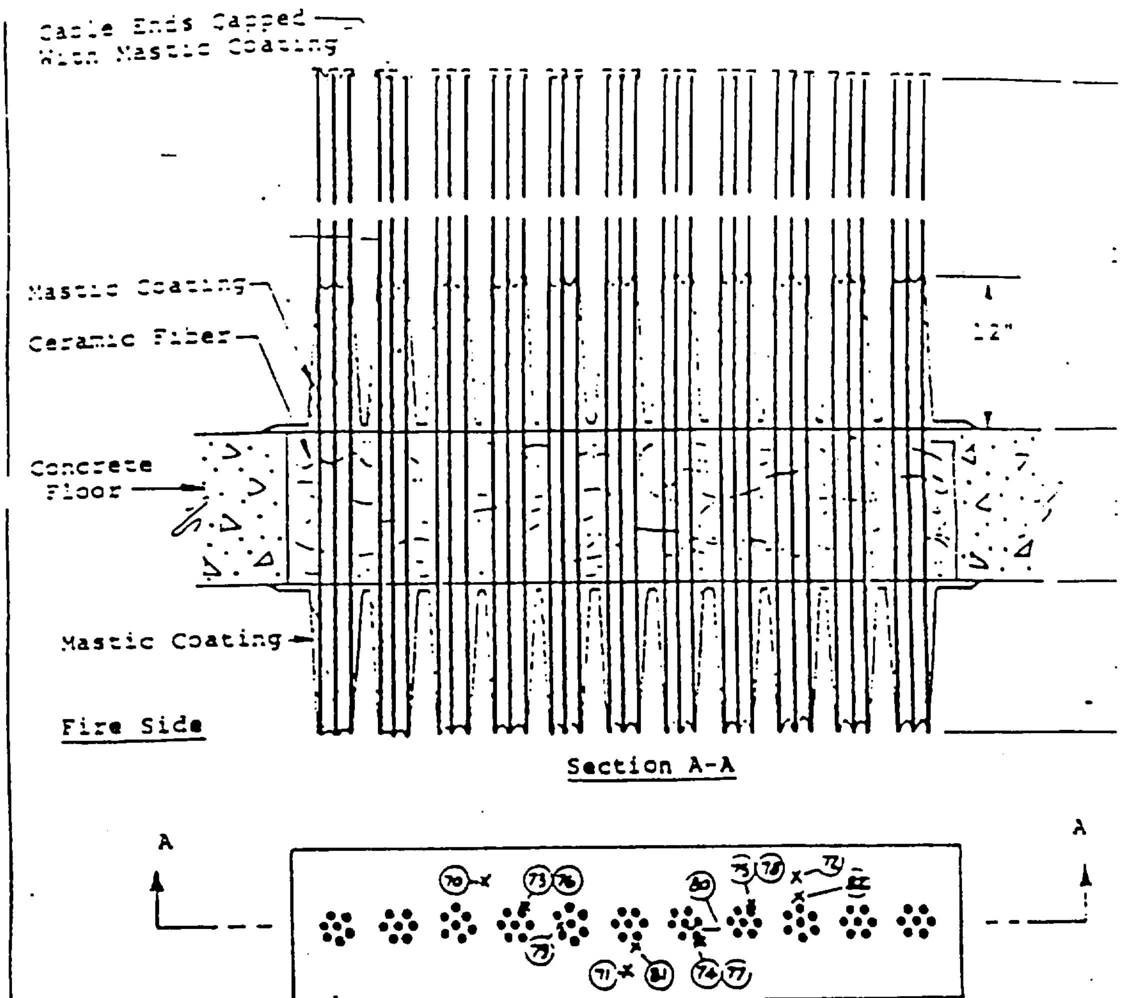


Section A-A



T.C.# 54,55,56 - ON MASTIC COATING IN FIELD OF FIRESTOP
T.C.# 57,58,59 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"
T.C.# 60 - ON MASTIC COATING 1/2" FROM BASE OF MASTIC COATING "CONE"
T.C.# 61,62,63 - ON CABLE JACKET/MASTIC COATING INTERFACE
T.C.# 64,65 - ON MASTIC COATING AT BASE OF CABLE IN THE INTERIOR OF CABLE BUNDLE
T.C.# 66,67 - ON MASTIC COATING / CABLE TRAY INTERFACE
T.C.# 68,69 - ON CABLE TRAY 1" ABOVE MASTIC COATING

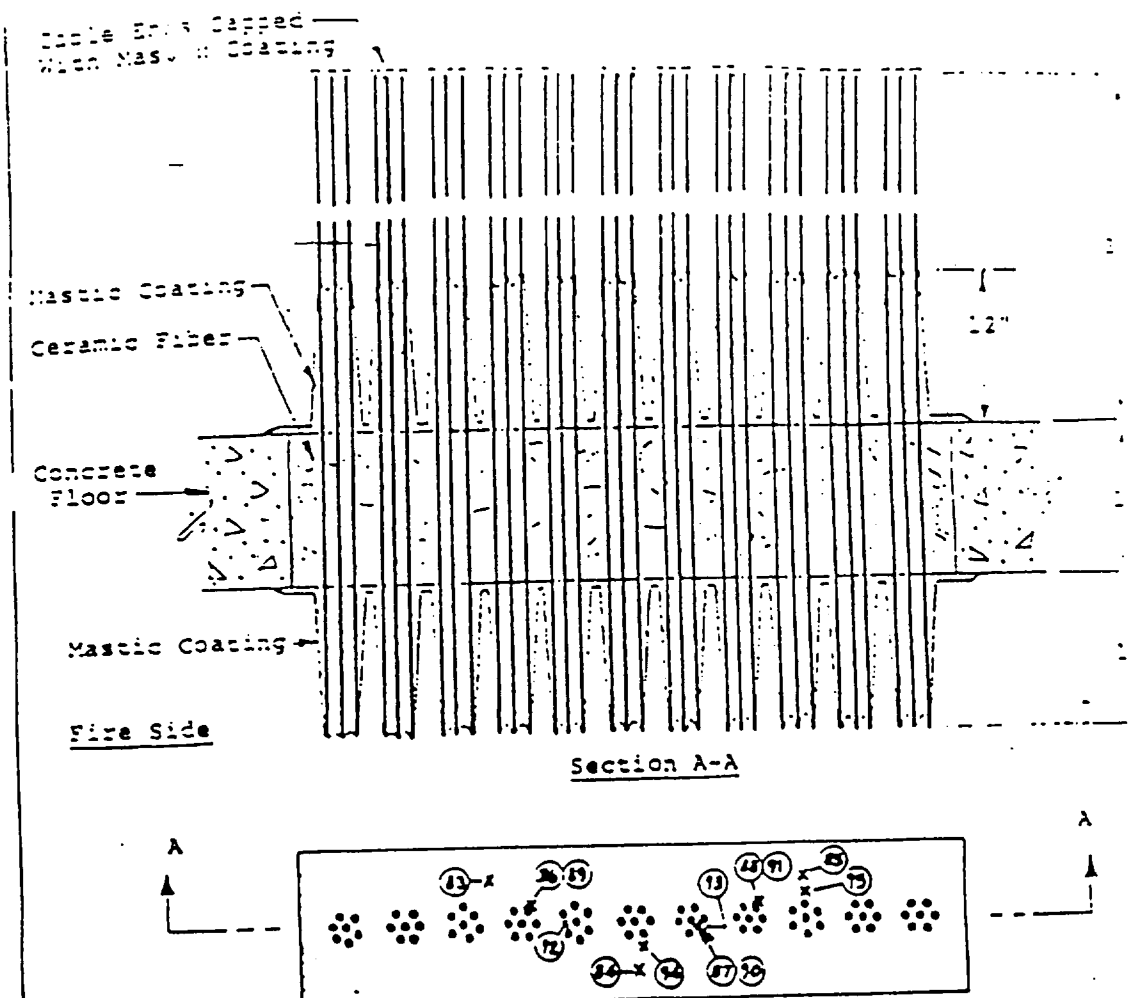
PENETRATION VOLUME - 7488 in^3 CABLE DIAMETER - .705 in. NUMBER OF CABLES - 198 (40.3% fill/tray) CERAMIC FIBER AMOUNT - 29.15 lb. CERAMIC FIBER DENSITY - 7.7 pcf MASTIC COATING TYPE - FLAMEMASTIC F77 [illegible] in (14 readings)	FLOOR TEST NO. PENETRATION NO. 14 - [redacted]



T.C.# 70,71,72 - ON MASTIC COATING IN FIELD OF FIRE STOP
T.C.# 73,74,75 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"
T.C.# 76,77,78 - ON CABLE JACKET/MASTIC COATING INTERFACE
T.C.# 79,80 - ON MASTIC COATING AT BASE OF CABLE IN THE INTERIOR OF CABLE BUNDL
T.C.# 81,82 - ON MASTIC COATING 1" FROM BASE OF MASTIC COATING "CONE"

PENETRATION VOLUME - 7488 in^3
CABLE DIAMETER - .705 in.
NUMBER OF CABLES - 138 (8.6 % fill)
CERAMIC FIBER AMOUNT - 30.75 lb.
CERAMIC FIBER DENSITY - 7.8 pcf
MASTIC COATING TYPE FLAMEMASTIC 77

FLOOR TEST N
PENETRATIC
NO. 15



T.C.# 83,84,85 - ON MASTIC COATING IN FIELD OF FIRESTOP

T.C.# 86,87,88 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"

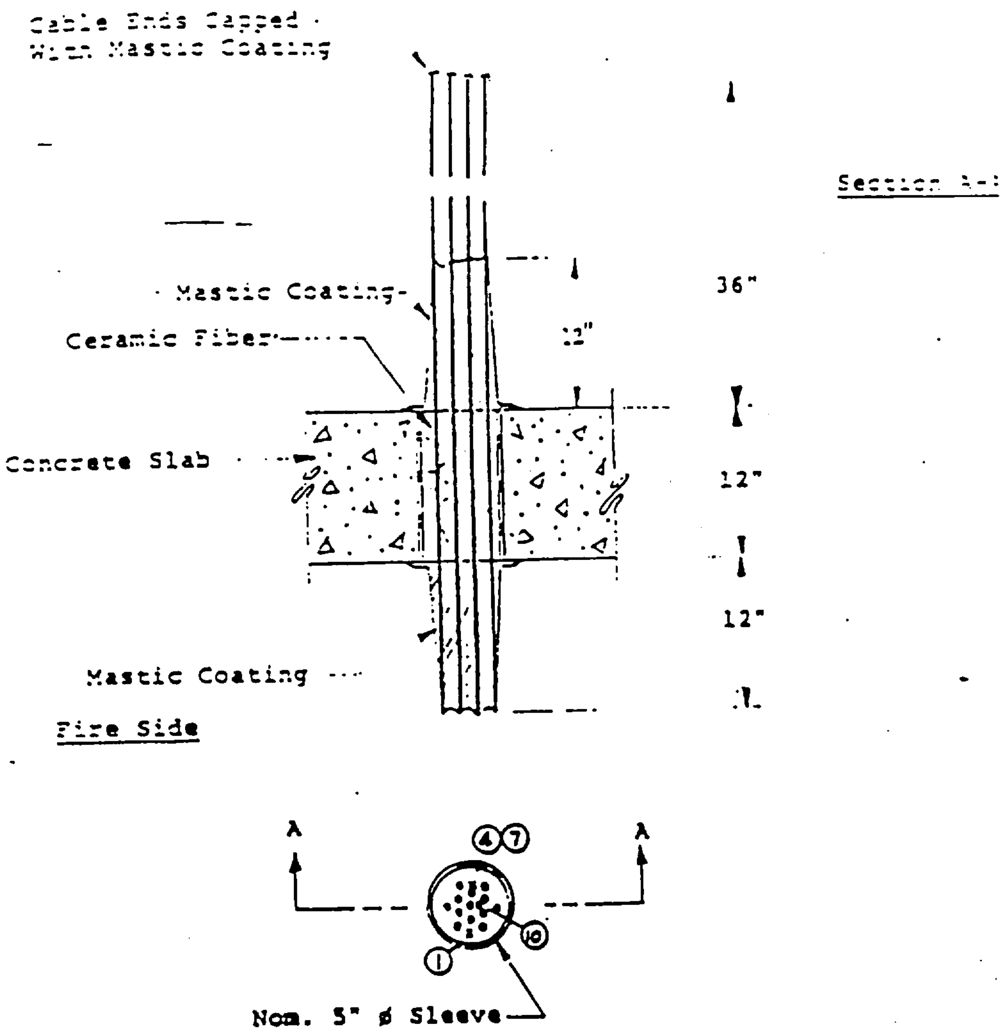
T.C.# 89,90,91 - ON CABLE JACKET/MASTIC COATING INTERFACE

T.C.# 92,93 - ON MASTIC COATING AT BASE OF CABLE IN THE INTERIOR OF CABLE BUNDLE

T.C.# 94,95 - ON MASTIC COATING 1" FROM BASE OF MASTIC COATING "CONE"

PENETRATION VOLUME - 7488 in^3
CABLE DIAMETER - .705 in.
NUMBER OF CABLES - 138 (8.6 % fill)
CERAMIC FIBER AMOUNT - 46.12 lb.
CERAMIC FIBER DENSITY - 11.6 pcf

FLOOR TEST NC
PENETRATIC
NO. 16



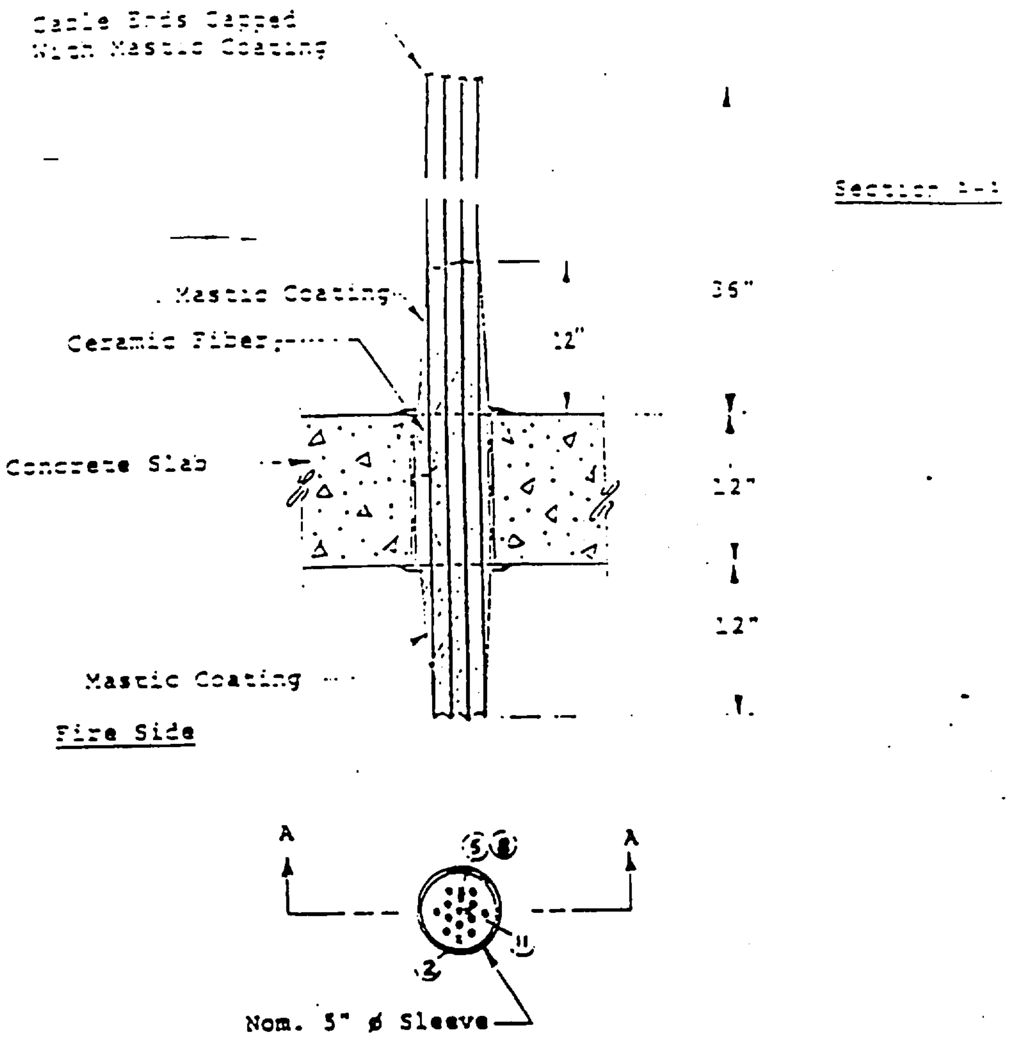
T.C.# 1 - ON MASTIC COATING IN FIELD OF FIRESTOP

T.C.# 4 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"

T.C.# 7 - ON CABLE JACKET AT INTERFACE WITH MASTIC COATING

T.C.# 10 - ON MASTIC COATING AT BASE OF CABLE IN THE INTERIOR OF CABLE BUNDLE

PENETRATION VOLUME - 240 in³ CABLE DIAMETER - .705 in. NUMBER OF CABLES - 16 (31.2% fill) CERAMIC FIBER AMOUNT - .65 lb. CERAMIC FIBER DENSITY - 6.8 pcf MASTIC COATING TYPE - FLAMEMASTIC F77	FLOOR TEST NO PENETRATION NO. 3 [redacted]

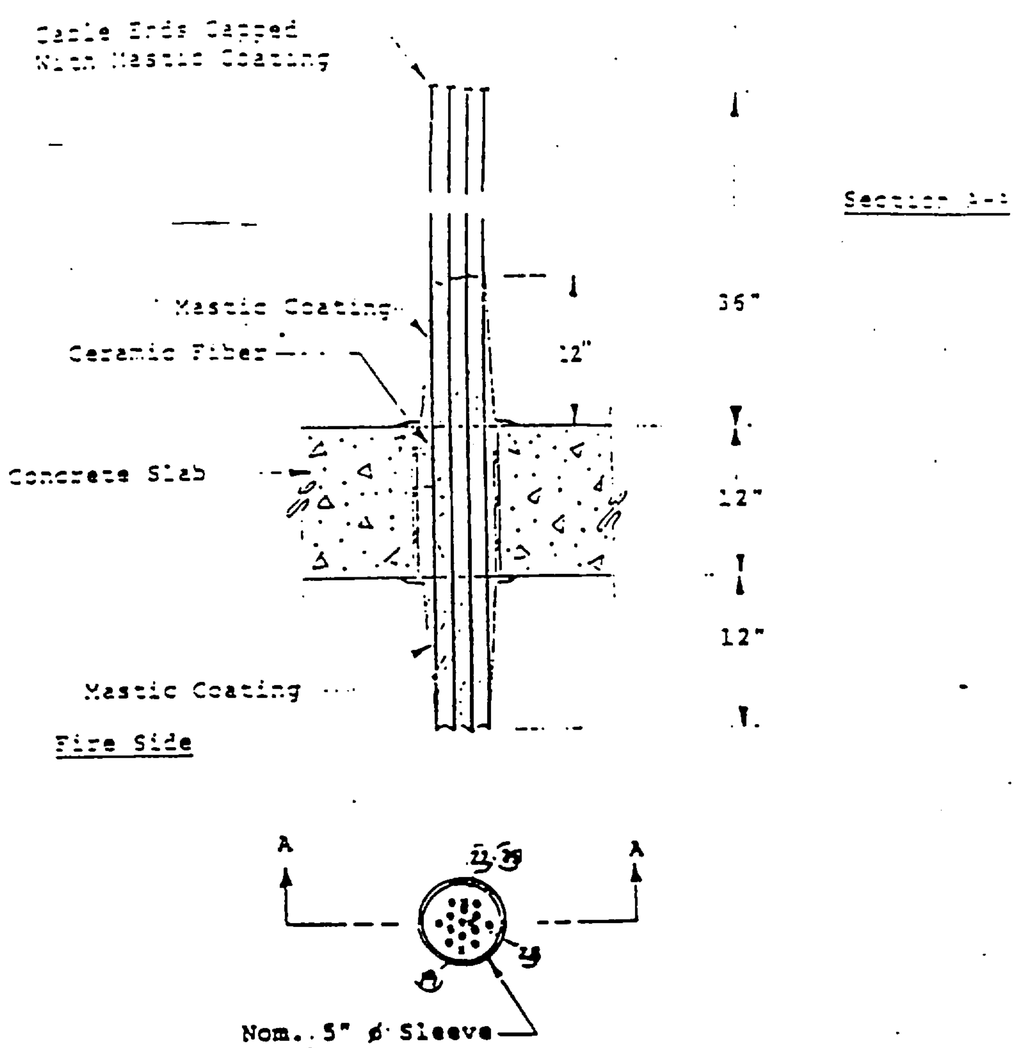


T.C.# 2 - ON MASTIC COATING IN FIELD OF FIRESTOP
T.C.# 5 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"
T.C.# 8 - ON CABLE JACKET AT INTERFACE WITH MASTIC COATING
T.C.# 11 - ON MASTIC COATING AT BASE OF CABLE IN THE INTERIOR OF CABLE BUNDLE

PENETRATION VOLUME - 240 in^3
CABLE DIAMETER - .705 in.
NUMBER OF CABLES - 16 (31.2 % fill)
CERAMIC FIBER AMOUNT - .65 lb.
CERAMIC FIBER DENSITY - 6.8 pcf
MASTIC COATING TYPE - FLAMEMASTIC F77

FLOOR TEST NO.
PENETRATION
NO. 4

[redacted]



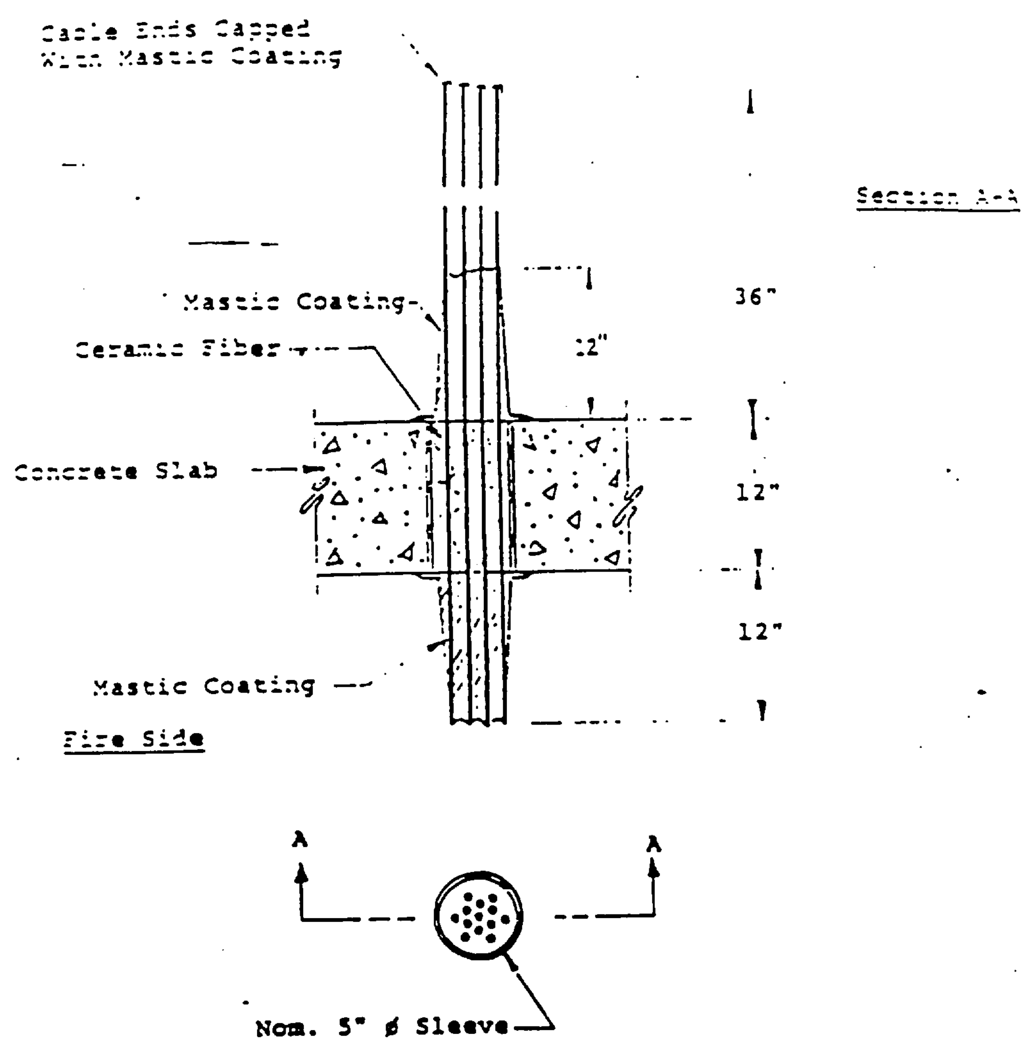
T.C.#19 - ON MASTIC COATING IN FIELD OF FIRESTOP

T.C.#22 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE".

T.C.#25 - ON CABLE JACKET AT INTERFACE WITH MASTIC COATING

T.C.#28 - ON MASTIC COATING AT BASE OF CABLE IN THE INTERIOR OF CABLE BUNDLE

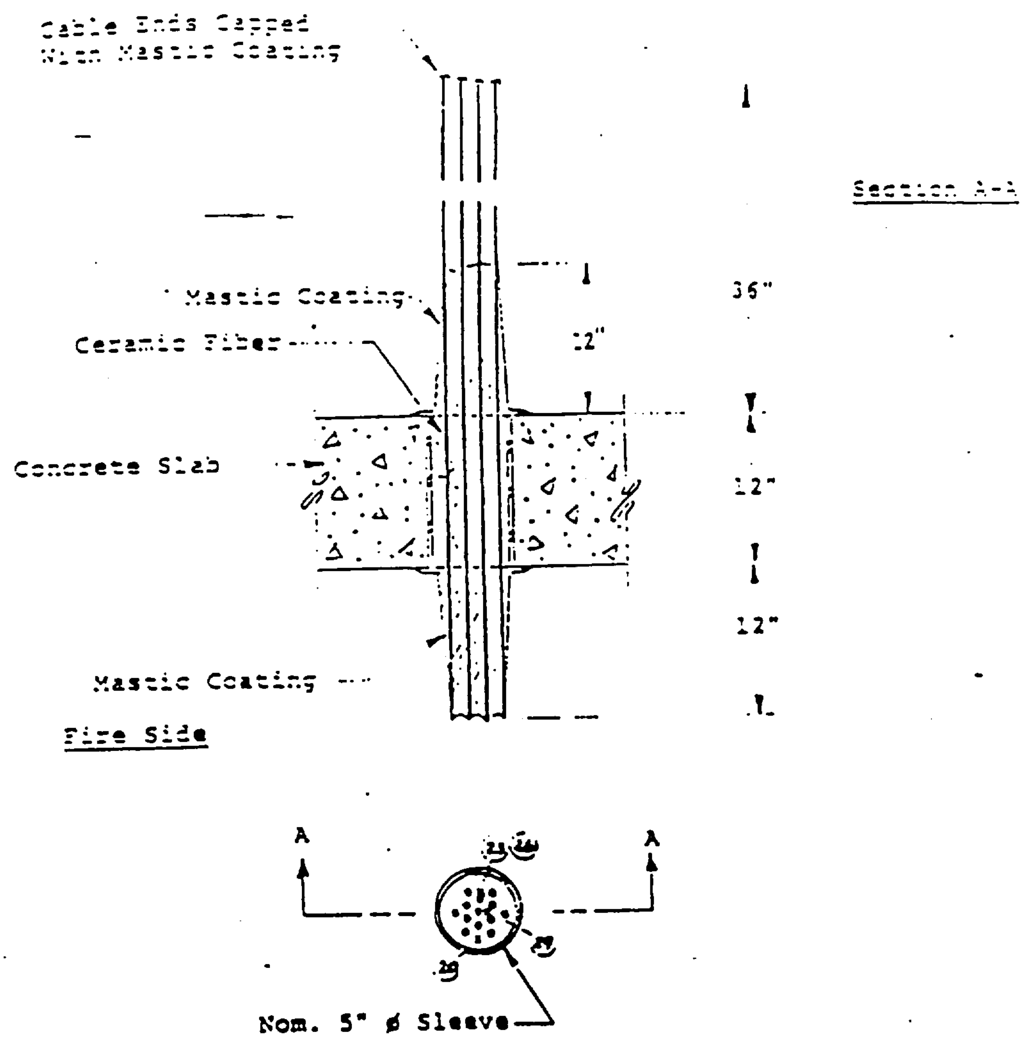
PENETRATION VOLUME - 240 in^3 CABLE DIAMETER - .705 in. NUMBER OF CABLES - 16 (31.2% fill) CERAMIC FIBER AMOUNT - .99 lb. CERAMIC FIBER DENSITY - 10.4 pcf	FLOOR TEST NO._ PENETRATION NO. 5



PENETRATION VOLUME - 240 in^3
CABLE DIAMETER - .705 in.
NUMBER OF CABLES - 16 (31.2% fill)
CERAMIC FIBER AMOUNT - .99 lb.
CERAMIC FIBER DENSITY - 10.4 pcf
MASTIC COATING TYPE - FLAMEMASTIC F77

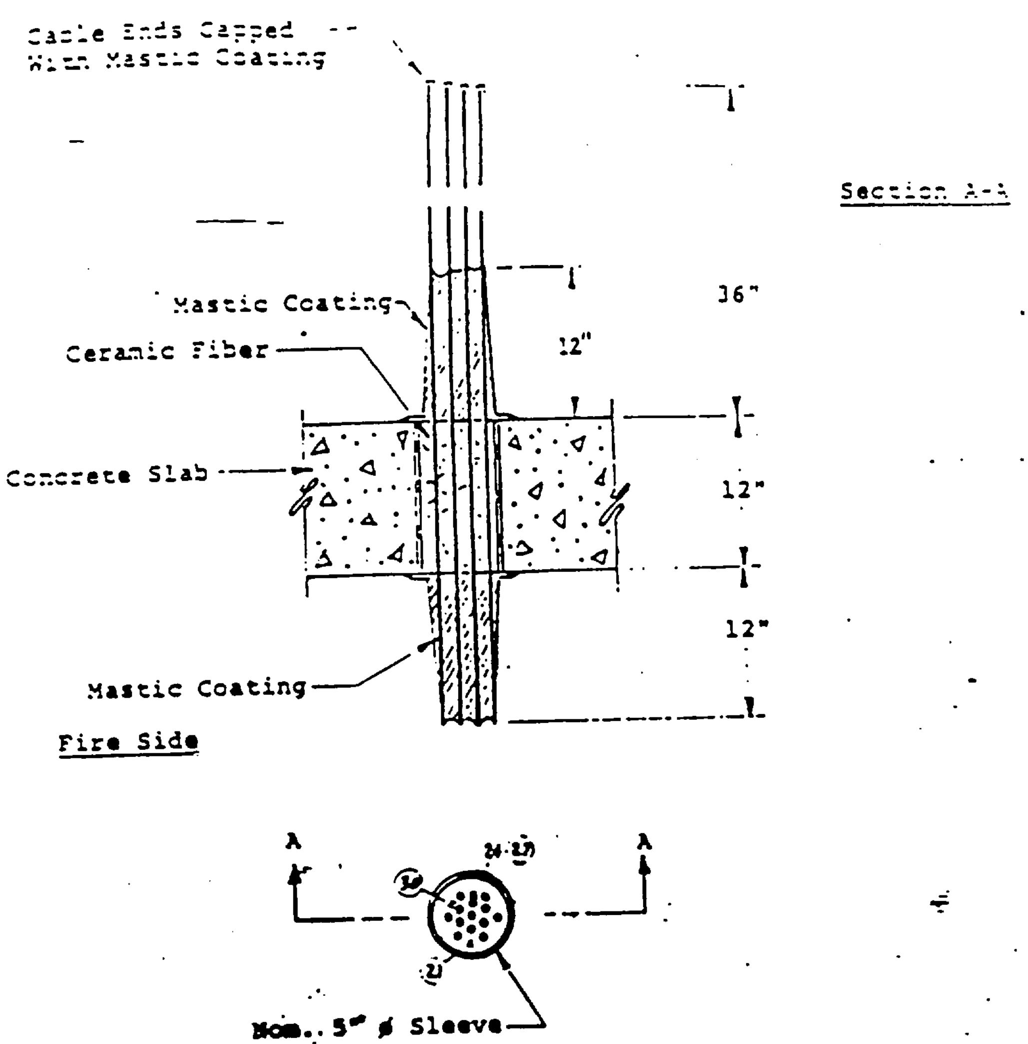
FLOOR TEST NO. 1
PENETRATION NO. 6

[redacted]



T.C.#20 - ON MASTIC COATING IN FIELD OF FIRESTOP
T.C.#23 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE".
T.C.#26 - ON CABLE JACKET AT INTERFACE WITH MASTIC COATING
T.C.#29 - ON MASTIC COATING AT BASE OF CABLE IN THE INTERIOR OF CABLE BUNDLE

PENETRATION VOLUME - 240 in³ - CABLE DIAMETER - .705 in. NUMBER OF CABLES - 16 (31.2 % fill) CERAMIC FIBER AMOUNT - .99 lb. CERAMIC FIBER DENSITY - 10.4 pcf	FLOOR TEST NO. 1 PENETRATION NO. 7



T.C.#21 - ON CABLE JACKET/MASTIC COATING INTERFACE

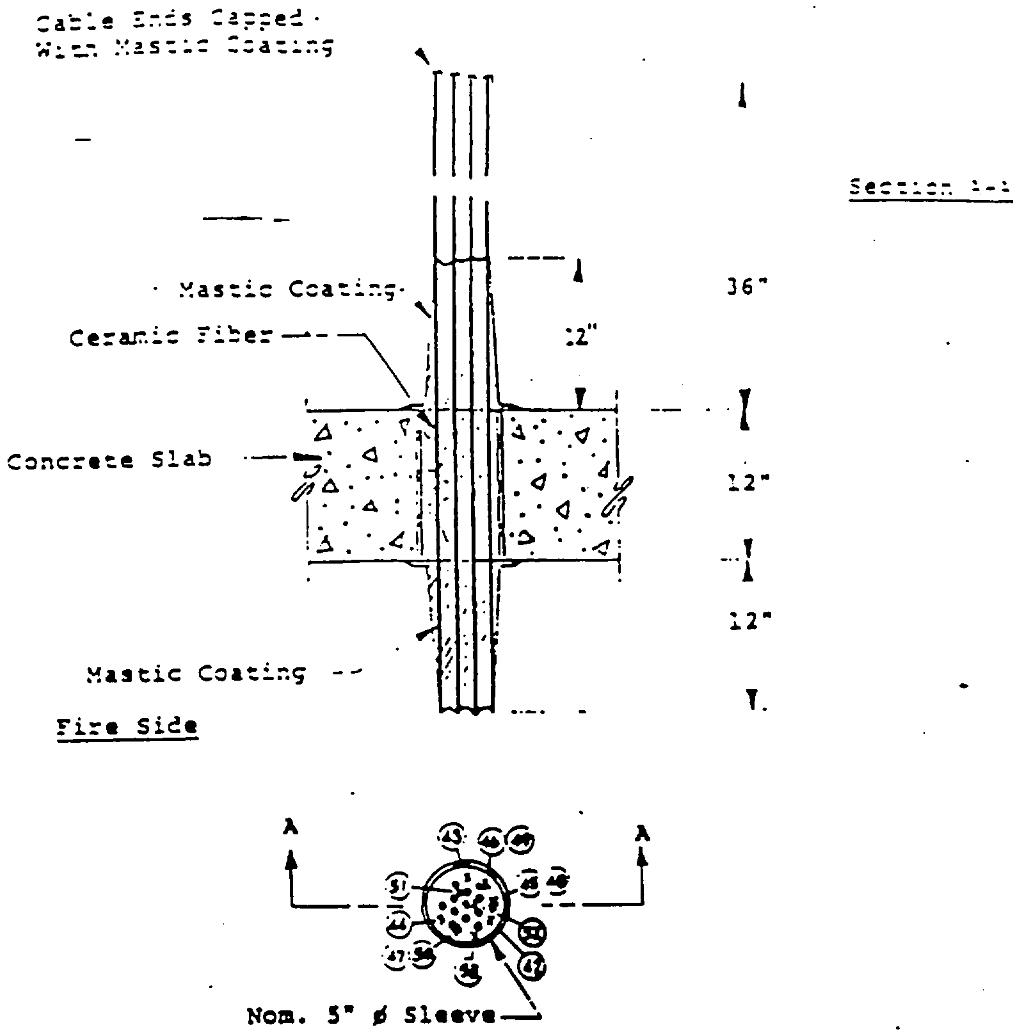
T.C.#24 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"

T.C.#27 - ON MASTIC COATING $\frac{1}{2}$ IN. FROM BASE OF MASTIC COATING "CONE"

T.C.#30 - ON MASTIC COATING IN FIELD OF FIRE STOP

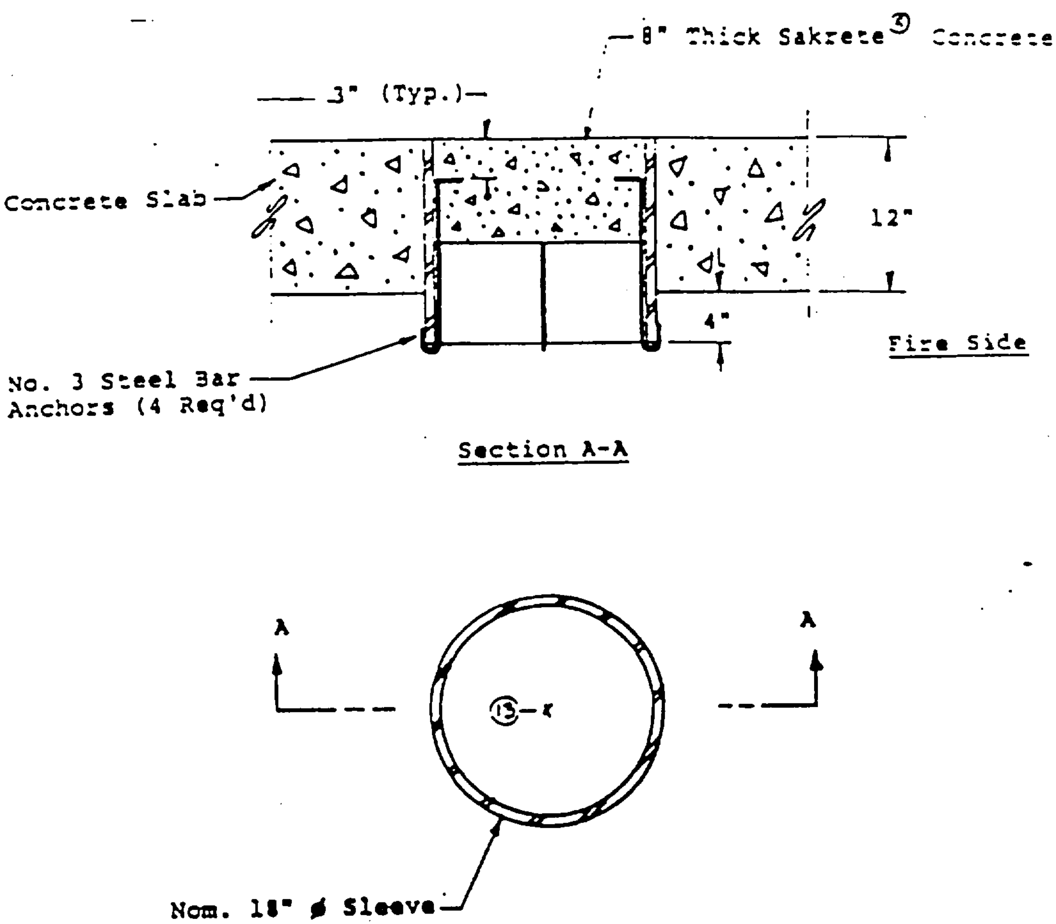
PENETRATION VOLUME - 240 in^3
CABLE DIAMETER - .705 in.
NUMBER OF CABLES - 16 (31.2 % fill)
CERAMIC FIBER AMOUNT - .99 lb.
CERAMIC FIBER DENSITY - 10.4 pcf

FLOOR TEST NO. 1
PENETRATION
NO. 8



T.C.# 42,43,44 - ON MASTIC COATING IN FIELD OF FIRE STOP
T.C.# 45,46,47 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"
T.C.# 48,49,50 - ON CABLE JACKET/MASTIC COATING INTERFACE
T.C.# 51,52 - ON MASTIC COATING AT BASE OF CABLE IN THE INTERIOR OF CABLE BUNDLE
T.C.# 53 - ON MASTIC COATING ½ IN. FROM BASE OF MASTIC COATING "CONE"

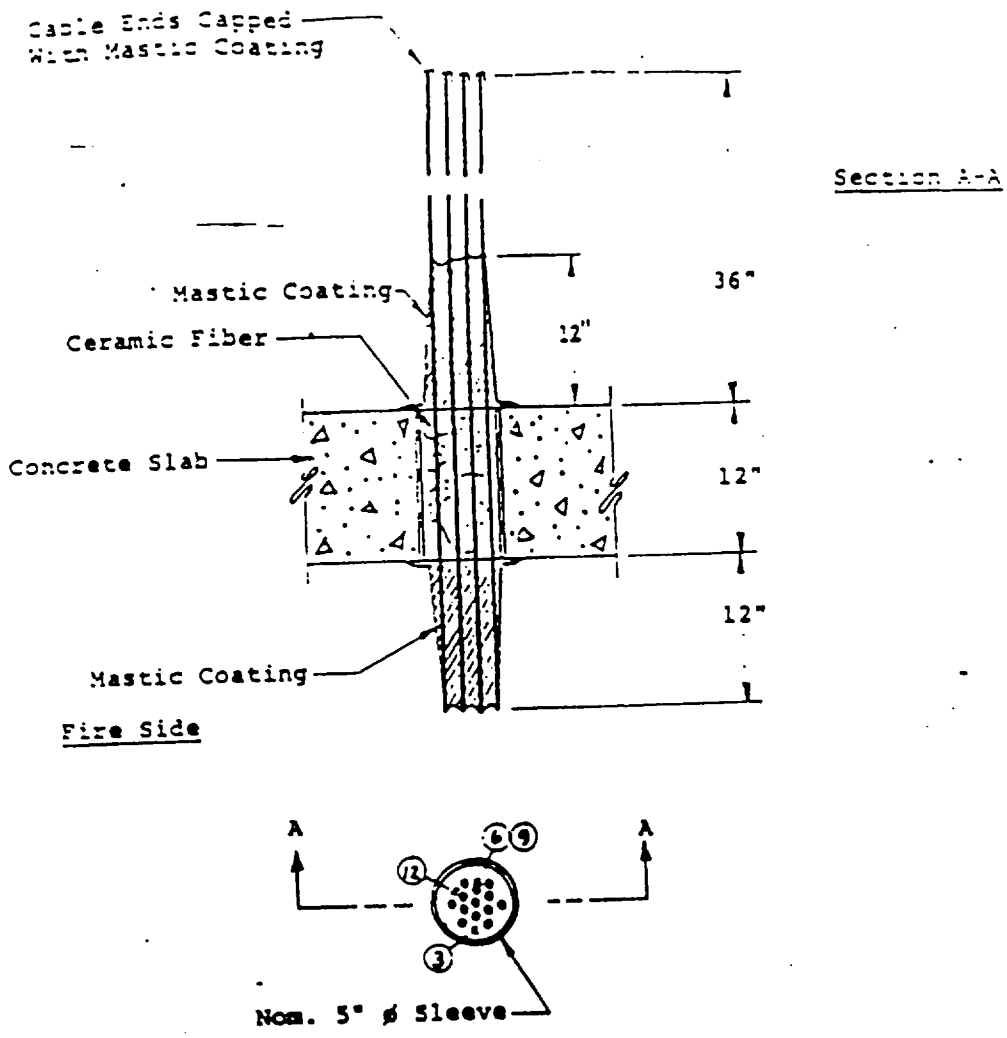
PENETRATION VOLUME - 240 in^3 CABLE DIAMETER - .705 in. NUMBER OF CABLES - 16 (31.2 % fill) CERAMIC FIBER AMOUNT - .65 lb. CERAMIC FIBER DENSITY - 6.8 pcf MASTIC COATING TYPE - FLAMEMASTIC F77	FLOOR TEST NO. 1 - PENETRATION NO. 9 [redacted]



~~PENETRATION VOLUME - in³~~
~~CABLE DIAMETER - in.~~
~~NUMBER OF CABLES - (% fill)~~
~~CERAMIC FIBER AMOUNT - lb~~
~~CERAMIC FIBER DENSITY - pcf~~
~~MASTIC COATING TYPE - FLAMEMASTIC~~

FLOOR TEST NO. 1
PENETRATION
NO. 10

[redacted]



T.C.# 3 - ON CABLE JACKET/MASTIC COATING INTERFACE

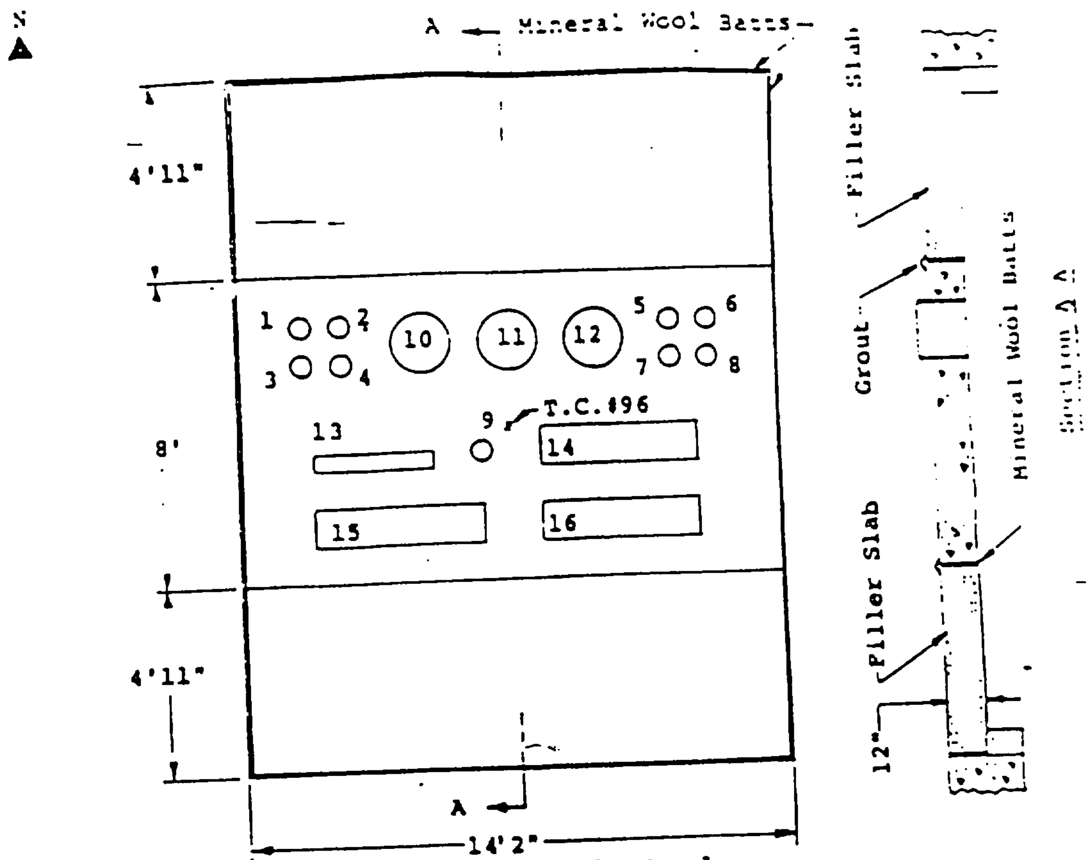
T.C.# 6 - ON MASTIC COATING AT INTERFACE WITH BASE OF MASTIC COATING "CONE"

T.C.# 9 - ON MASTIC COATING ½ IN. FROM BASE OF MASTIC COATING "CONE"

T.C.# 12 - ON MASTIC COATING IN FIELD OF FIRE STOP

PENETRATION VOLUME - 240 in³
CABLE DIAMETER - .705 in.
NUMBER OF CABLES - 16 (31.2 % fill)
CERAMIC FIBER AMOUNT - .65 lb.
CERAMIC FIBER DENSITY - 6.8 pcf
MASTIC COATING TYPE - FLAMEMASTIC F77

FLOOR TEST NO. 1
PENETRATION
NO. 2

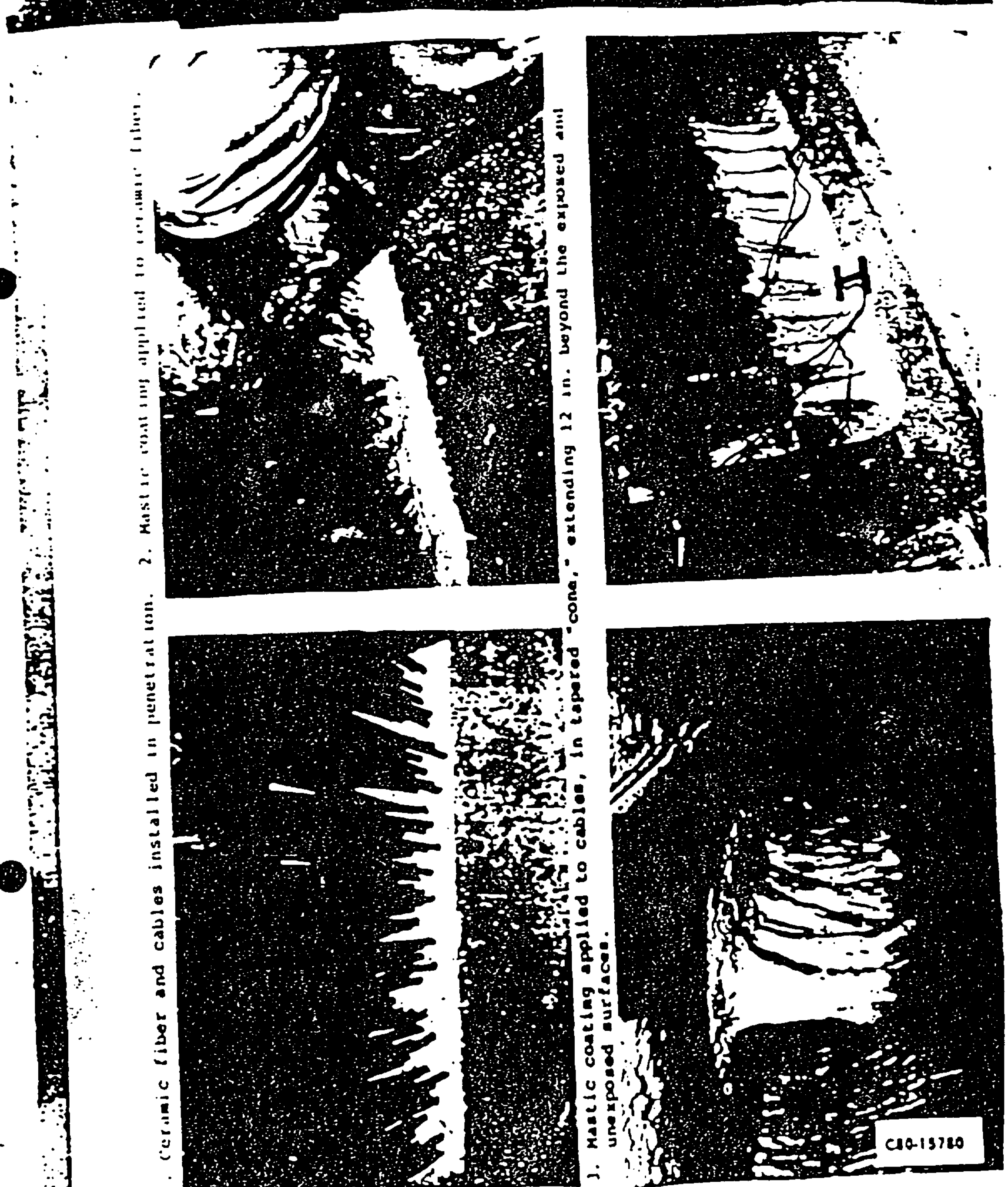


Construction Details - Floor Assembly No. 1

Penetration No.	Thermocouple Nos.	Construction Details And Thermocouple Locations
1	-	ILL. 3
2	3, 6, 9, 12	ILL. 4
3	1, 4, 7, 10	ILL. 5
4	2, 5, 8, 11	ILL. 6
5	19, 22, 25, 28	ILL. 7
6	-	ILL. 8
7	20, 23, 26, 29	ILL. 9
8	21, 24, 27, 30	ILL. 10
9	42-53	ILL. 11
10	13	ILL. 12
11	15, 16, 17, 18	ILL. 13
12	14	ILL. 14
13	31-41	ILL. 15
14	54-69	ILL. 16
15	70-82	ILL. 17
16	83-95	ILL. 18
Concrete	96	See Above

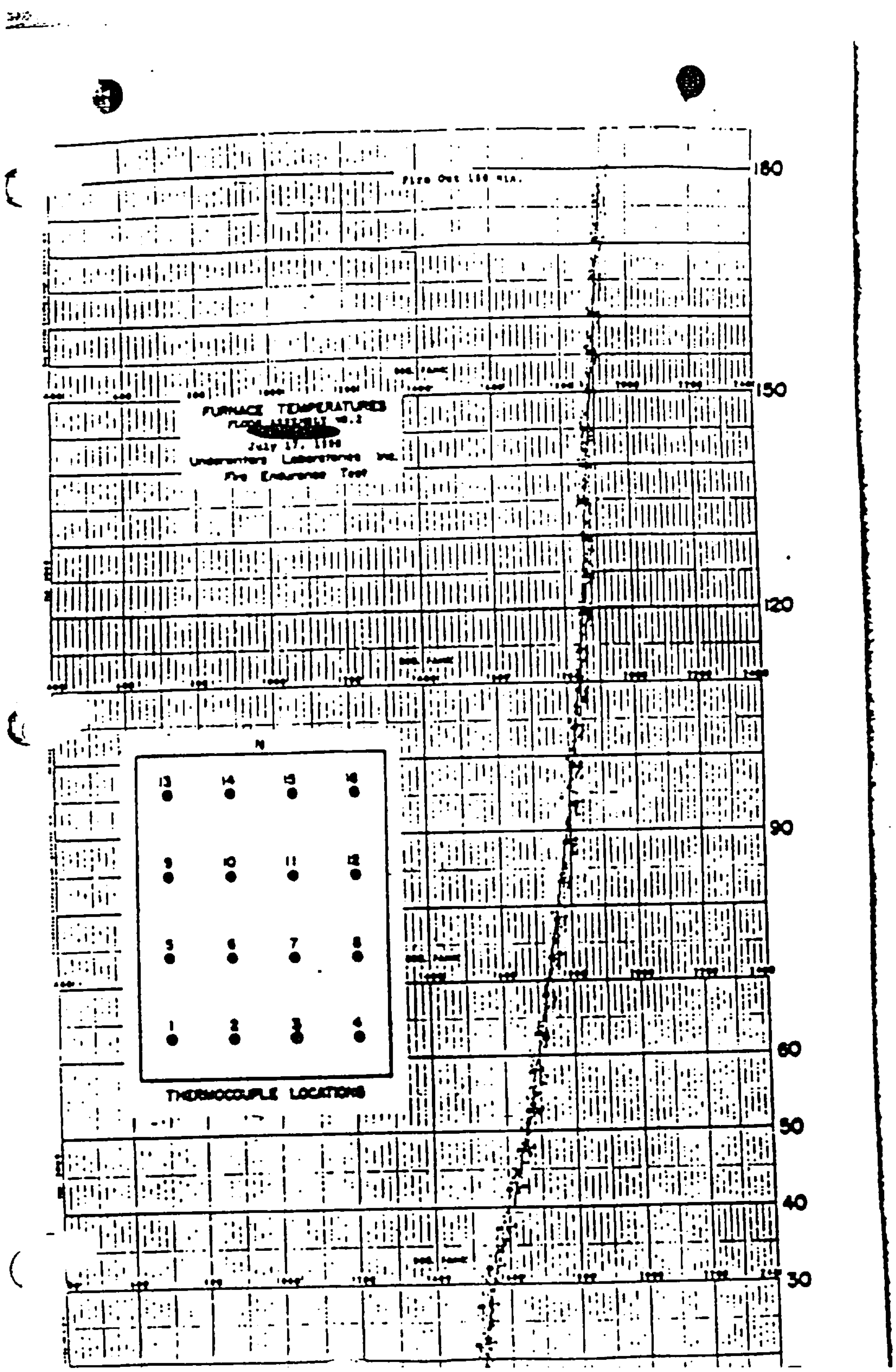
[redacted]
ILL. 1

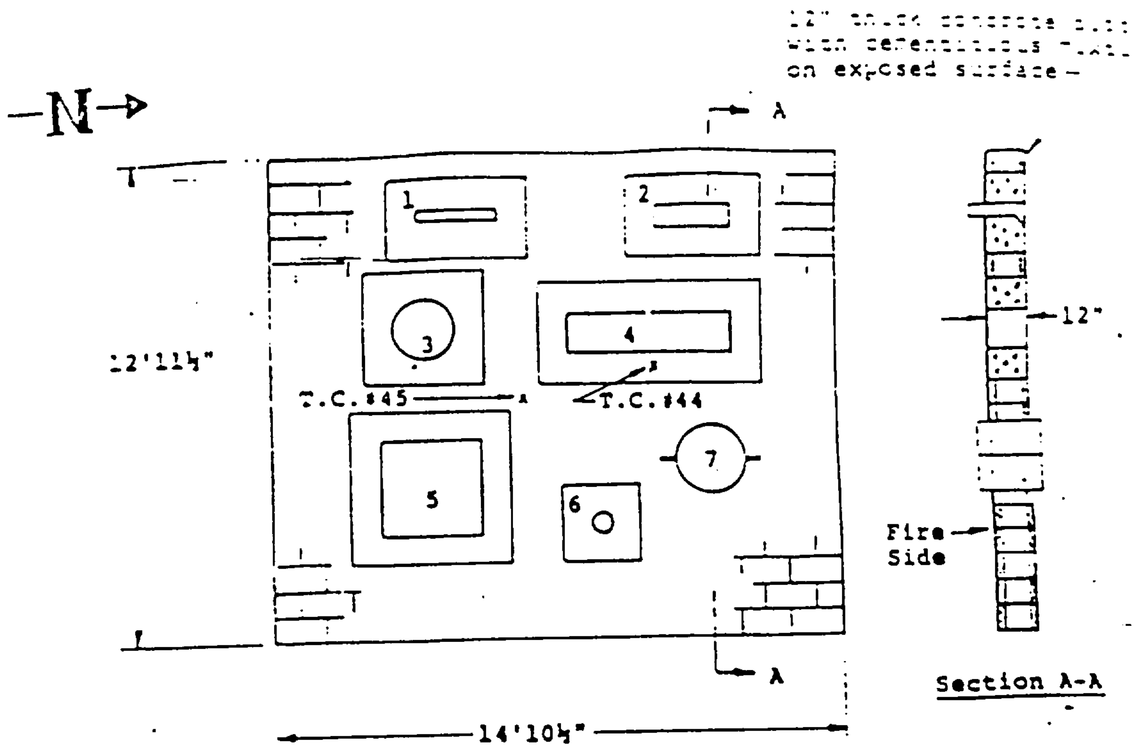
ILL. 2



1. Ceramic fiber and cables installed in penetration. 2. Mastic coating applied to ceramic fiber.

3. Mastic coating applied to cables, in tapered "cone," extending 12 in. beyond the exposed and unexposed surfaces.

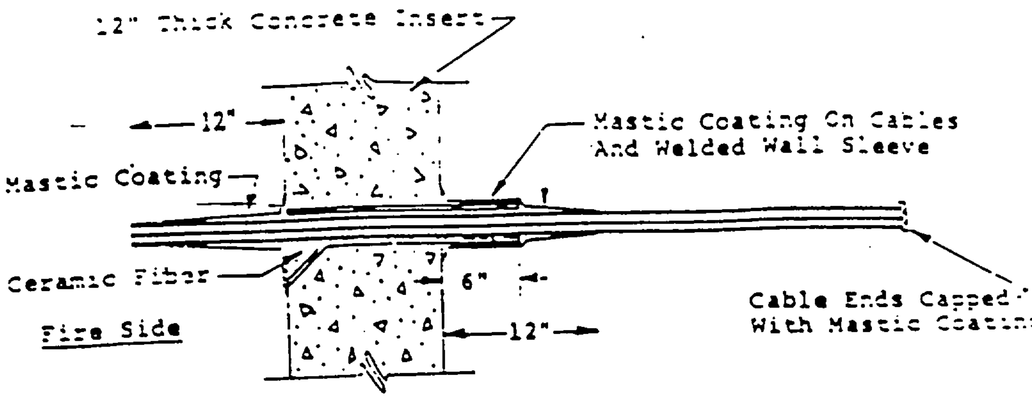

180
150
120
90
60
50
40
30
FURNACE TEMPERATURES
Underwriters Laboratories Inc.
Fire Endurance Test
N
13
14
15
16
9
10
11
12
5
6
7
8
1
2
3
4
THERMOCOUPLE LOCATIONS



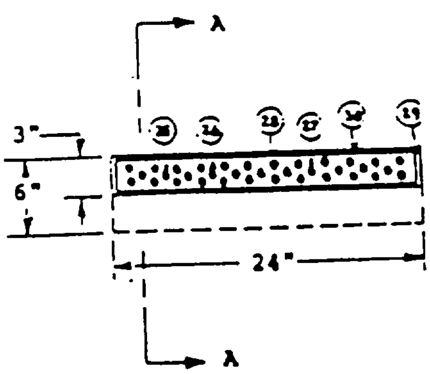
Construction Details - Wall Assembly No. 1

Penetration No.	Thermocouple Nos.	Construction Details And Thermocouple Locations
1	25-30	ILL. 43
2	10-15	ILL. 44
3	37-40	ILL. 45
4	1-9	ILL. 46
5	16-24	ILL. 47
6	31-36	ILL. 48
7	41-43	ILL. 49
Concrete	44	See above
Conc. Block	45	See above

[redacted]
ILL. 42

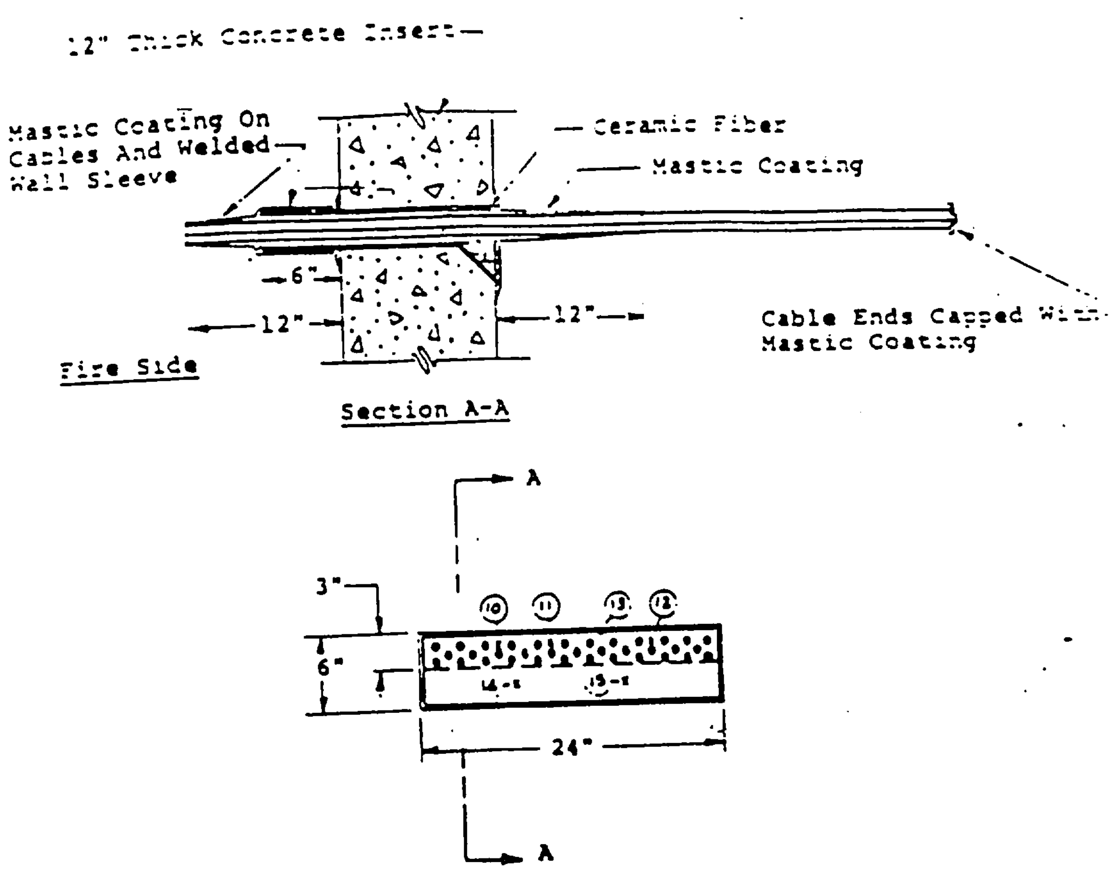


Section A-A



T.C. #25,26,27 - ON CABLE JACKET/MASTIC COATING INTERFACE
T.C. #28 - ON MASTIC COATING AT EDGE OF SLEEVE
T.C. #29 - ON MASTIC COATING AT CORNER OF SLEEVE
T.C. #30 - ON SLEEVE/CONCRETE INTERFACE

PENETRATION VOLUME - 1154 in^3 CABLE DIAMETER - .705 in. NUMBER OF CABLES - 59 (32.2% fill) CERAMIC FIBER AMOUNT - 4.07 lb. CERAMIC FIBER DENSITY - 9.5 pcf MASTIC COATING TYPE - FLAMEMASTIC F77	WALL TEST NO. PENETRATION NO. 1

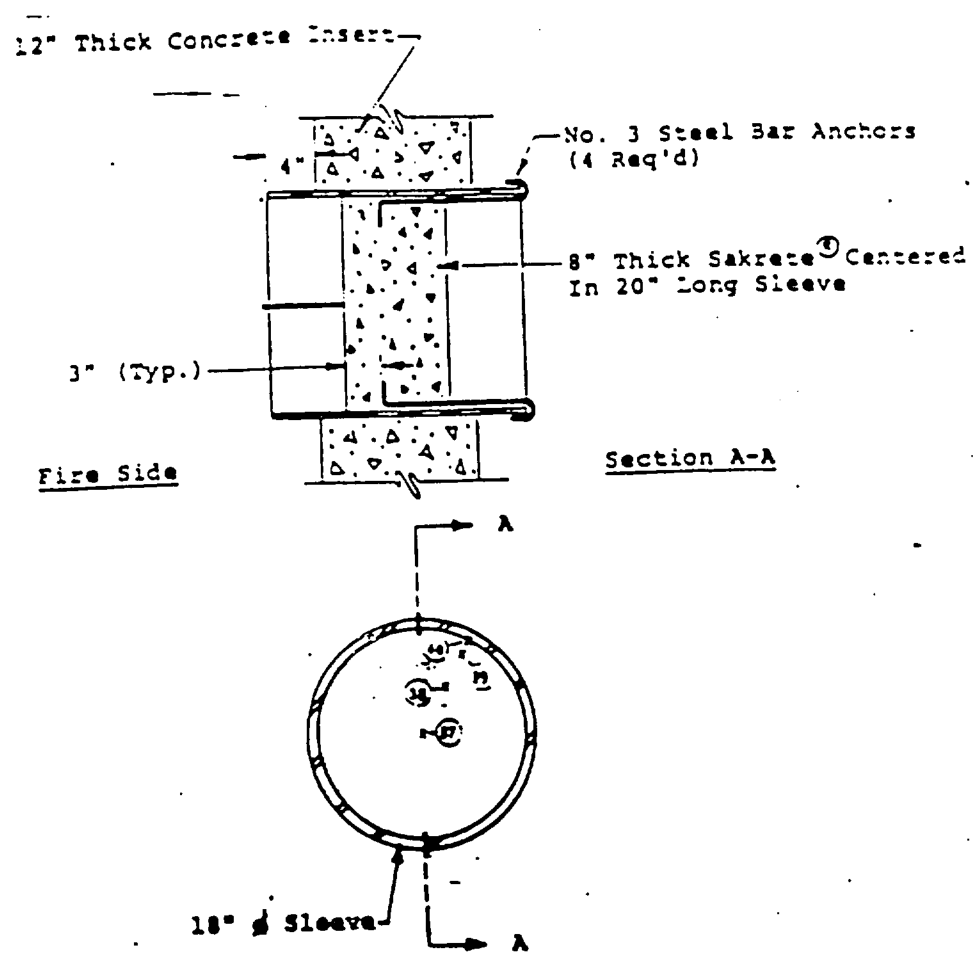


T.C.# 10, 11, 12 - ON CABLE JACKET/MASTIC COATING INTERFACE
T.C.# 13 - ON MASTIC COATING AT EDGE OF OPENING
T.C.# 14, 15 - ON MASTIC COATING BETWEEN CABLES AND EDGE OF OPENING

PENETRATION VOLUME - 1154 in^3
CABLE DIAMETER - .705 in.
NUMBER OF CABLES - 59 (39.2 % fill)
CERAMIC FIBER AMOUNT - 4.07 lb.
CERAMIC FIBER DENSITY - 9.5 pcf
MASTIC COATING TYPE - FLAMEMASTIC F77

WALL TEST NO. 1
PENETRATION NO. 2

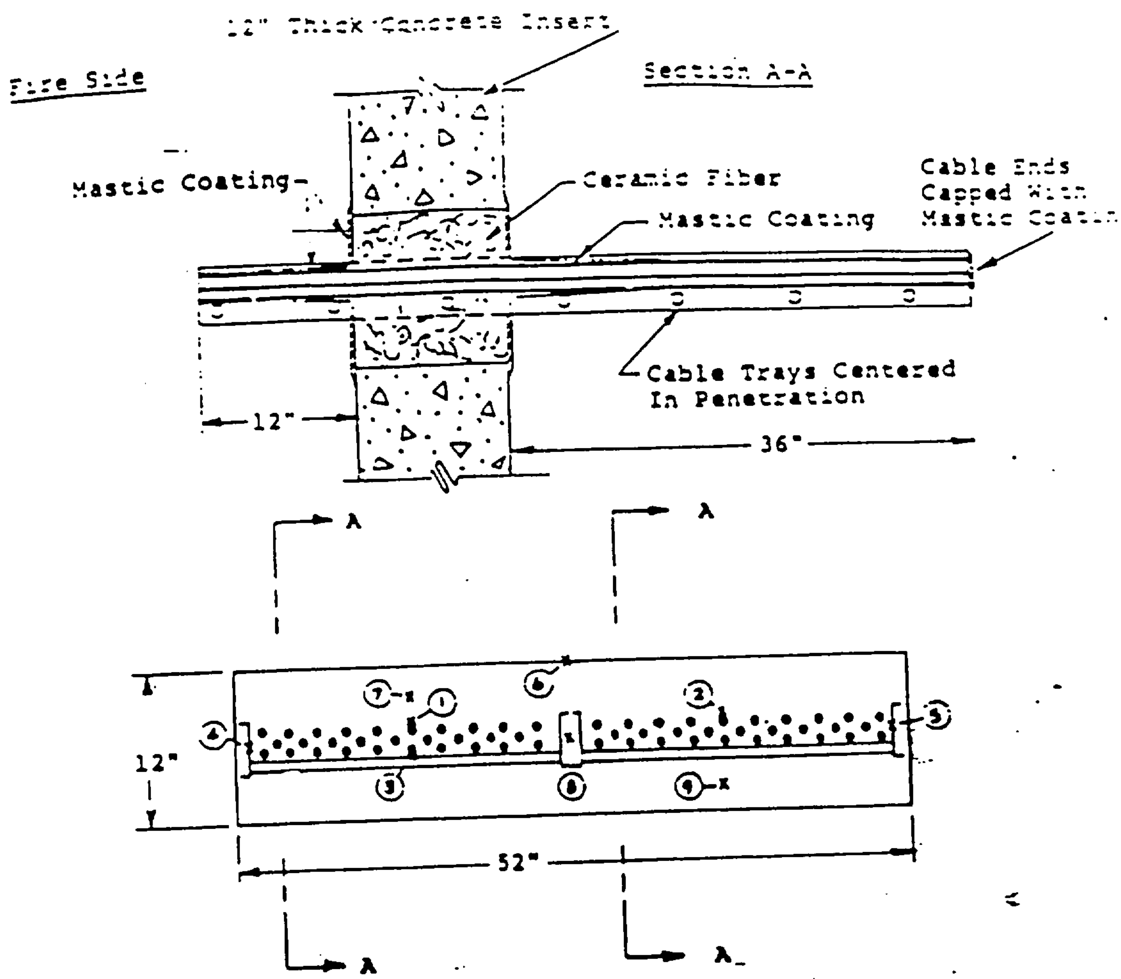
[redacted]



T.C.#37 - ON CONCRETE AT CENTER OF SLEEVE
T.C.#38 - ON CONCRETE 4½" FROM SLEEVE WALL
T.C.#39 - ON CONCRETE 1" FROM SLEEVE WALL
T.C.#40 - ON CONCRETE/SLEEVE INTERFACE

PENETRATION VOLUME - in³		WALL TEST NO. 1
CABLE DIAMETER - in.		PENETRATION NO. 3
NUMBER OF CABLES - (% fill)		
CERAMIC FIBER AMOUNT - lb.		
CERAMIC FIBER DENSITY - pcf		
MASTIC COATING TYPE - FLAMEMASTIC		

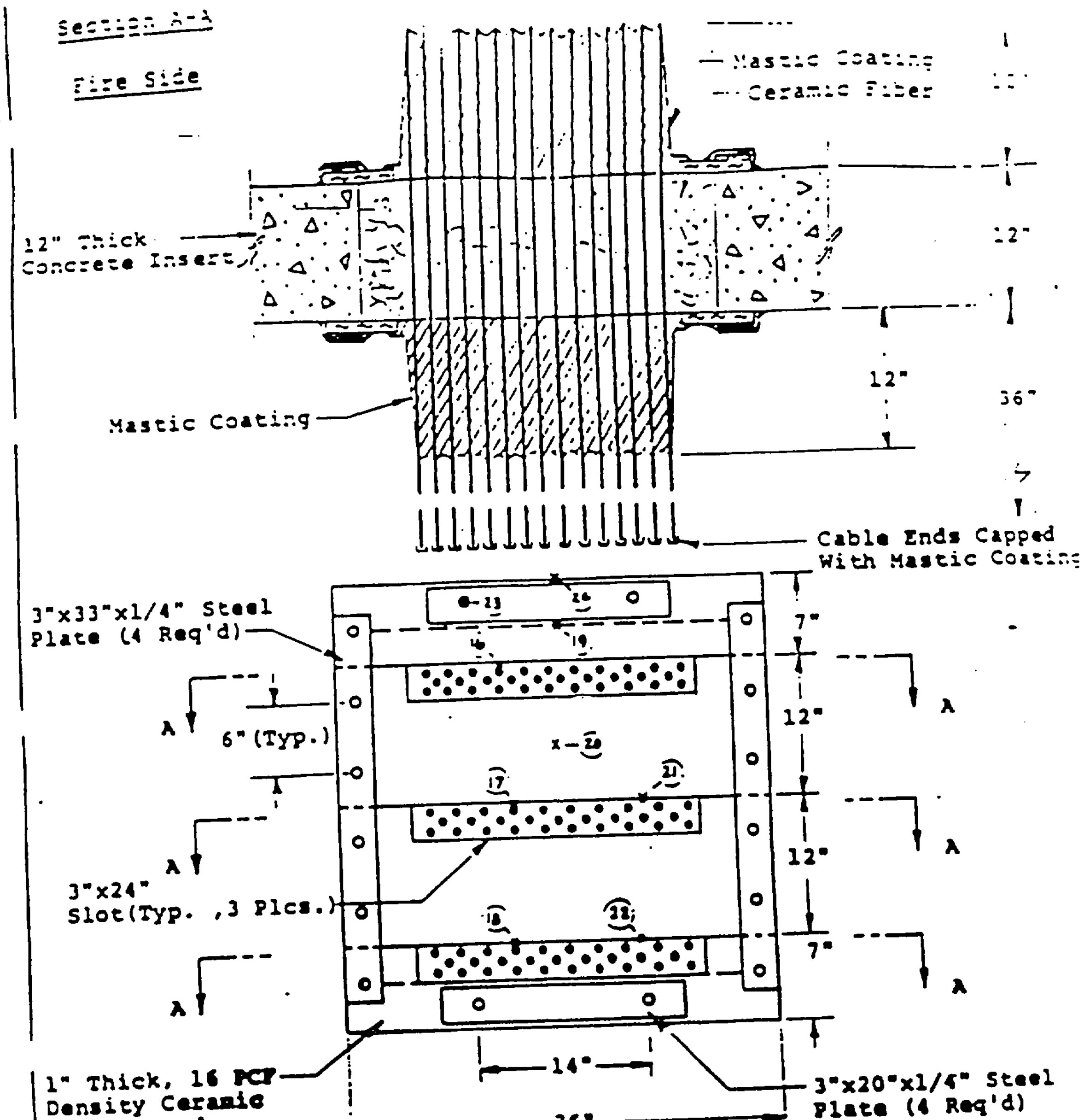
[redacted] III.2.G-292



T.C.# 1,2,3 - ON CABLE JACKET/MASTIC COATING INTERFACE
T.C.# 4,5 - ON CABLE TRAY/MASTIC COATING INTERFACE
T.C.# 6 - ON MASTIC COATING AT EDGE OF OPENING
T.C.# 7,9 - ON MASTIC COATING BETWEEN CABLES AND EDGE OF OPENING
T.C.# 8 - ON MASTIC COATING BETWEEN CABLE TRAYS

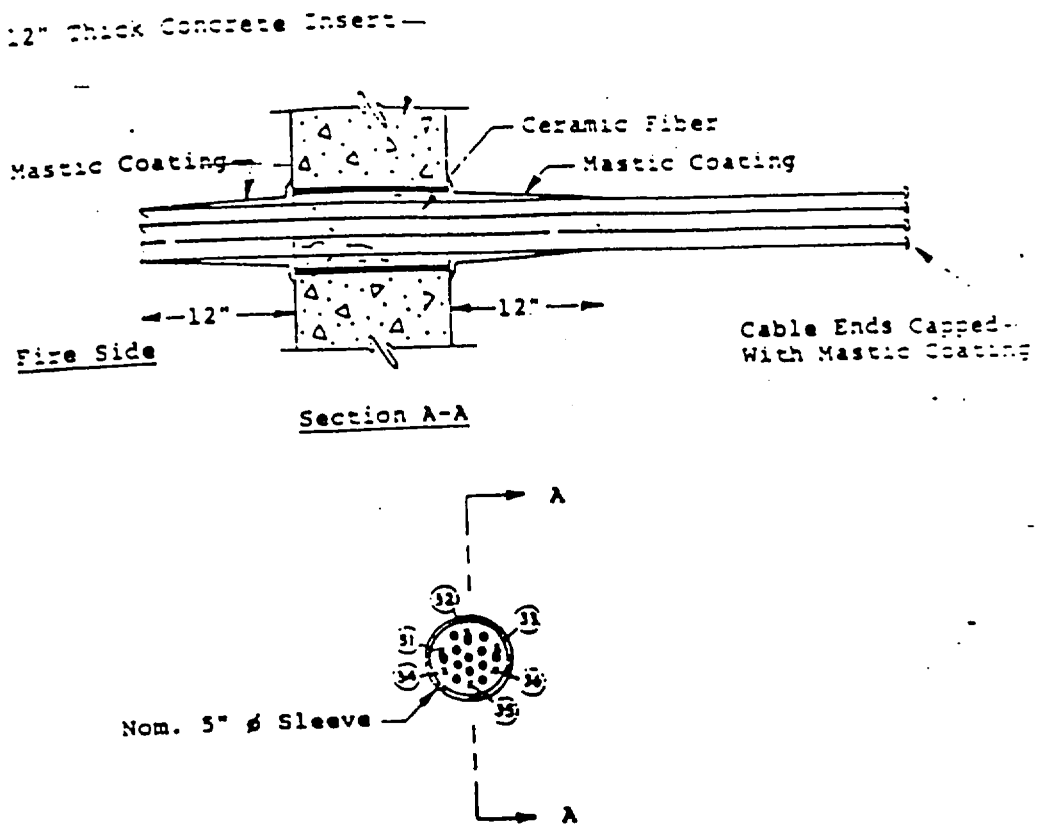
PENETRATION VOLUME - 7488 in^3 CABLE DIAMETER - .705 in. NUMBER OF CABLES - 198 (40.3% fill/tray) CERAMIC FIBER AMOUNT - 27.55 lb. CERAMIC FIBER DENSITY - 7.3 pcf MASTIC COATING TYPE - FLAMEMASTIC F77 - .234 in. (8 readings)	WALL TEST NO. I PENETRATION NO. 4

[redacted] III.2.G-293



T.C.#16,17 & 18 ON CABLE JACKET/MASTIC COATING INTERFACE. T.C.#24 ON CERAMIC FIBER BOARD/CONCRETE INTERFACE. REMAINING T.C.'s ON SURFACES DEPICTED.

PENETRATION VOLUME - 10,800 in^3 CABLE DIAMETER - .705 in. NUMBER OF CABLES - 177 (32.0% fill/slot) CERAMIC FIBER AMOUNT - 44.9 lb. CERAMIC FIBER DENSITY - 7.8 pcf MASTIC COATING TYPE - FLAMEMASTIC F77 AVG DRY COATING THKNS. EXP. SURF. - .244 in. (10 readings)	WALL TEST NO. PENETRATION NO. 5 [redacted] III.2.G-294 III 47

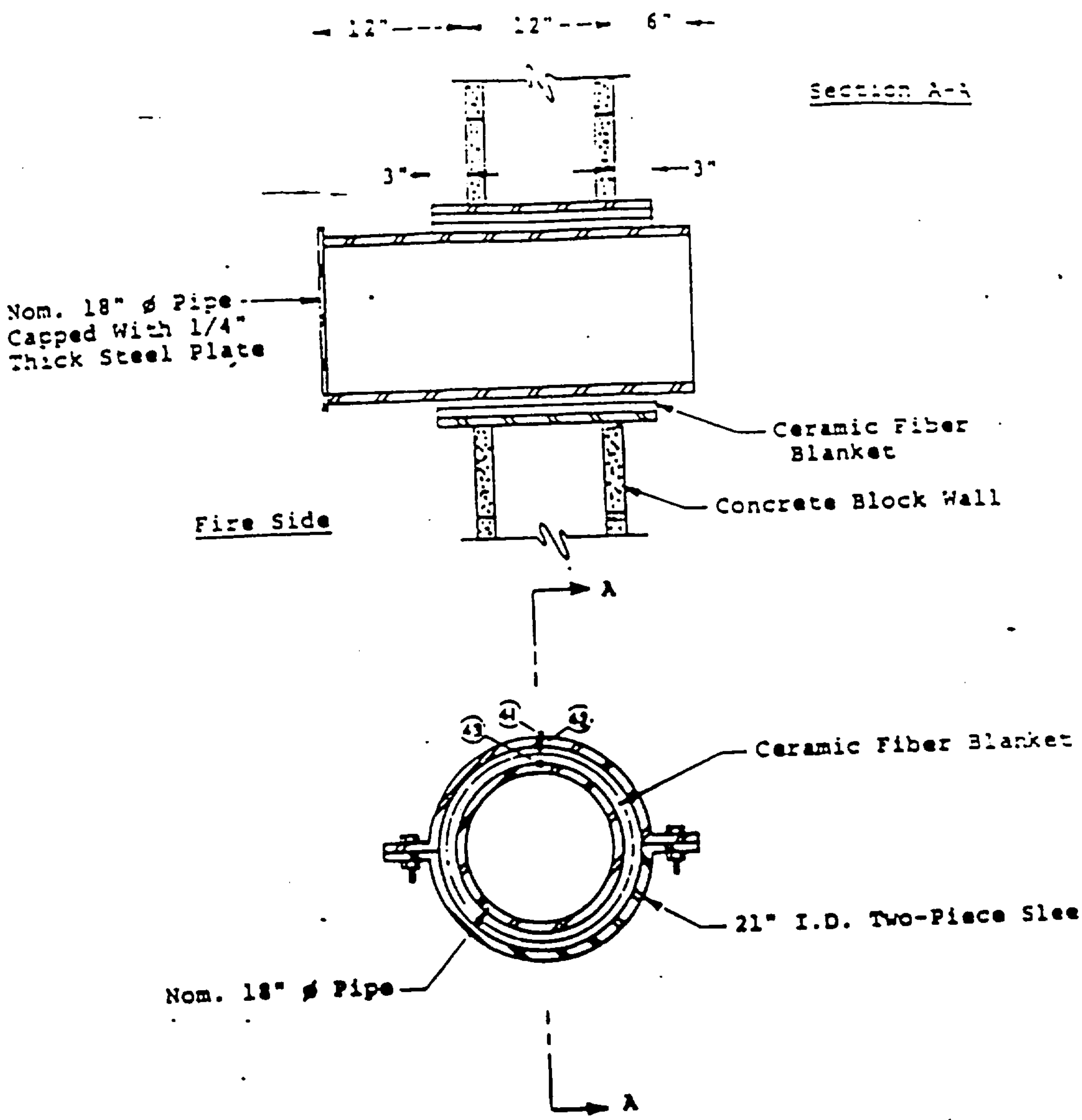


T.C.# 31,32,33 - ON CABLE JACKET/MASTIC COATING INTERFACE

T.C.# 34,35,36 - ON MASTIC COATING MIDWAY BETWEEN CABLES AND OPENING

PENETRATION VOLUME - 240 in^3 CABLE DIAMETER - .705 in. NUMBER OF CABLES - 16 (31.2% fill) CERAMIC FIBER AMOUNT - .65 lb. CERAMIC FIBER DENSITY - 6.8 pcf MASTIC COATING TYPE - FLAMEMASTIC F77 AVG DRY COATING THKNS EXP SURF. - .229 in. (3 readings)	WALL TEST NO. 1 PENETRATION NO. 6

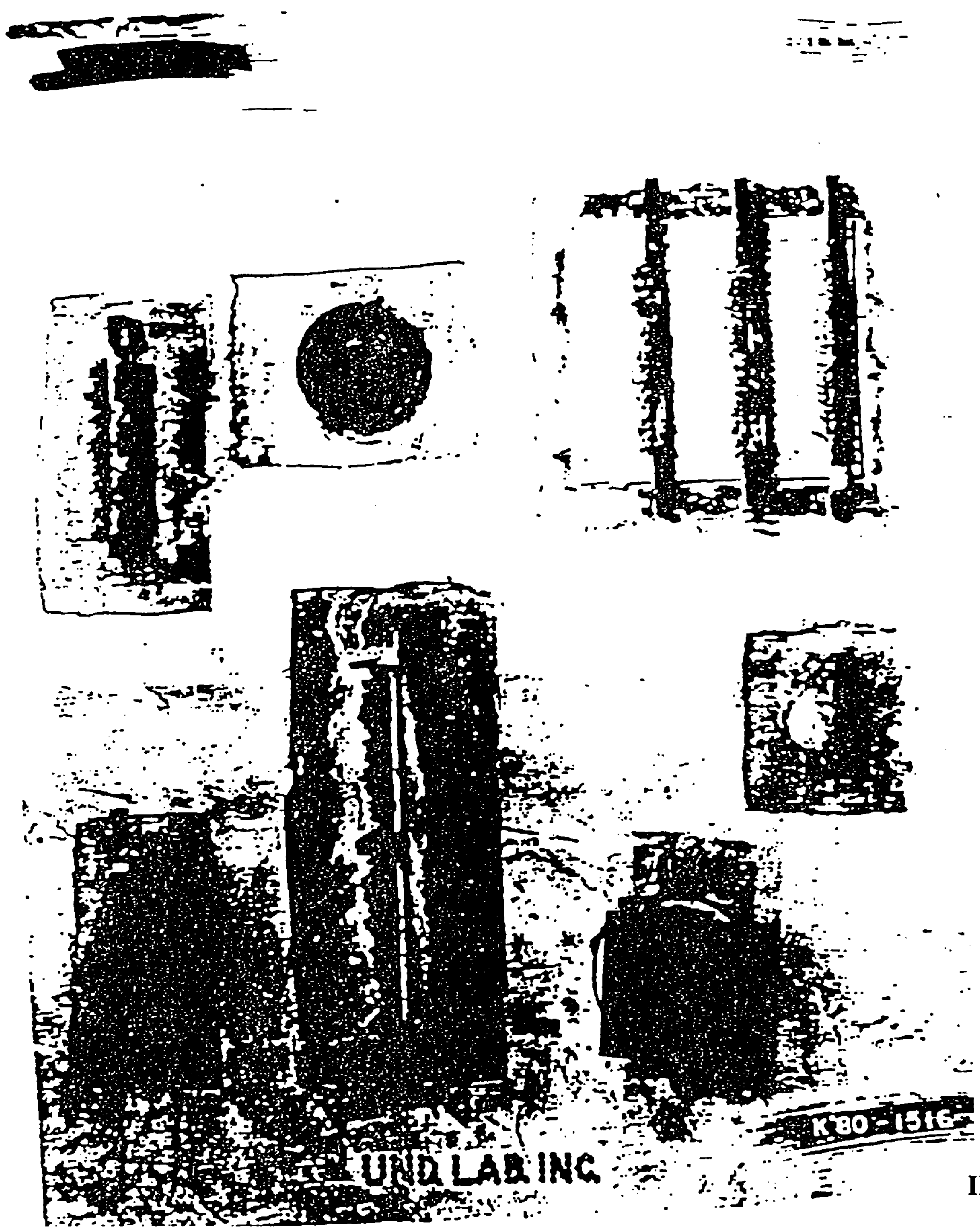
[redacted]

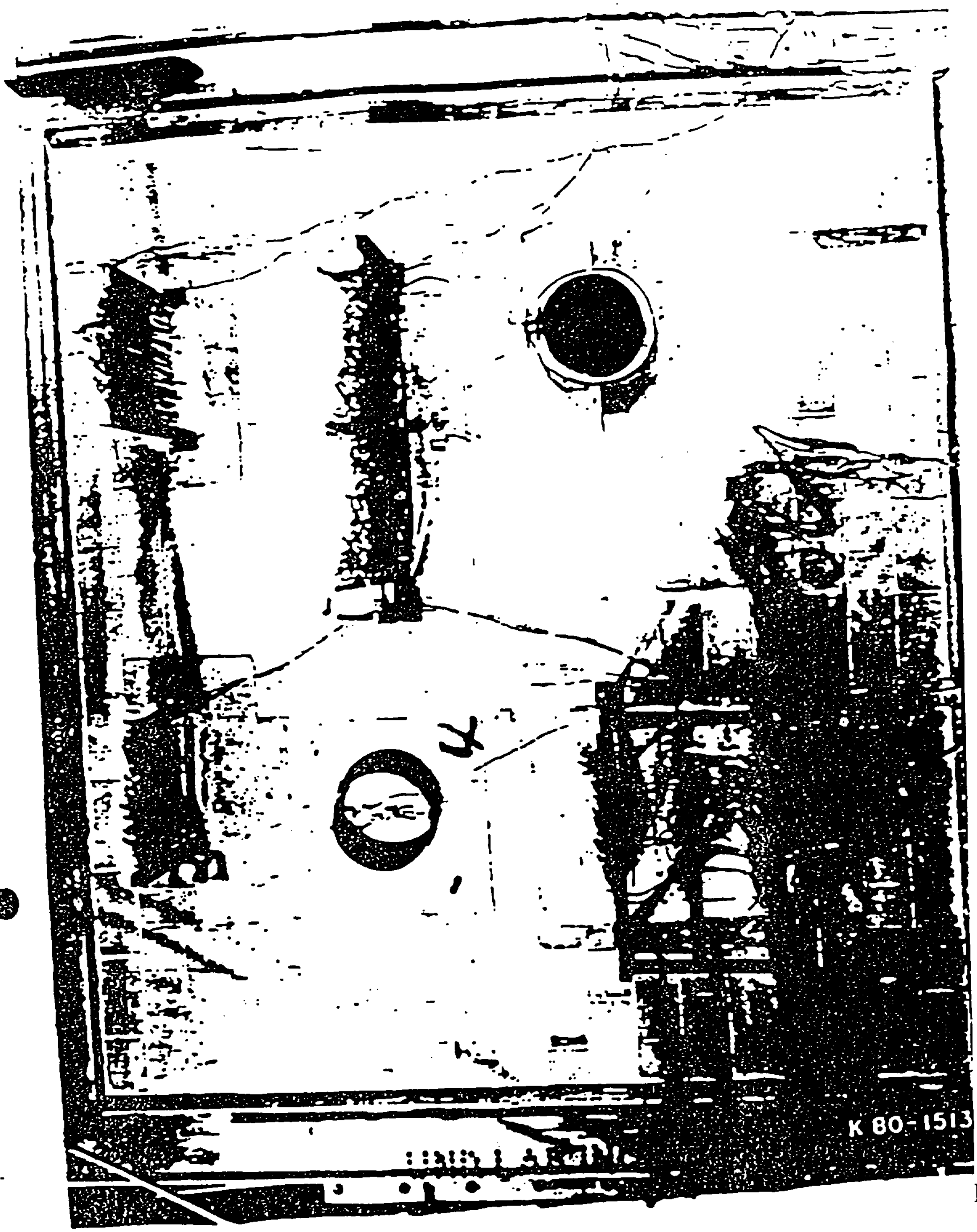


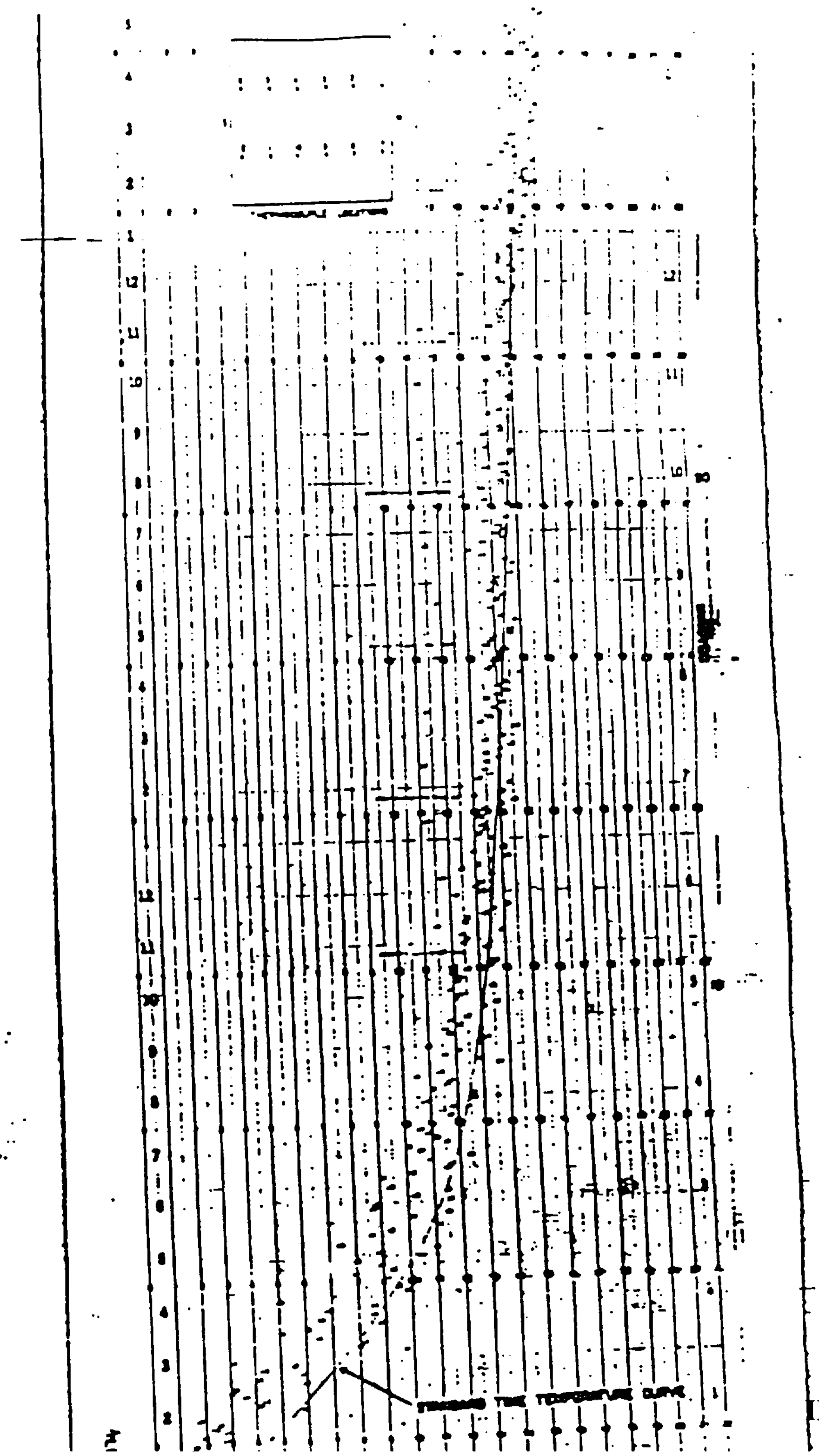
T.C.#41- ON SLEEVE/MASONRY INTERFACE
T.C.#42- ON CERAMIC FIBER BLANKET/SLEEVE INTERFACE
T.C.#43- ON PIPE/CERAMIC FIBER BLANKET INTERFACE

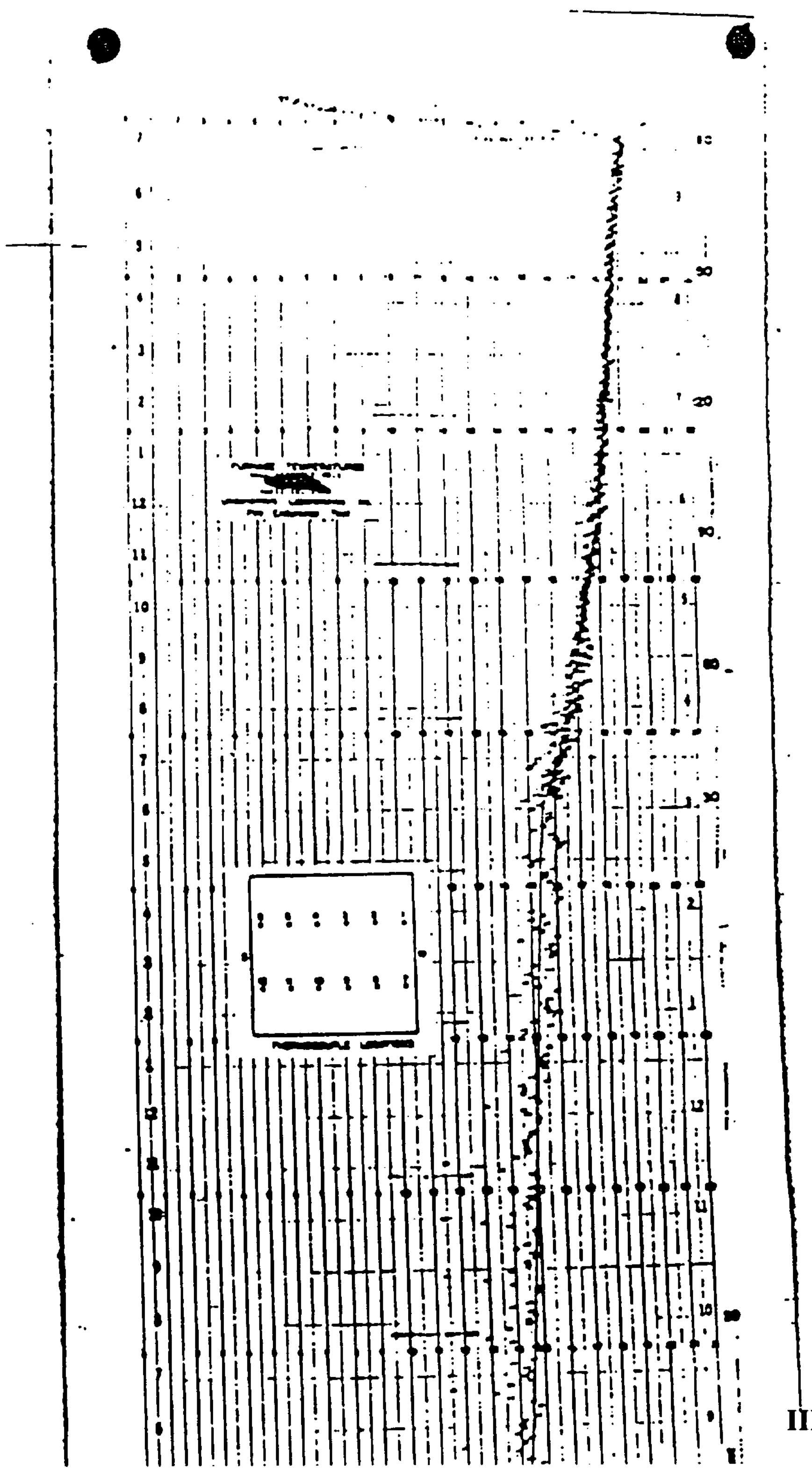
PENETRATION VOLUME - in³
CABLE DIAMETER - in.
NUMBER OF CABLES - (% fill)
CERAMIC FIBER AMOUNT - lb
CERAMIC FIBER DENSITY - pcf
FLAMEMASTIC

WALL TEST NO.
PENETRATION
NO. 7

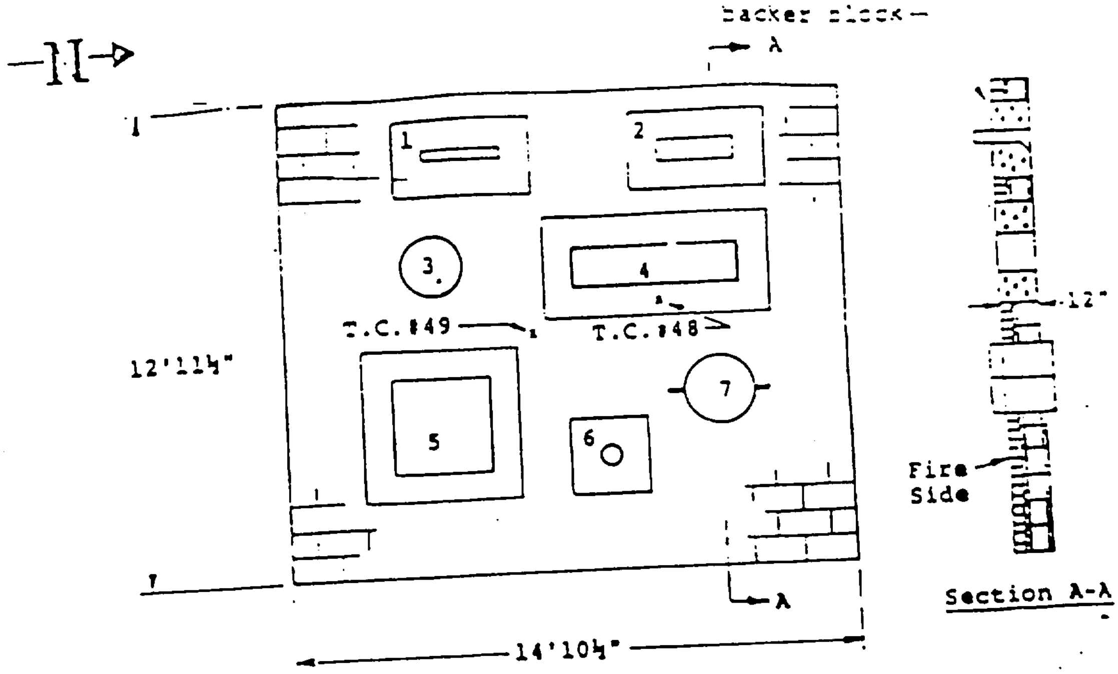

K80-1516
UND LAB INC


K 80-1513





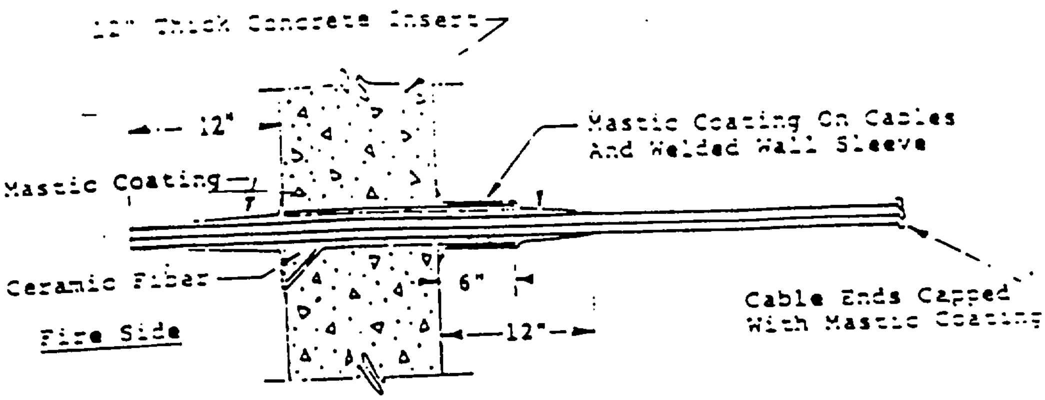
III.2.G-300



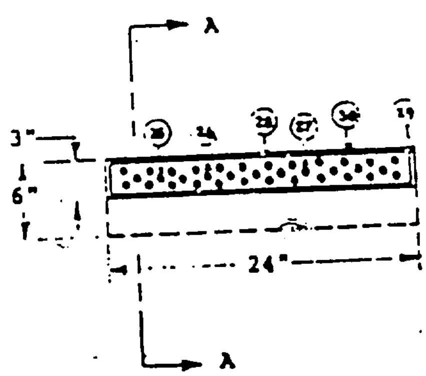
Construction Details - Wall Assembly No. 2

Penetration No.	Thermocouple Nos.	Construction Details And Thermocouple Locations
1	25-30	ILL. 54
2	10-15	ILL. 55
3	37-44	ILL. 56
4	1-9	ILL. 57
5	16-24	ILL. 58
6	31-36	ILL. 59
7	45-47	ILL. 60
Concrete	48	See above
Conc. Block	49	See above

[redacted]
ILL. 53



Section A-A

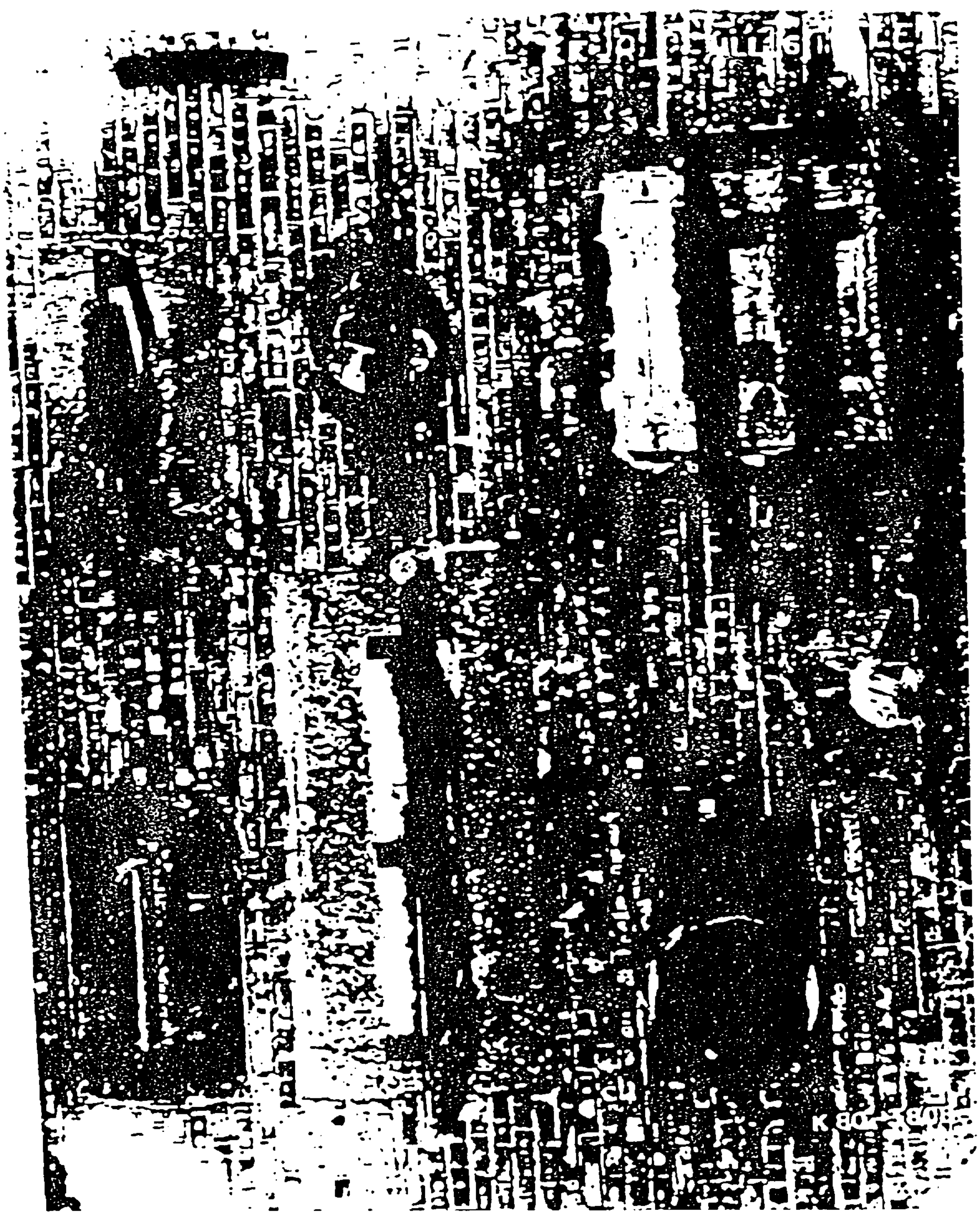


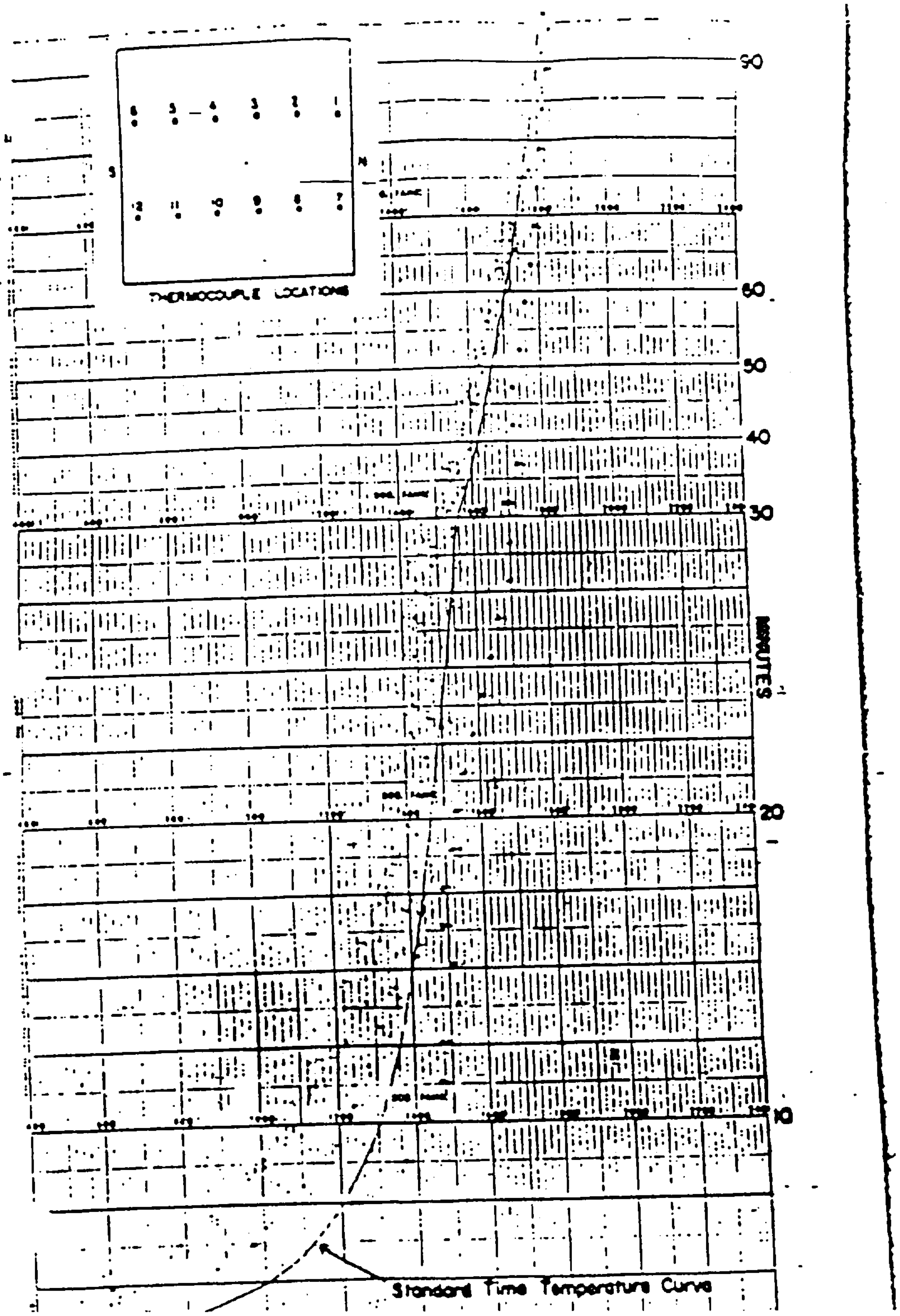
T.C.#25,26,27 - ON CABLE JACKET/MASTIC COATING INTERFACE
T.C.#28 - ON MASTIC COATING AT EDGE OF SLEEVE
T.C.#29 - ON MASTIC COATING AT CORNER OF SLEEVE
T.C.#30 - ON SLEEVE/CONCRETE INTERFACE

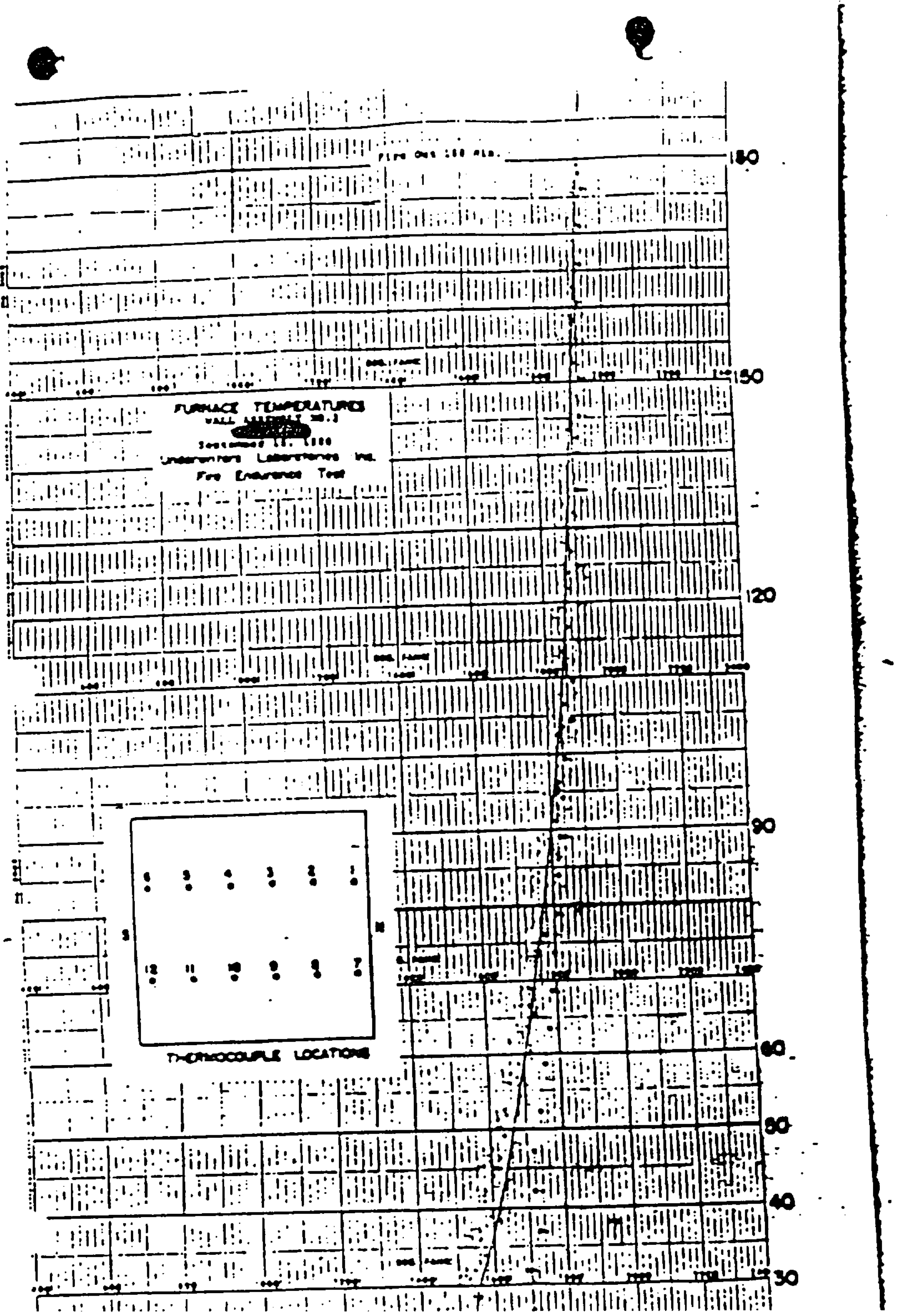
PENETRATION VOLUME - 1154 in^3
CABLE DIAMETER - .765 in.
NUMBER OF CABLES - 50 (39.1% fill)
CERAMIC FIBER AMOUNT - 2.24 lb.
CERAMIC FIBER DENSITY - 5.2 pcf

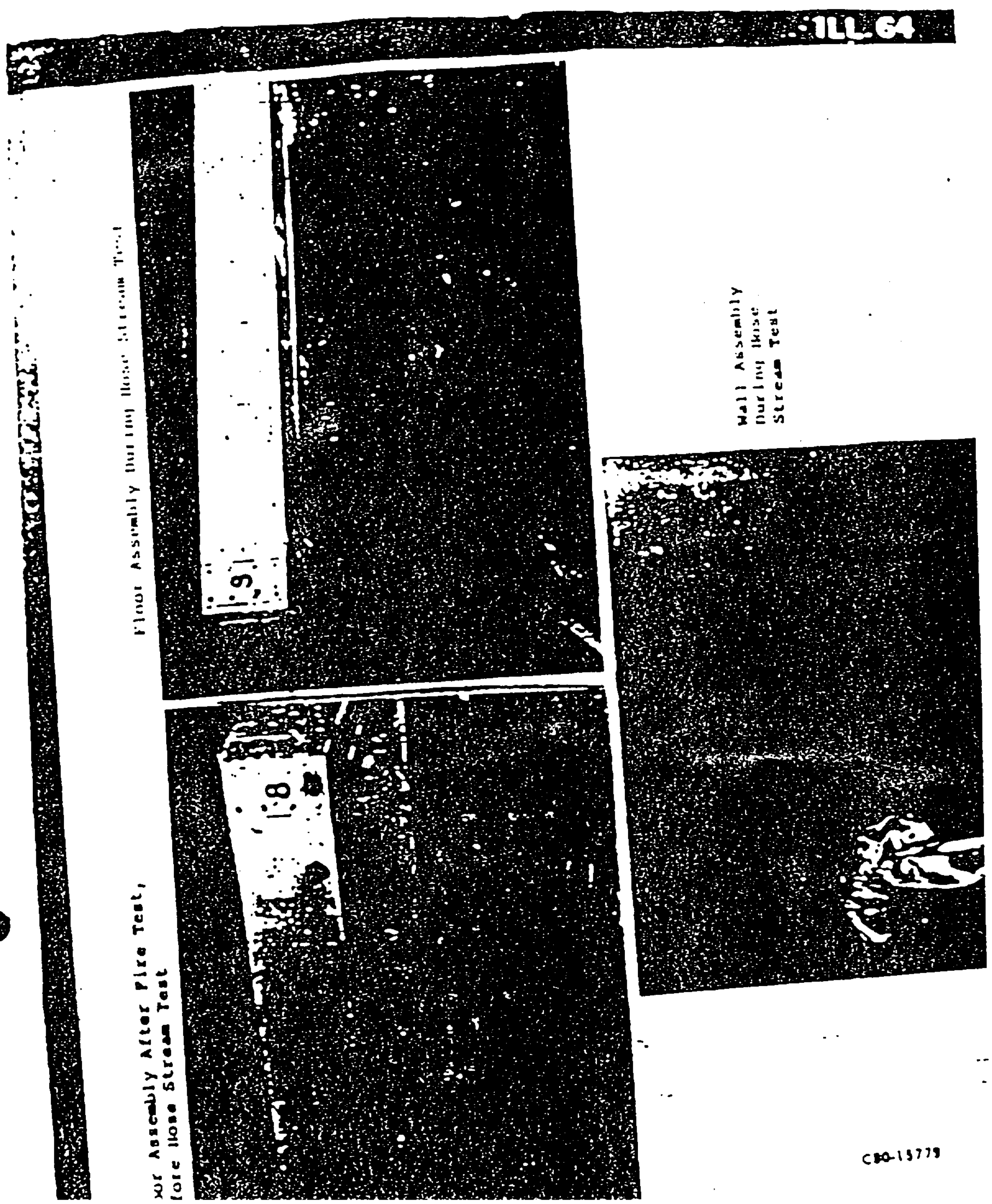
WALL TEST NO. - PENETRATION NO. 1

III.2.G-303

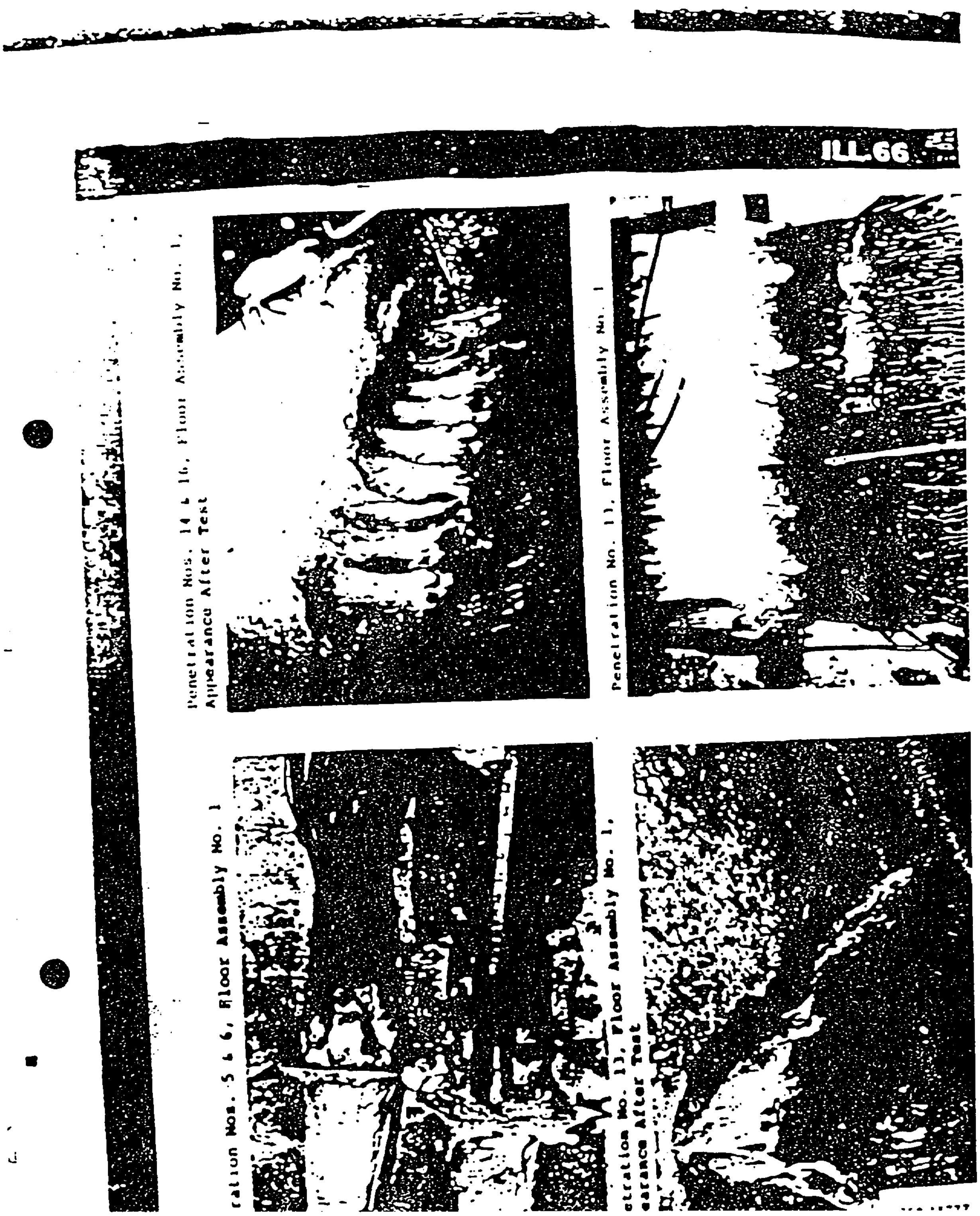



THERMOCOUPLE LOCATIONS
90
60
50
40
30
MINUTES
20
10
Standard Time Temperature Curve

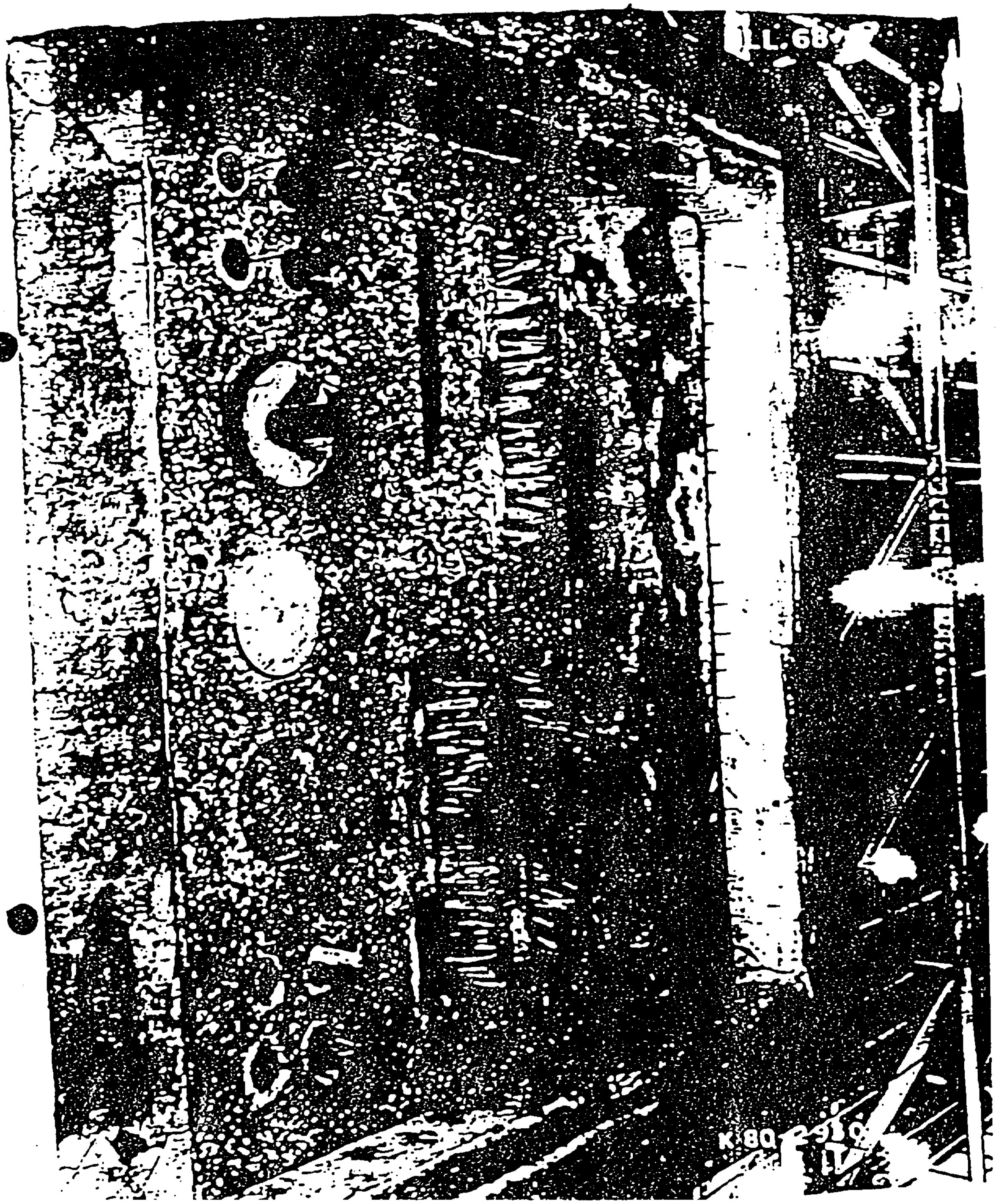

FURNACE TEMPERATURES
Underwriters Laboratories Inc.
Fire Endurance Test
THERMOCOUPLE LOCATIONS
150
120
90
60
50
40
30


ILL 64
Floor Assembly During Hose Stream Test
Wall Assembly During Hose Stream Test
Assembly After Fire Test,
Hose Stream Test


ILL.65
Penetration No. 11, Floor Assembly No. 1
Appearance After Test
Penetration No. 15, Floor Assembly No. 1
Unexposed Surface After Fire Test -
Floor Assembly No. 1
Penetration No. 15, Floor Assembly No. 1,
Appearance After Test
C10-15778


ILL.66
Penetration Nos. 14 & 16, Floor Assembly No. 1,
Appearance After Test
Penetration No. 13, Floor Assembly No. 1
ration Nos. 5 & 6, Floor Assembly No. 1
etration No. 13, Floor Assembly No. 1,
earance After Test


ILL-67
Penetration No. 14, Floor Assembly No. 1
...tration No. 16, Floor Assembly No. 1
...enetration Nos. 5, 6, 7 & 8, Floor Assembly No. 1, Appearance After Test


L.68
K 80

ILL 69

Penetration No. 14, Floor Assembly No. 2, Appearance After Test.

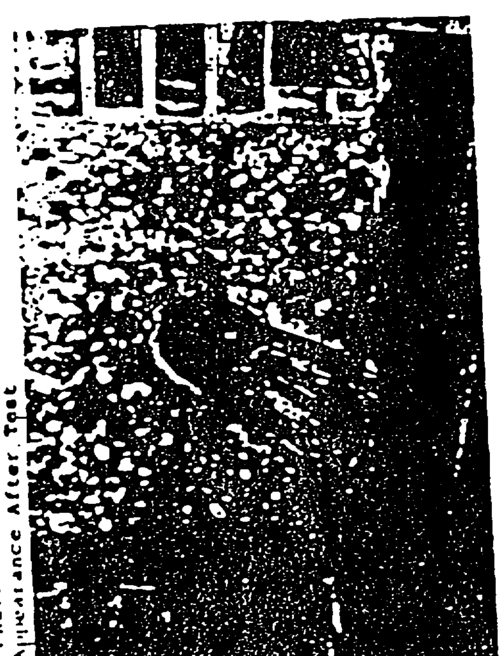
Penetration No. 10, Floor Assembly No. 2, Appearance After Test

Unexposed Surface After Fire & Hose Stream Tests - Floor Assembly No. 2

Penetration No. 10, Floor Assembly No. 2, Appearance After Test

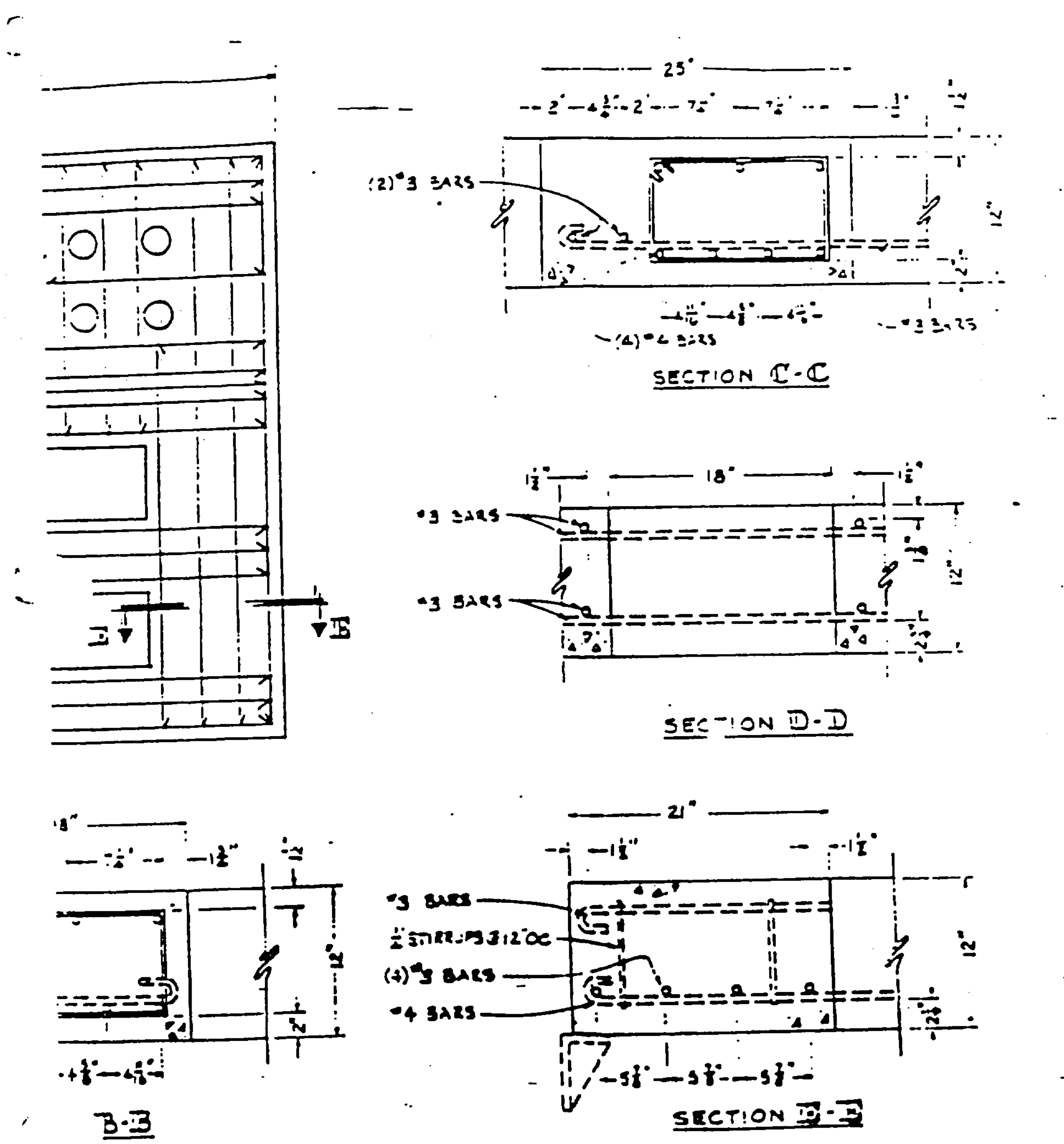
Penetration No. 6, Wall Assembly No. 2, Appearance After Test

Penetration No. 7, Wall Assembly No. 2, Appearance After Test

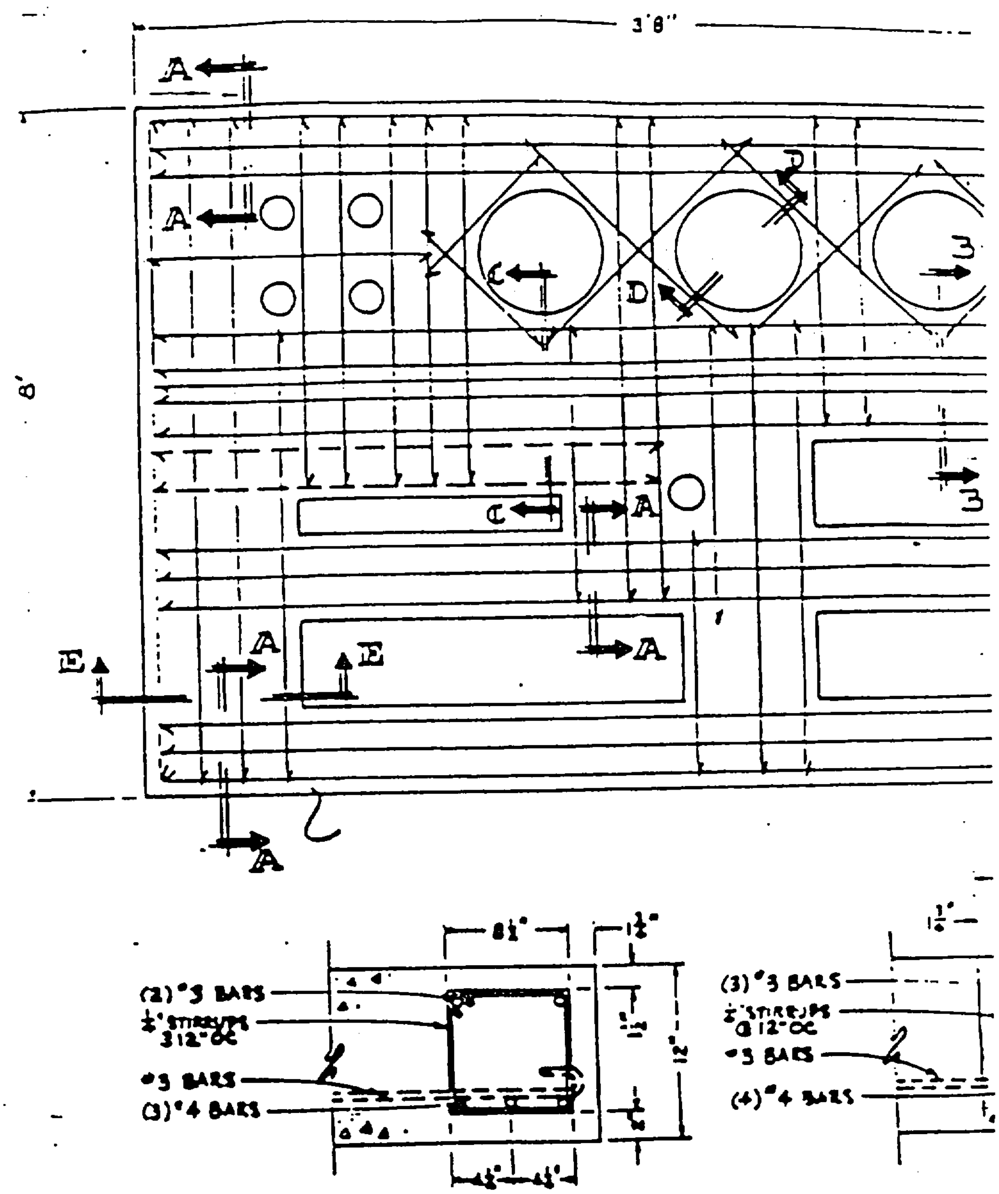


Penetration No. 6, Wall Assembly No. 2, Appearance After Test

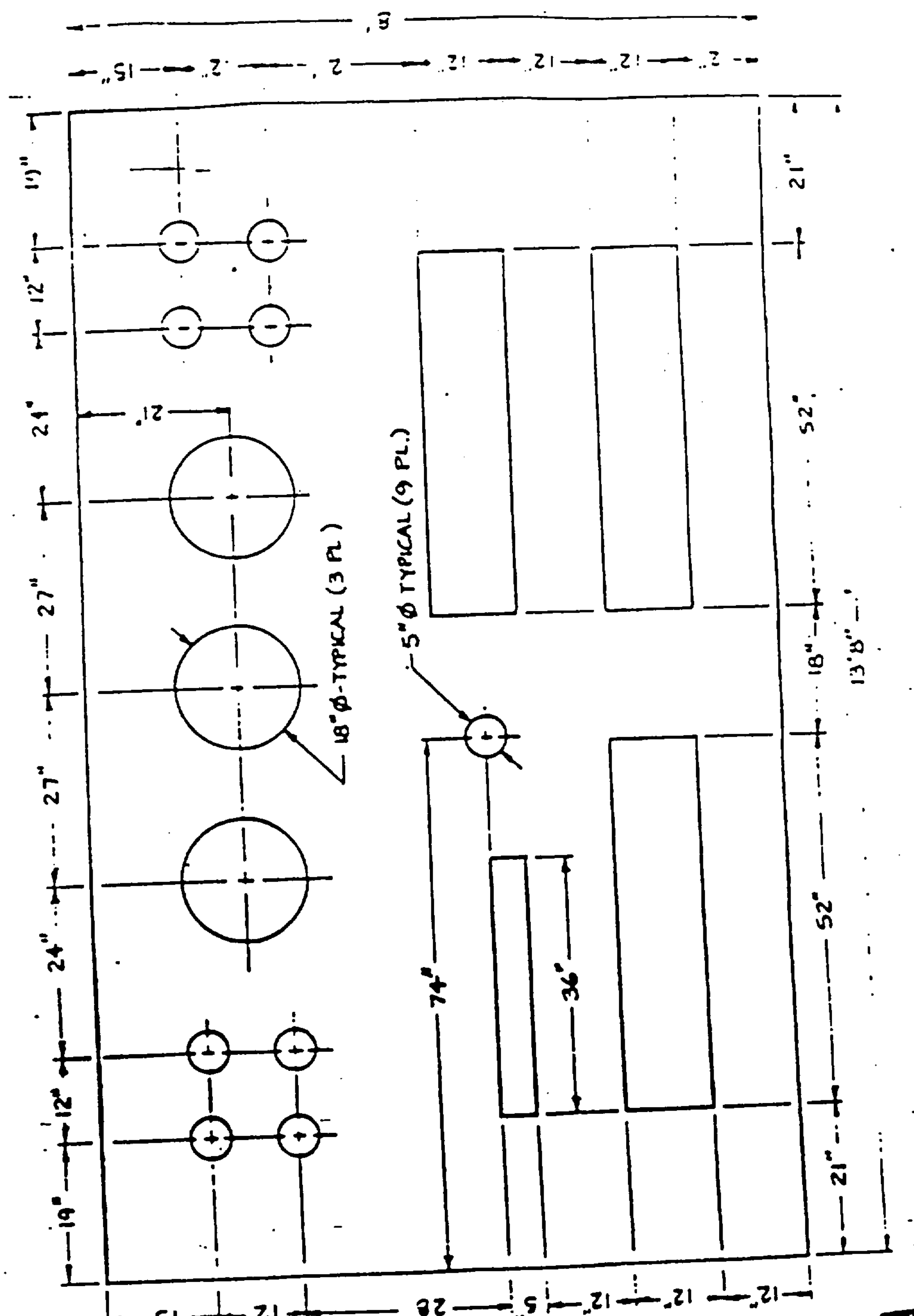
Penetration No. 6, Wall Assembly No. 2


25"
(2) #3 BARS
(4) #4 BARS
#3 BARS
SECTION C-C
18"
#3 BARS
#3 BARS
SECTION D-D
21"
#3 BARS
(4) #3 BARS
#4 BARS
SECTION E-E
B-B

[redacted]


3'8"
8'
A
C
D
E
(2) #3 BARS
½" STIRRUPS @ 12" OC
#3 BARS
(3) #4 BARS
(3) #3 BARS
(4) #4 BARS
8½"
1½"
12"

SECTION A-A


18"Ø-TYPICAL (3 PL.)
5"Ø TYPICAL (9 PL.)
13'8"
74"
36"
52"
21"
18"
24"
27"
12"
19"

APPENDIX B

B. CONCRETE WALL INSERT DESIGN

B.1 DESIGN OF REINFORCED CONCRETE:

The nominal 12 in. (305 mm) thick reinforced concrete wall inserts were designed in accordance with the recommendations of the American Concrete Institute to provide a minimum 3 hr fire resistance.

B.2 MATERIALS:

Concrete - The ready-mixed concrete, obtained from a local source, was composed of one part Type I Portland cement, 2.1 parts sand, and 3.2 parts gravel (siliceous aggregate) by bulk volume, mixed with approximately 8.4 gal (31.8 l) of water per bag of cement. The average strength and density of the concrete, as determined from four standard 6 by 12 in. (152 by 305 mm) cylinders aged 28 days, were 4490 psi (3.10×10^7 n/m^2) and 153.8 pcf (2.42×10^4 n/m^3), respectively. The strength ranged from 4400 to 4560 psi (3.03×10^7 to 3.14×10^7 n/m^2). The density ranged from 153.1 to 154.5 pcf (2.40×10^4 to 2.43×10^4 n/m^3). The average slump during placement was 6-7/8 in. (175 mm).

Reinforcement - The reinforcement for the concrete wall inserts consisted of No. 3 deformed steel bars (ASTM A36 steel). The reinforcement bars were shop-fabricated by a local source.

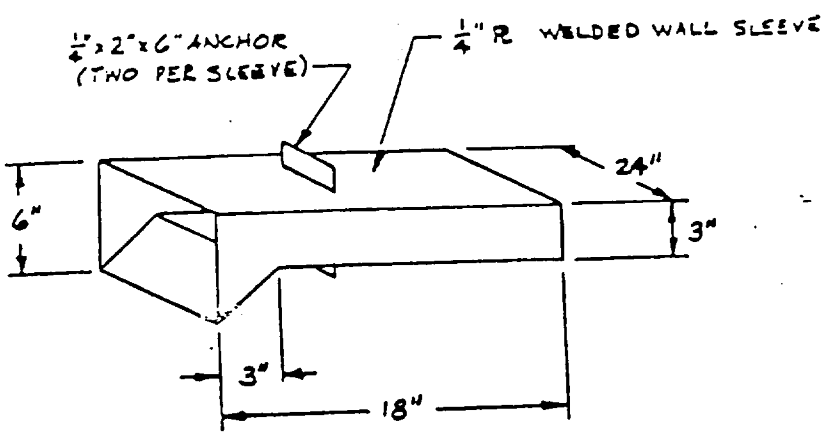
Sleeves - Two sizes of pipe and welded rectangular assemblies were used as sleeves in the concrete wall inserts. The sleeve for Penetration No. 6 was a nominal 5 in. (127 mm) diameter steel Schedule 40 pipe, 12 in. (305 mm) long, having an inside diameter of 5.047 in. (128 mm) and a wall thickness of 0.258 in. (6.55 mm). The sleeve was provided with three 8 by 1-1/2 by 3/16 in. (203 by 38 by 4.76 mm) thick steel anchor plates welded to the outside of the sleeve at the sleeve mid-height with 3/16 in. (4.76 mm) fillet welds.

The welded rectangular sleeves for Penetration Nos. 1 and 2 were formed from ~~1/4~~ in. (6.4 mm) steel plate, as shown in ILL. B1. Each sleeve was provided with two 2 by 6 by 1/4 in. (51 by 152 by 6.4 mm) thick steel anchor plates welded to the outside of the sleeve, at the sleeve mid-depth, with 3/16 in. (4.76 mm) fillet welds.

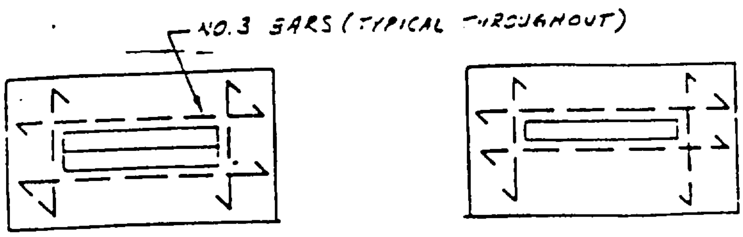
B.3 CONSTRUCTION:

The concrete wall inserts were each constructed on the floor in a lumber framework. For Penetration Nos. 1 and 2, the sleeves were centered in the lumber framework with their splayed end down such that 6 in. (152 mm) of the narrow end would protrude from the concrete. For Penetration No. 6, the pipe sleeve was placed, vertically, in the center of the lumber framework and was filled with sand so as to exclude concrete from the interior of the pipe sleeve. For Penetration No. 3, a plywood platform was constructed within the lumber framework such that the sleeve was centered in the lumber framework and such that both ends of the pipe sleeve would protrude 4 in. (102 mm) from the concrete wall insert. For Penetration Nos. 4 and 5, lumber forms for the rectangular and square openings, respectively, were fabricated and centered in the lumber frameworks.

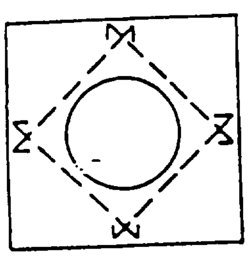
The concrete was placed in each lumber framework, internally vibrated, and was finished to a smooth, flat surface with a trowel and wood float. The reinforcement bars were embedded in the concrete during its placement such that a set of the reinforcement bars was located approximately 1-1/2 in. (38.1 mm) from the exposed and unexposed surfaces of each concrete wall inserts, as shown in ILL. B2.



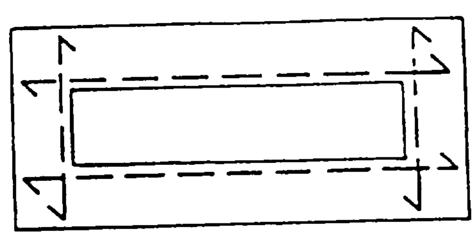
WELDED WALL SLEEVE FOR PENETRATION
NOS. 1 AND 2 - WALL ASSEMBLIES 1 AND 2



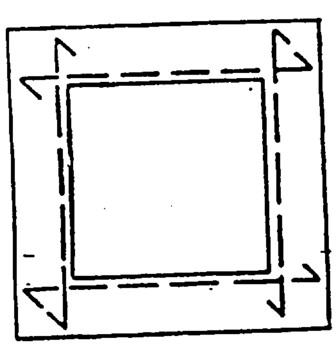
REINFORCEMENT DETAILS, PENETRATION NOS. 1 AND 2



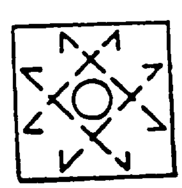
REINFORCEMENT DETAILS, PENETRATION NO. 3 (WALL ASSEMBLY NO. 1 ONLY)



REINFORCEMENT DETAILS, PENETRATION NO. 4



REINFORCEMENT DETAILS, PENETRATION NO. 5



REINFORCEMENT DETAILS, PENETRATION NO 6

APPENDIX C

C. CALIBRATION RECORDS

C.1 SCALE:

The scale used throughout the investigation was "Toledo Honest Weight," Model No. 4030, Serial No. 7043, UL Instrument No. 4FB5MS. The scale calibration was checked by a Toledo Scale representative on July 23, 1979, January 4, 1980, March 21, 1980, and May 28, 1980.

C.2 FURNACE TEMPERATURE RECORDERS:

C.2.1 FLOOR FURNACE TEMPERATURE RECORDER

The temperature recorded used for both floor fire tests was Leeds & Northrup, Model No. G, Serial No. 58-32931-1-1, UL Instrument No. 6FB5TR. The recorder calibration was checked by a Leeds & Northrup representative on June 19, 1979, December 14, 1979, and October 16, 1980.

C.2.2 WALL FURNACE TEMPERATURE RECORDER

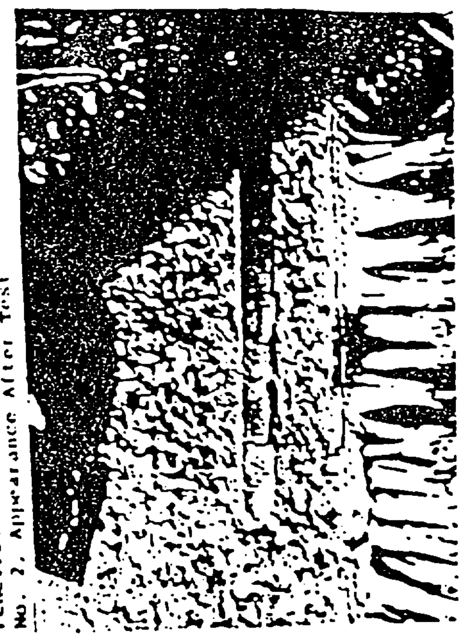
The temperature recorder used for the first wall fire test (NC601-2) was Honeywell, Model No. Y112-74180-58020-00000-00-00000-(106)-18, UL Instrument No. 30FD5TR. The recorder calibration was checked by a Honeywell representative on March 31, May 1, and June 27, 1980.

The temperature recorder used for the second wall fire test (NC601-4) was the same recorder used for the two floor fire tests.

C.3 DIGITAL DATA ACQUISITION SYSTEM:

The digital data acquisition system used throughout the investigation was Accurex Autodata Nine, Serial No. 1-763. The recorder calibration was checked by an Accurex representative on September 8, 1979, and February 27, 1980.

Penetration No. 7, Floor Assembly No. 2, Appearance After Test



Penetration Nos. 11 & 15, Floor Assembly No. 2, Appearance After Test

Penetration Nos. 1, 2, 3 & 4, Floor Assembly No. 2, Appearance After Test

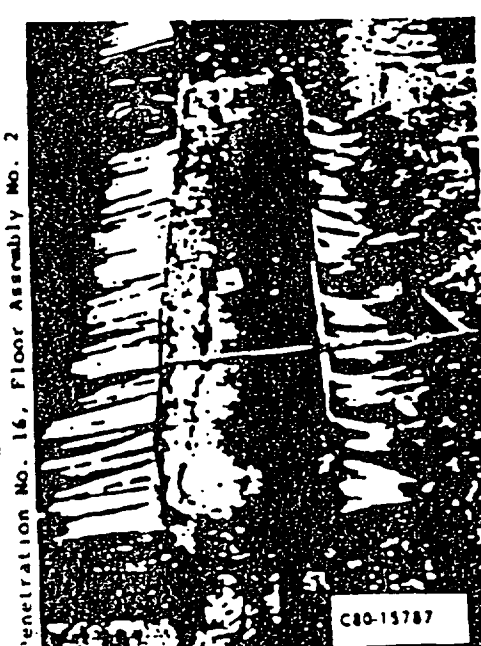
Penetration No. 3, Floor Assembly No. 2

ILL-71

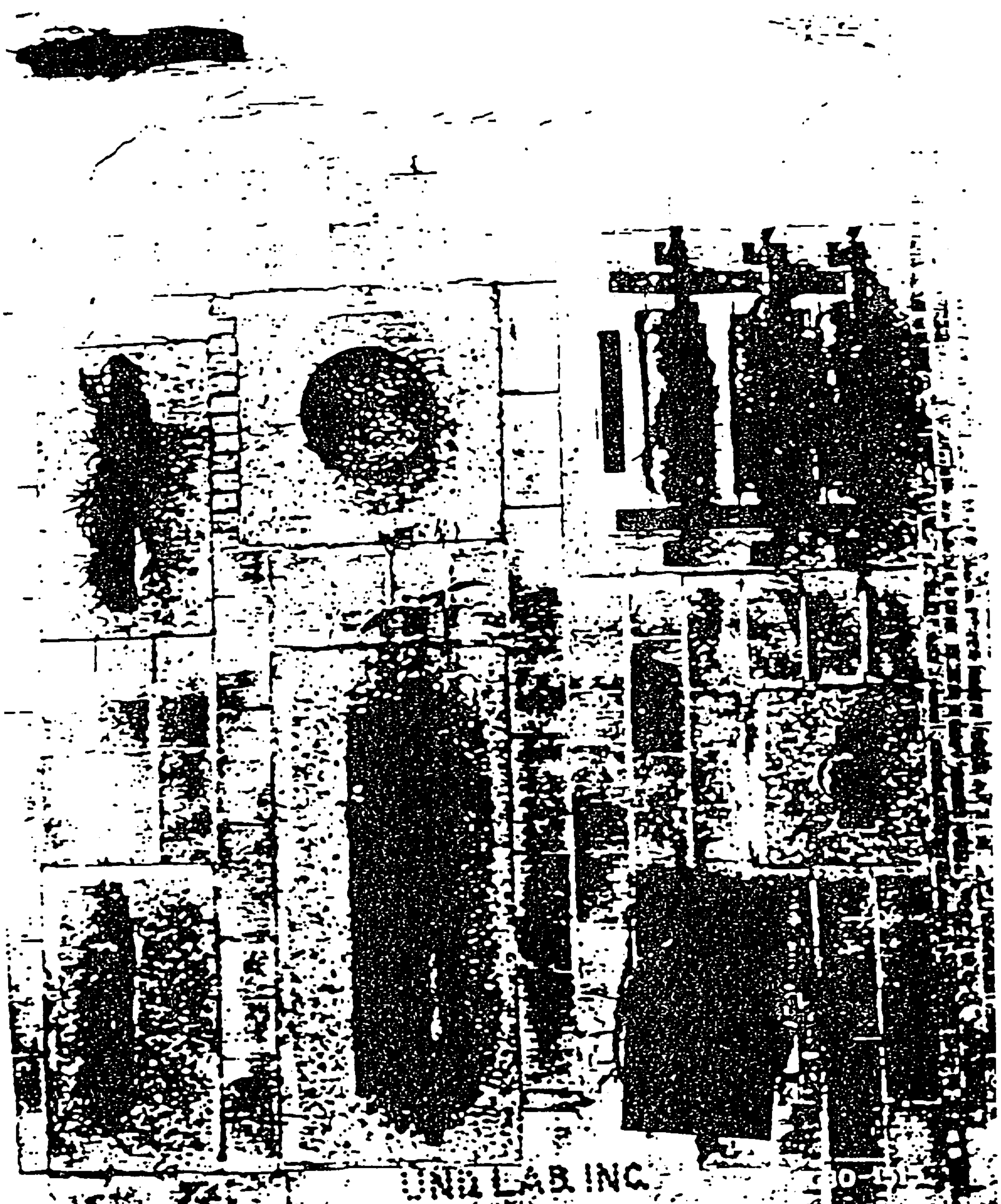
Penetration No. 16, Floor Assembly No. 2, Appearance After Test

Penetration No. 14, Floor Assembly No. 2, Appearance After Test

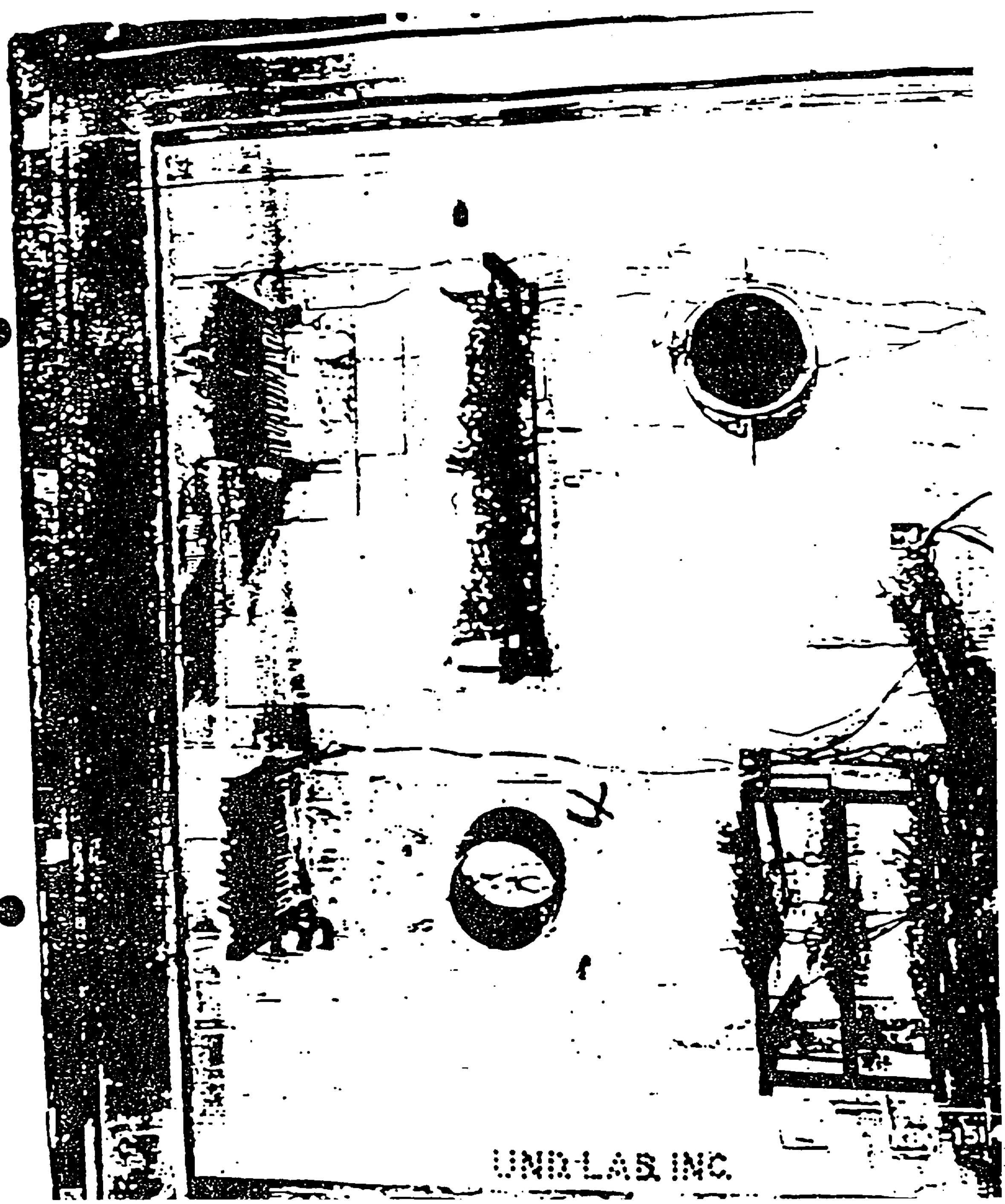
Penetration No. 16, Floor Assembly No. 2, Appearance After Test



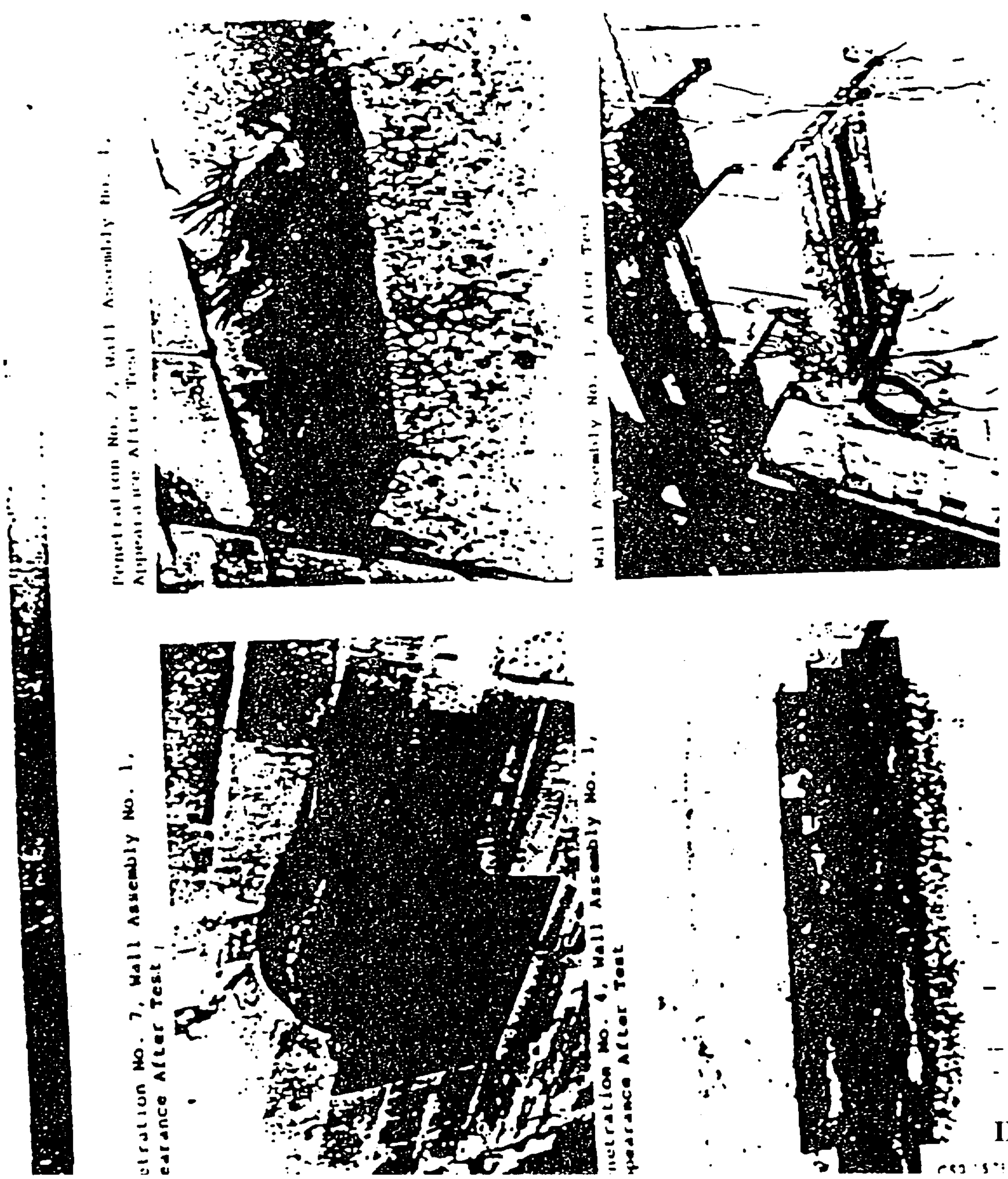
Penetration No. 16, Floor Assembly No. 2



III.2.G-324



II.2.G-325



Penetration No. 2, Wall Assembly No. 1, Appearance After Test

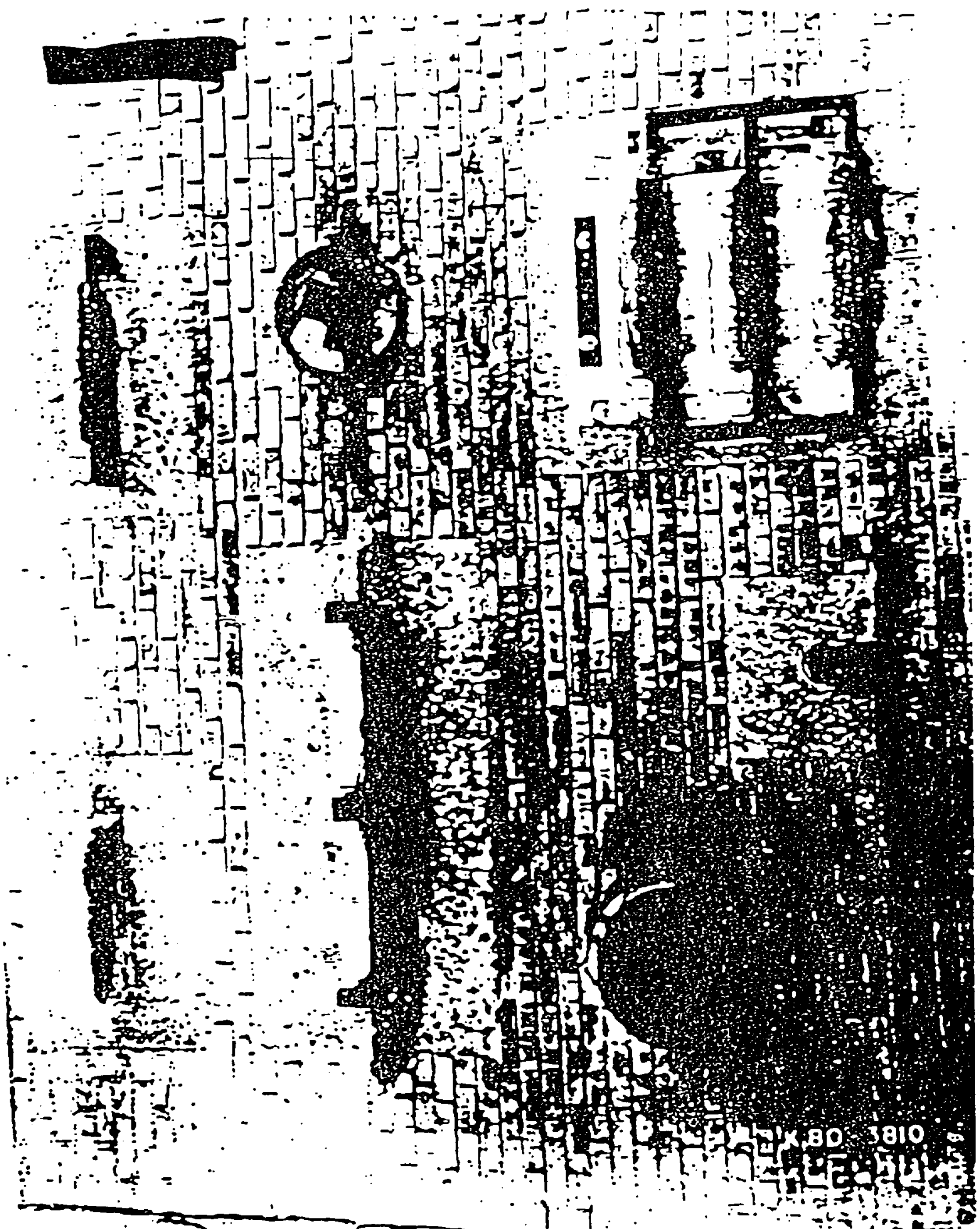
Wall Assembly No. 1, After Test

etration No. 7, Wall Assembly No. 1, earance After Test

netration No. 4, Wall Assembly No. 1, pearance After Test

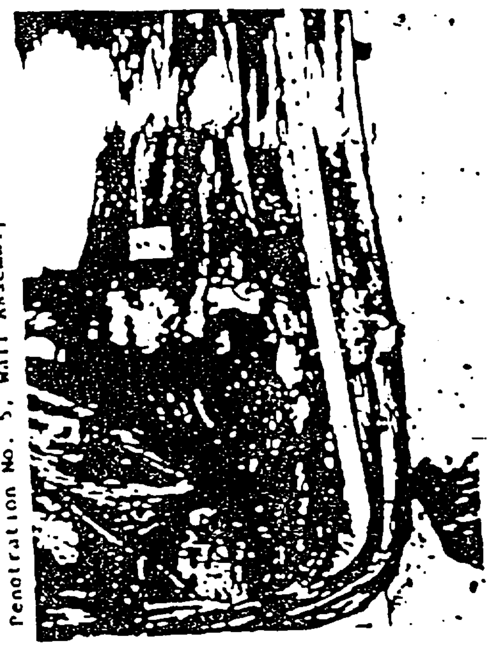
netration No. 5, Wall Assembly No. 1, Appearance After Test

Penetration No. 5, Wall Assembly No. 1, Appearance After Test


X80 3810


K80-381

Penetration No. 5, Wall Assembly No. 2, Appearance After Test



Penetration No. 5, Wall Assembly No. 2

Penetration No. 5, Wall Assembly No. 2, Appearance After Test

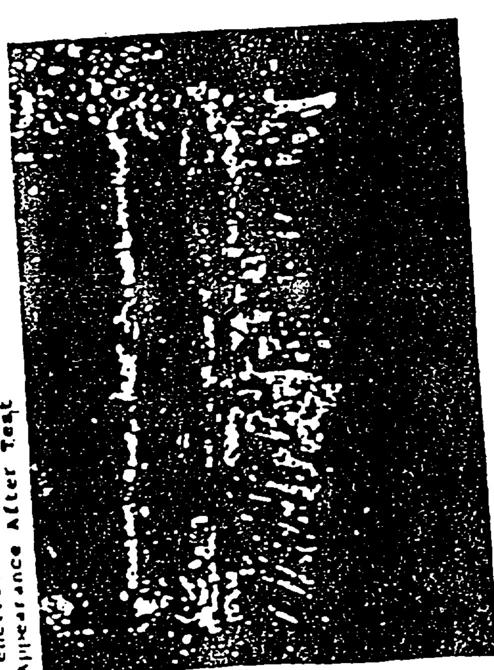
Penetration No. 5, Wall Assembly No. 2, Appearance After Test

C80-15'84

ILL-79

Penetration No. 2, Wall Assembly No. 2, Appearance After Test

Penetration No. 3, Wall Assembly No. 2, Appearance After Test

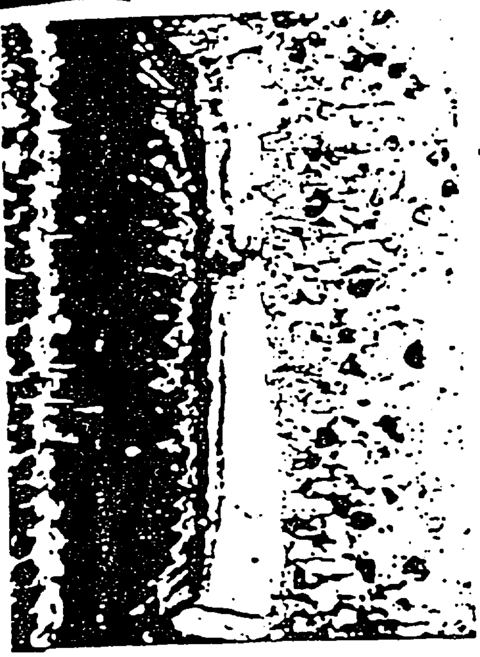


Penetration No. 2, Wall Assembly No. 2, Appearance After Test

Penetration No. 2, Wall Assembly No. 2

C80-1578

ILL-80-



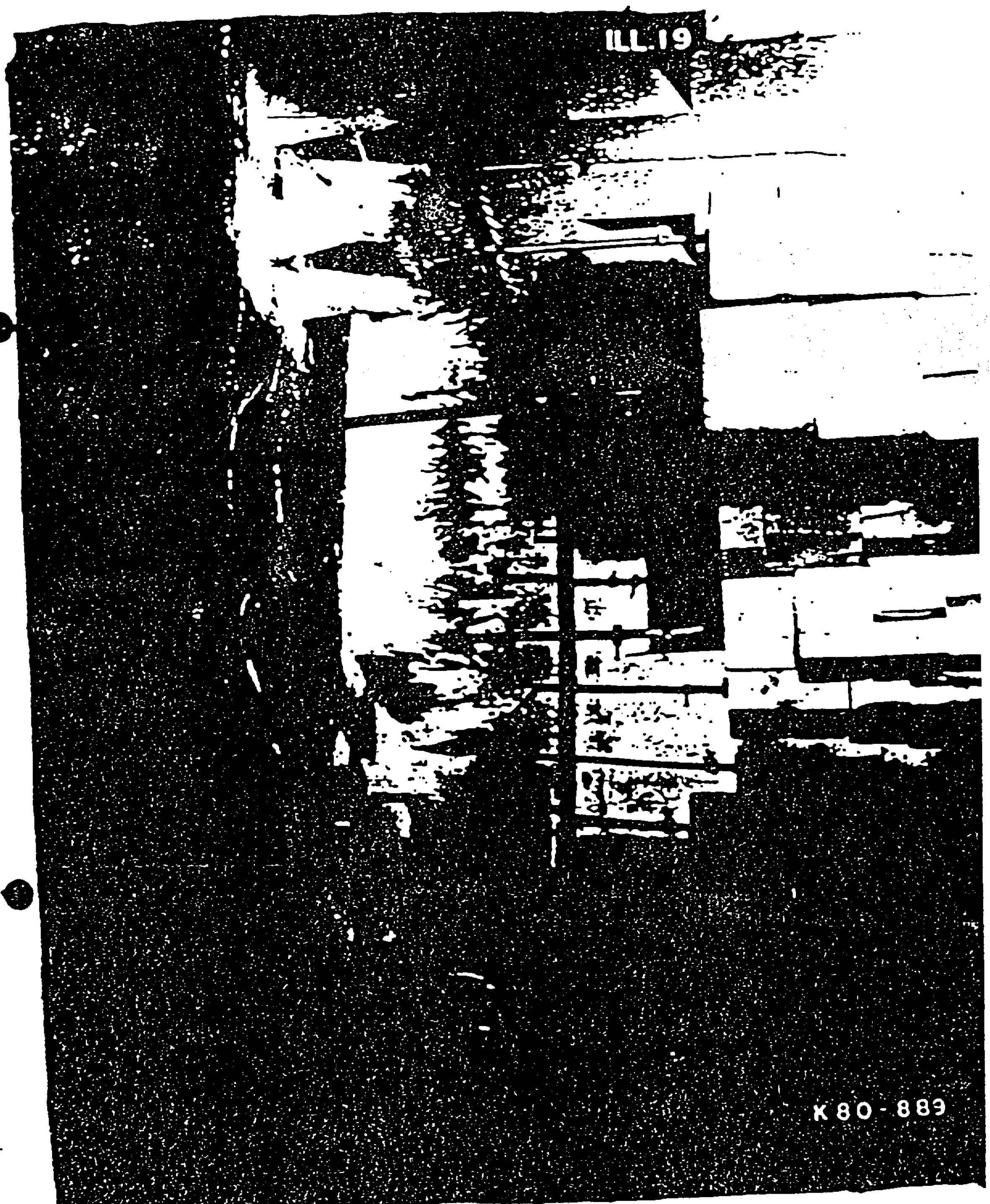
Penetration No. 1, Wall Assembly No. 2, Appearance After Test

Penetration No. 1, Wall Assembly No. 2

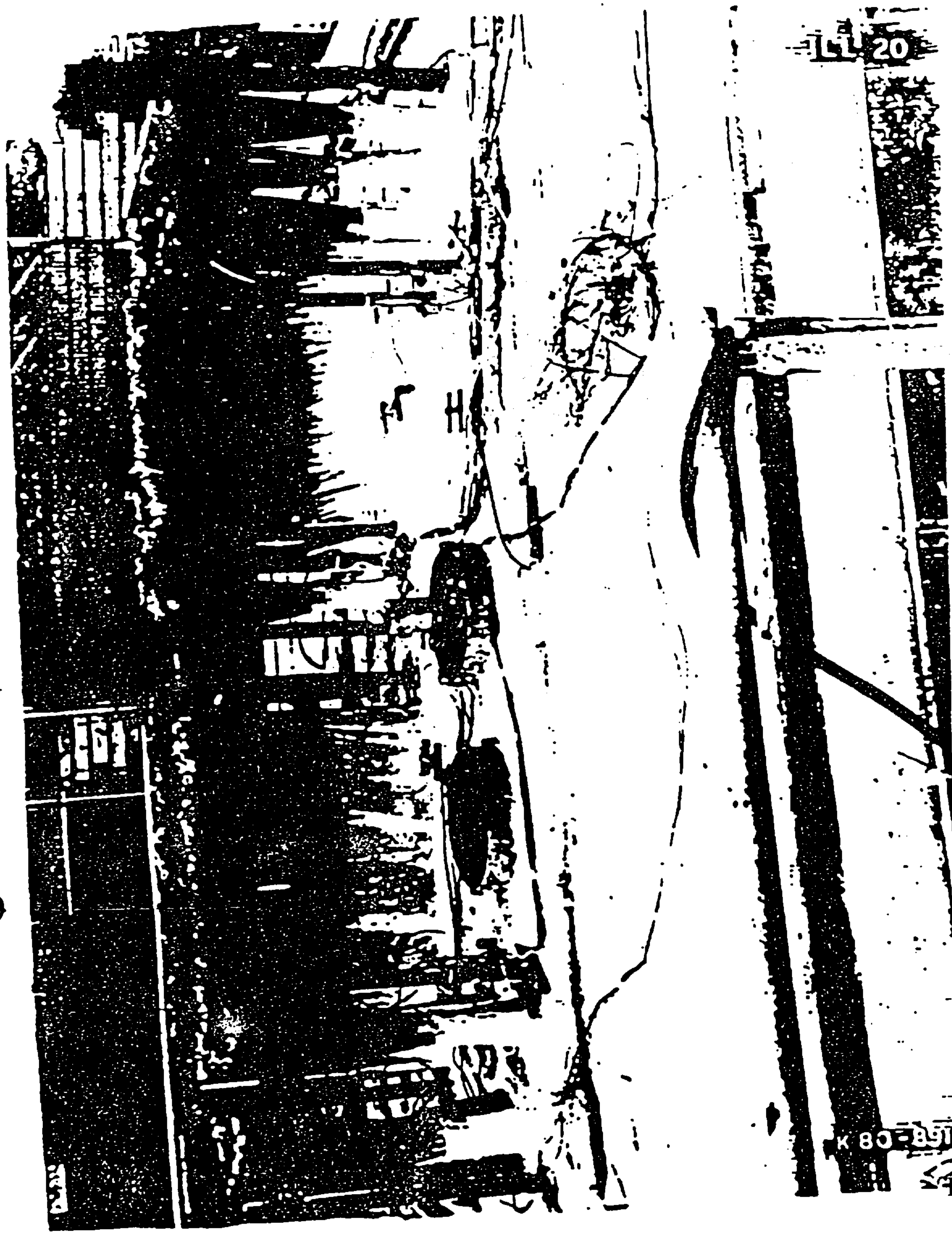
Penetration No. 3, Wall Assembly No. 2, Appearance After Test

Penetration No. 1, Wall Assembly No. 2, Appearance After Test

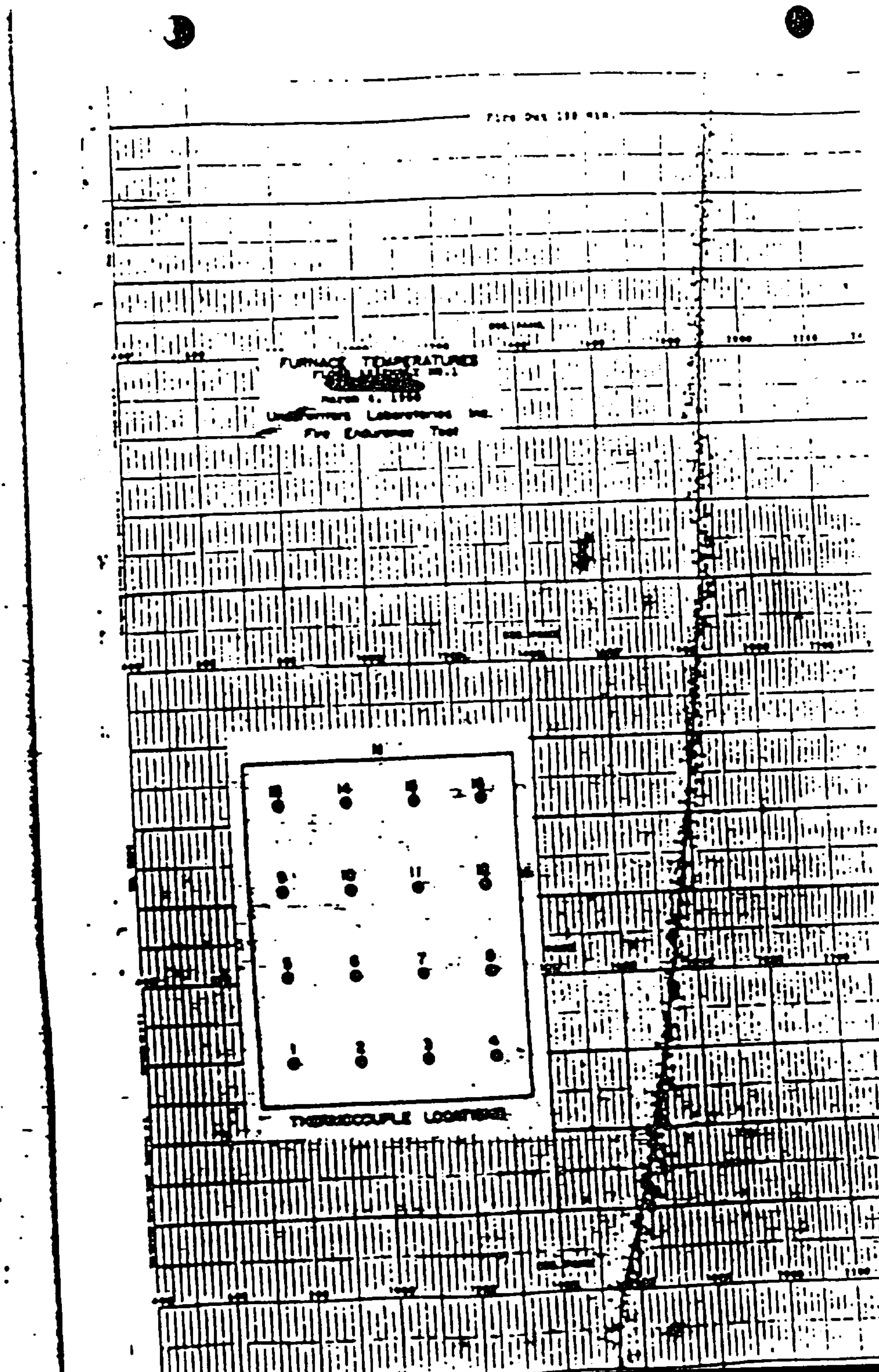
C80-13782

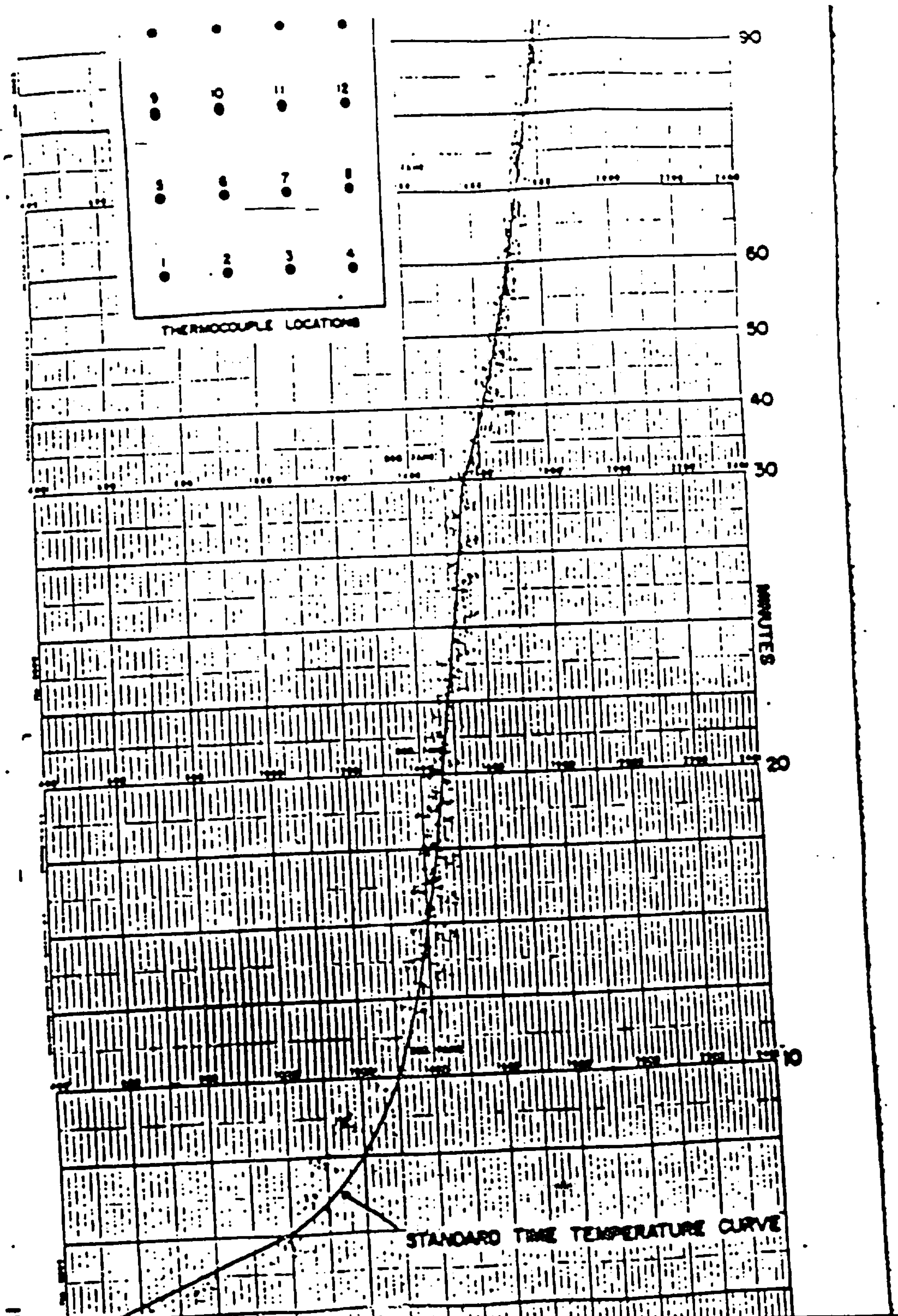


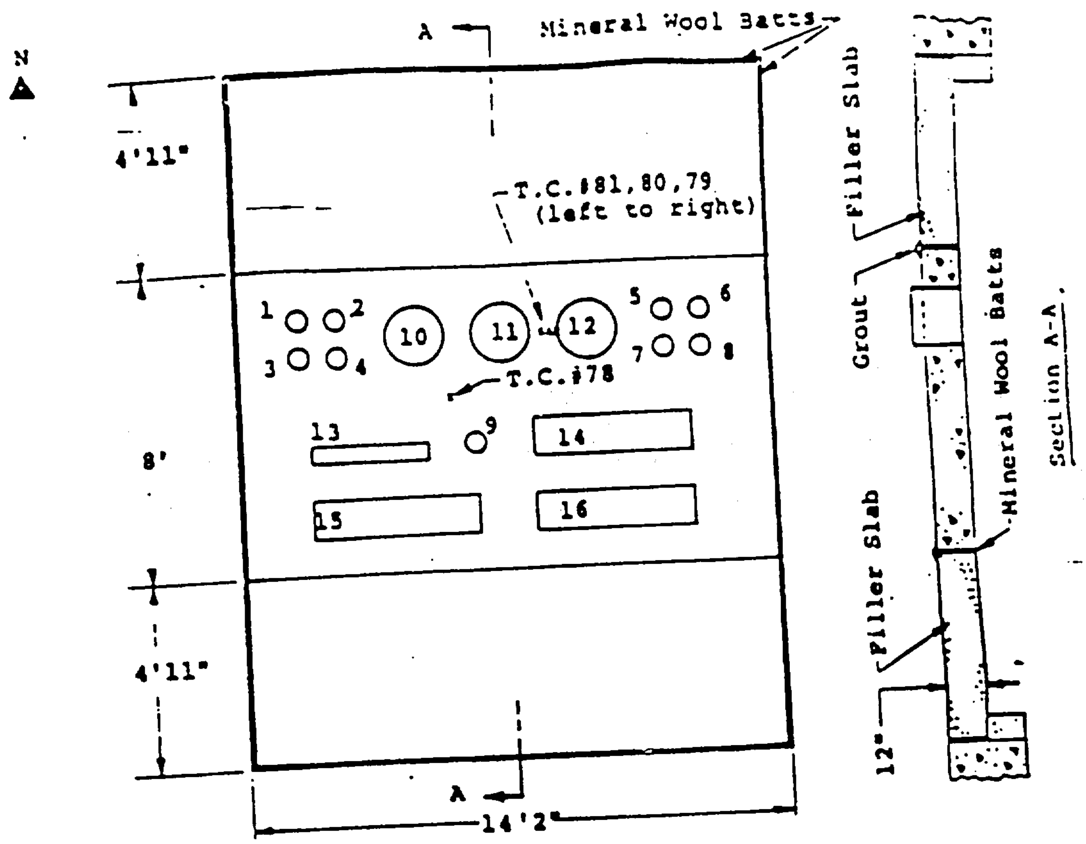
III.2.G-333



III.2.G-334


FURNACE TEMPERATURES

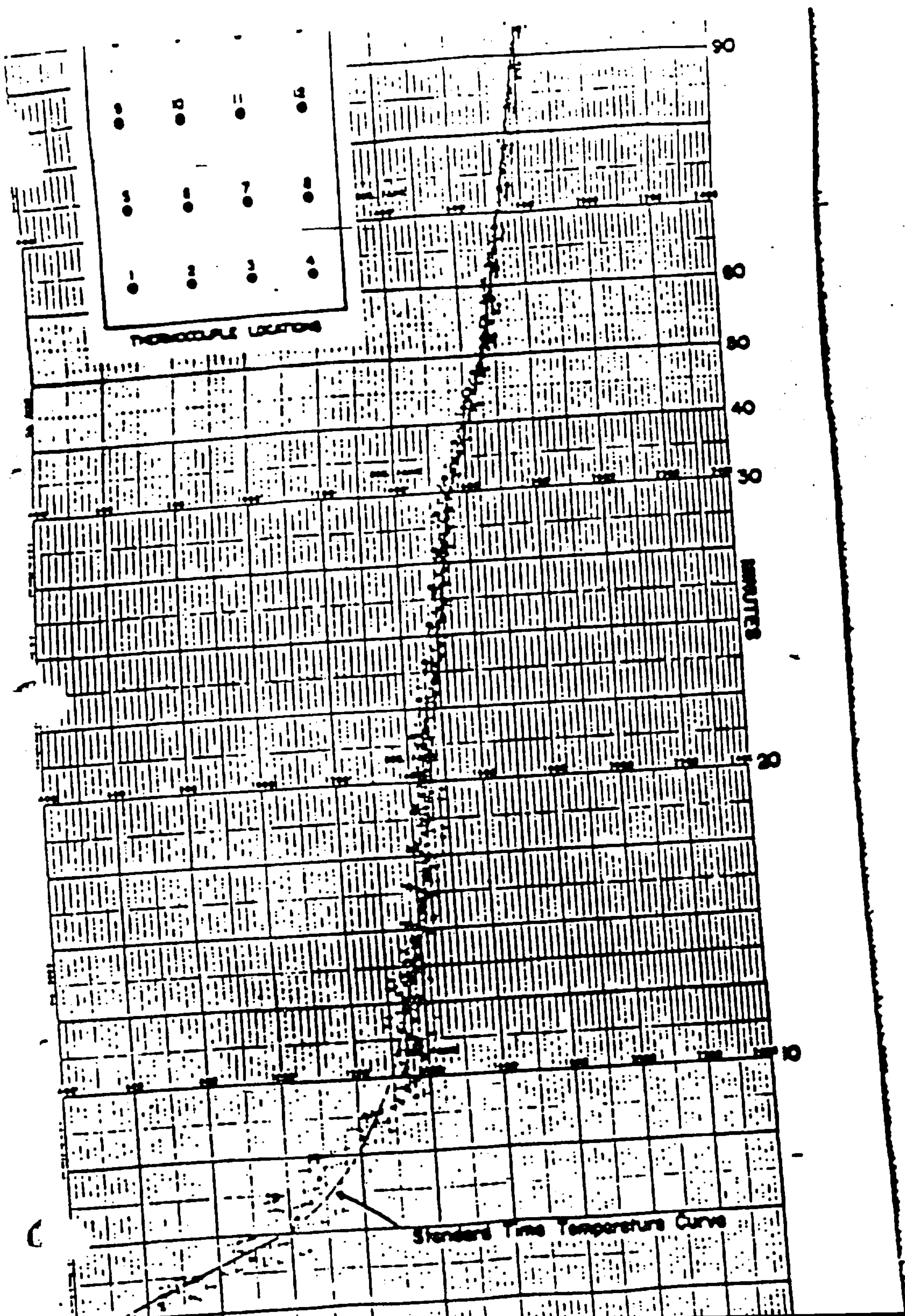

THERMOCOUPLE LOCATIONS
STANDARD TIME TEMPERATURE CURVE
MINUTES
90
60
50
40
30
20
10



Construction Details - Floor Assembly No. 2

Penetration No.	Thermocouple Nos.	Construction Details And Thermocouple Locations
1	1, 5, 9, 13	ILL. 23
2	2, 6, 10, 14	ILL. 24
3	17, 21, 25, 29	ILL. 25
4	18, 22, 26, 30	ILL. 26
5	3, 7, 11, 15	ILL. 27
6	4, 8, 12, 16	ILL. 28
7	19, 23, 27, 31	ILL. 29
8	20, 24, 28, 32	ILL. 30
9	77	ILL. 31
10	33-36	ILL. 32
11	37, 38	ILL. 33
12	39	ILL. 34
13	75, 76	ILL. 35
14	40-52	ILL. 36
15	53-63	ILL. 37
16	64-74	ILL. 38
Concrete	78-81	See Above


UND. LAB. INC.


THERMOCOUPLE LOCATIONS
MINUTES
90
30
20
10
Standard Time Temperature Curve

DRESDEN 2&3

FIRE PROTECTION PROGRAM DOCUMENTATION PACKAGE

Test Reports

QUALIFICATION FIRE TEST OF A PROTECTIVE ENVELOPE SYSTEM

FINAL REPORT

SwRI PROJECT NO. 01-7912a[1]

FEBRUARY 1985

REVISED JUNE 1985

Prepared for

3M, INCORPORATED
3M CENTER
ST. PAUL, MINNESOTA 55144

FPDCC	830
INITIAL	IG

SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO HOUSTON

DRESDEN 2&3

FIRE PROTECTION PROGRAM DOCUMENTATION PACKAGE

The document entitled "Qualification Fire Test of a Protective Envelope System," volume I, dated June 1985, is found on microfiche following Tab IX of Volume 7.

QUALIFICATION FIRE TEST OF A PROTECTIVE ENVELOPE SYSTEM

REVISED FINAL REPORT
SwRI PROJECT NO. 01-7912[2]
JUNE 1985

Prepared for

3M, INCORPORATED
3M CENTER
ST. PAUL, MINNESOTA 55144

FPDCO	830
INITIAL	ILA

SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO HOUSTON

DRESDEN 2&3

FIRE PROTECTION PROGRAM DOCUMENTATION PACKAGE

The document entitled "Qualification Fire Test of a Protective Envelope System," volume II, dated June 1985, is found on microfiche following Tab IX of Volume 7.