CONDUIT FIRE PROTECTION RESEARCH PROGRAM

FINAL REPORT

PROFESSIONAL LOSS CONTROL, INC.
FIRE PROTECTION, SAFETY, & ENVIRONMENTAL ENGINEERING

PROFESSIONAL LOSS CONTROL, INC.

CONDUIT FIRE TEST PROGRAM

Final Report - June 1, 1987

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PROPRIETARY INFORMATION

Acknowledgment

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Executive Summary

In response to differing regulatory guidance and in the interest of providing cost-effective fire protection based on sound technical information, a group of nuclear utilities embarked on this project to evaluate internal conduit sealing requirements and develop design guidelines based on fire test data.

The first step was to review existing test data to identify gaps in the technical basis for conduit sealing. Next, the participating utilities provided an assessment of the important parameters to be incorporated in a test program. Based on these data, a test was designed to evaluate the importance of the following variables:

A test slab incorporating conduit penetrations was constructed and tested at the Construction Technology Laboratories of the Portland Cement Association. The test was conducted on November 13, 1986. The test slab was exposed to the ASTM E-119 standard fire exposure for 3 hours.

During the test, no flames propagated through the conduits and no cables were ignited on the unexposed side of the slab. Considerable was during the first hour of the test, mostly from the open conduits, especially those with cable fill.

Based on the test, design guidelines were developed to prevent the propagation of fire through conduits penetrating fire barriers. These guidelines include the following:

Conduits that terminate in or other need no additional sealing. Conduits that run through an but do not terminate in that need not be sealed in that

Open conduits smaller than diameter that terminate or greater from the barrier need not be sealed.

Open conduits of " diameter that terminate feet or greater from the barrier need not be sealed.

Open conduits larger than diameter were not specifically tested in the program. Based on internal conduit temperature measurements in the , , and closed conduits, it can be concluded that fire will not propagate through larger conduits with a cable of or more, that terminate feet or greater from the fire barrier.

Where it is determined that additional sealing for limiting smoke propagation is to be provided, guidance is provided in Section based on conduit diameter, cable and termination distance.

CONDUIT SEAL TEST PROGRAM

1.0 INTRODUCTION

The NRC issued guidance in BTP 9.5-1, Appendix A on cable penetrations in fire barriers in paragraph D.3.d:

> (d) Cable and Cable tray penetration of fire barriers (vertical and horizontal) should be sealed to give protection at least equivalent to that fire barrier. The design of fire barriers for horizontal and vertical cable trays should, as a minimum, meet the requirements of ASTM E-119, "Fire Test of Building Construction and Materials," including the hose stream test.

This position did not provide specific reference to conduits. In 10 CFR 50.48 Appendix R, paragraph M, clarification is provided for penetration seal acceptance criteria:

> 10 CFR 50.48, Appendix R
>
> M. Fire Cable Penetration Seal Qualification
>
> Penetration seal designs shall utilize only noncombustible materials and shall be qualified by tests that are comparable to tests used to rate fire barriers. The acceptance criteria for the test shall include:
>
> 1. The cable fire barrier penetration seal has withstood the fire endurance test without passage of flame or ignition of cables on the unexposed side for a period of time equivalent to the fire resistance rating required of the barrier:
> 2. The temperature levels recorded for the unexposed side are analyzed and demonstrate that the maximum temperature is sufficiently below the cable insulation ignition temperature; and
> 3. The fire barrier penetration seal remains intact and does not allow projection of water beyond the unexposed surface during the hose stream test.

Again, this rule does not provide specific reference to conduits. In NUREG 0800, paragraph 5.a.(3), specific guidance is provided for conduits.

> (3) Openings through fire barriers for pipe, conduit, and cable trays which separate fire areas should be sealed or closed to provide a fire resistance rating at least equal to that required of the barrier itself. Openings inside conduit larger than 4 inches in diameter should be sealed at the fire barrier penetration. Openings inside conduit 4 inches or less in diameter should be sealed at the fire barrier unless the conduit extends at least 5 feet on each side of the fire barrier and is sealed either at both ends or at the fire barrier with noncombustible materials to prevent the passage of smoke and hot gases.

In response to the differing guidance in BTP 9.5-1 Appendix A, NUREG 0800 and 10CFR 50.48 Appendix R, and in the interest of providing cost-effective fire protection based on sound technical information, a group of nuclear utilities (see Appendix 1) embarked on a project to evaluate internal conduit sealing requirements and develop design guidelines based on fire test data. This project was coordinated by Wisconsin Electric Power Company with the technical assistance of Professional Loss Control, Inc.

The project consisted of the following tasks:

1. Collect and evaluate existing fire test data on internal conduit sealing.

2. Survey existing plant configurations of conduit penetrations.

3. Develop and conduct a test program to provide missing data.

4. Develop design guidance for internal sealing of conduits.

This report identifies the data collected on existing fire tests and actual plant configurations, summarizes and ranks test parameters based on the consensus of those utilities responding, and explains the results of the test program. The final section contains conclusions and suggested guidance for internal sealing of conduits, based on these test results.

2.0 DATA COLLECTION

Participating utilities submitted test reports and information on the importance of test parameters and the prevailing plant configuration. This information was evaluated by the steering committee and used as the basis for designing the test program.

2.1 Test Parameter Priorities

parameters were identified from discussions with utilities, vendors and consultants as having an impact on the fire exposure performance of conduits penetrating fire barriers. The participating utilities were requested to rank these parameters regarding the importance of each on conduit penetration response to fire exposure. Table 1 lists those parameters in order of importance as determined by the utilities responses.

Additional parameters were also identified by the survey as having an impact on conduit performance. These are shown in Table 2. The most frequently mentioned of these was the

c . Three of the parameters, effects, and of conduits are beyond the scope of this test program. effects and are plant specific items which must be incorporated in a plant specific analysis, but were not incorporated in this test program. The of conduits will have an impact on the external sealing of the conduit but will have no effect on internal sealing. External sealing was not tested in this program.

2.2 Plant Configuration

The information provided in response to this portion of the survey was not as complete or useful as hoped. The basic conclusions were that:

(1) conduit diameters varied from diameter to diameter, with the bulk between and , and

(2) cable varied, the most common . being

.

Other information was nonspecific. Based on this information, the test program incorporated as broad a cross section of configurations as practical.

TABLE 1 Order of Importance

TABLE 2 Additional Variables

2.3 REVIEW OF TEST DATA

The results of tests which specifically addressed internal sealing of conduit were collected and reviewed. The majority of these test configurations were conduits terminating or the test , representing rather than conduits. In reviewing the test reports against the parameters established in the industry survey, the information presented was . The testing most germane to the objectives of this program was conducted by Cleveland Electric Illuminating for the Perry Nuclear Power Plant. This testing evaluated conduit penetrations terminating in .

Specific test information was offered by various vendors interested in supporting this test effort. Since these data address sealing configurations and not unsealed conduits, they have not been evaluated as part of this project.

3.0 TEST PROGRAM

It was the objective of this test program to determine the minimum internal conduit sealing requirements to prevent the spread of fire from one side of a fire barrier to the other. In that regard, this test was not an "acceptance" test but a "research" test, which is informational and allows definition of acceptance criteria on a plant specific basis.

3.1 Test Parameters

The information gathered through the review of test reports, and the survey of participating companies indicated that additional testing was required. Based on these data and discussions of the steering committee, the following parameters were determined to be evaluated by testing.

1.

2.

3.

4.

5.

Types of sealing materials and designs were not tested. Two conduits were sealed with a inside or outside the furnace prior to the test for comparison purposes. Additionally, was available to during the test if it became necessary for continuation of the test. For test purposes, conduits identified as conduits were on both ends and conduits identified as conduits were on both ends. A few cases were tested where conduits were on only one end (some inside, some outside) to evaluate trends. Based on the assumption that in applying the resulting guidance each conduit will be evaluated from both sides of the fire barrier independently, the sealing criteria need not depend on the knowledge of the condition of both sides simultaneously but rather that the same criteria are applied to both sides independently. However, sufficient test data from conduits only on one side will allow the option of evaluating conduits on one side only or both sides simultaneously.

3.2 Specific Test Configuration

Figure 1 shows the layout of the test slab. This floor slab test was conducted in the beam furnace of Construction Technology Laboratories of the Portland Cement Association. A floor slab was chosen as being the worst case for conduit penetrations.

Most conduits penetrated into the furnace . A few samples were tested with the conduits penetrating into the furnace and to evaluate trends. All cable used was , as a cable.

Fig. 1 Plan View of Test Slab.

The specific test parameters were as follows:

Instrumentation

Thermocouples were used to monitor the temperature inside the conduits at their terminations outside the furnace. They were also used to monitor temperature gradients within some conduits to establish trends for evaluation purposes. The specific locations of all thermocouples are shown in the test report in Appendix 2. All penetrations were visually observed during the test. This test was also videotaped.

4.0 RESULTS

The single most significant result of the test was that none of the conduit penetrations allowed the propagation of fire through the barrier. A discussion of the effect of each of the variables on performance is provided below. These effects are expressed in terms of peak temperatures reached during the test measured each conduit at its on the side of the test slab. A tabulation of these peak temperatures at the end of the conduit for each penetration is provided in Table 3.

A general conclusion for conduits is that the the cross sectional area of the conduit (i.e., internal area minus the cable cross sectional area) the the fire exposure performance. This is clearly seen in the comparison of conduit (see Section 4.2) and cable (see Section 4.3). Another general conclusion is that the guidance provided in NUREG 0800 is excessively conservative.

4.1

TABLE 4

4.2

TABLE 7

4.3

TABLE 9

4.4

4.5

TABLE 10

4.6

4.7

5.0 DESIGN GUIDANCE

The purpose of a fire barrier is to prevent the spread of a fire from one side of the barrier to the other. Openings in the barrier must be protected to the level necessary to prevent fire propagation. The design objective for conduit penetrations as with door openings, duct penetrations and cable tray penetrations is to prevent the spread of fire through the barrier.

Through out this test program the terms , and have been used to describe the of conduits. For purposes of the design guidance these terms and the term are defined as follows:

conduits that terminate the wall should be treated as and should be with . General rules for sealing of other conduits penetrating fire barriers to prevent the propagation of fire are summarized in Figure 2 and are outlined below.

5.1 Conduits that terminate in or other need no additional sealing. Conduits that run through but do not terminate in that need not be sealed in that

5.2 Conduits smaller than diameter that terminate or greater from the barrier need not be sealed.

5.3 Open conduits of diameter that terminate feet or greater from the barrier need not be sealed.

5.4 Open conduits of greater than in diameter that terminate feet or greater from the barrier and have a cable of or greater need not be sealed.

The passage of smoke through conduits penetrating fire barriers does not constitute a breach of the fire barrier and is not a requirement for the rating of a fire barrier penetration just as with door openings, duct penetrations and cable tray penetrations. However, based upon plant specific parameters the minimization of smoke propagation through conduits may be prudent. The test results indicate that conduits which terminate , such as at a or with a , satisfactorily limit smoke propagation. In addition, conduits of diameter and standard effectively limit smoke propagation. Conduits which terminate ', have quantities, are of diameter and which to the fire barrier may allow the propagation of greater quantities of smoke. General guidance based on the test results regarding the limiting of smoke propagation through conduits is outlined below (see Table 12). These can be applied where limitation of smoke propagation is desired.

5.5

5.6

5.7

5.8

5.9

5.10

TABLE 12

Ref: PD-01-01-120

FIGURE 2 SEAL LOGIC FLOW DIAGRAM

REF: FIGURE/120

APPENDIX 1

APPENDIX 1

CONDUIT FIRE RESEARCH

PARTICIPATING COMPANY LISTING

ALABAMA POWER COMPANY
AMERICAN ELECTRIC POWER SERVICE CORPORATION
ARIZONA PUBLIC SERVICE COMPANY
BALTIMORE GAS & ELECTRIC COMPANY
BOSTON EDISON
CAROLINA POWER & LIGHT COMPANY
COMMONWEALTH EDISON COMPANY
DETROIT EDISON COMPANY
DUKE POWER COMPANY
GEORGIA POWER COMPANY
GPU NUCLEAR CORPORATION
NIAGARA MOHAWK CORPORATION
NORTHEAST UTILITIES COMPANY
PACIFIC GAS & ELECTRIC
PHILADELPHIA ELECTRIC COMPANY
PROFESSIONAL LOSS CONTROL, INC.
PUBLIC SERVICE E & G COMPANY
ROCHESTER G & E CORPORATION
SOUTHERN CALIFORNIA EDISON COMPANY
SOUTHERN COMPANY SERVICES INC.
TENNESSEE VALLEY AUTHORITY
TEXAS UTILITIES
UNION ELECTRIC COMPANY
VIRGINIA POWER COMPANY
WISCONSIN ELECTRIC POWER COMPANY
WISCONSIN PUBLIC SERVICE CORPORATION

APPENDIX 2

Report to

PROFESSIONAL LOSS CONTROL, INC.
Oak Ridge, Tennessee

CONDUIT SEAL FIRE TEST OF ELECTRICAL CONDUIT PENETRATIONS

by

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Submitted by

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CONDUIT SEAL FIRE TEST OF
ELECTRICAL CONDUIT PENETRATIONS

by

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INTRODUCTION

A three hour fire test was performed on a test configuration consisting of conduits filled with selected quantities of , and/or cable conductors. The objective of the test program was to determine minimum internal seal requirements for the conduits to prevent spread of fire from one side of a fire barrier to the other. This objective was achieved through the fire test by evaluating the following parameters as test variables:

1.

2.

3.

4.

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5.

This test was performed for Professional Loss Control, Inc. (PLC) in accordance with the program defined in the PLC report entitled, "Conduit Seal Test Program First Interim Report," dated July 18, 1986. Testing was performed in the Fire Research Laboratory of the Fire/Thermal Technology Section of the Construction Technology Laboratories on November 13, 1986.

TEST SLAB CONDUIT CONFIGURATION

Conduits were primarily schedule , with the remainder consisting of and conduits. Each conduit was filled with combinations of , and/or cable conductors. Cable conductors were copper and had insulation. Conduits required to have ends were with either a or with a , or had placed in the appropriate of the conduit. The following paragraphs describe the test configuration in detail.

Conduit Configuration

Test specimen conduit configuration, locations and end closure details are shown in Figs. 1 through 14. Figures 1 and 2 show a plan view of the test slab while Figs. 3 through 14 show section-elevations of each row of conduits across the test specimen width. The as-built unexposed surface of the test assembly is shown in Fig. 15. Conduit locations were planned

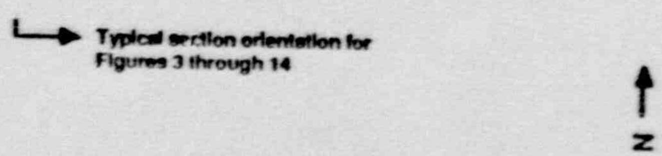

Fig. 1 Plan View of Test Slab.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 15.

to facilitate visual observations of the unexposed side of the specimen during testing.

The numbering system for each conduit identifies conduit type and nominal diameter. For instance, the number refers to . nominal diameter . . . location . Likewise, ' designation specifies a nominal diameter . , location . The key to interpreting the numbering system is shown below.

All conduits were located in a . thick concrete slab. The slab measured . . x ' in plan with a . at the east end. . . with at each end were in the slab. These pieces were with the exposed and unexposed surfaces of the test slab. The provided a means of the various lengths of conduit to the exposed and unexposed sides of the test slab (the ends of each , pipe were '' for ease of construction).

At locations where or conduits were used, continuous lengths were into the test slab. The and conduits were placed within the opening (detail 1, Fig. 1) in the test slab and . The opening around the and conduits was filled with a mix of .

<u>Conduit Closures</u>

Most conduit ends were , however selected conduits were consisted of either , or a . The conduits which required had around and between as evenly as possible. The was to a uniform of approximately . Conduit No. 1.22 and Conduit had placed within the end of the conduit run as shown in Fig. 11.

Conduits with and nominal diameters were using as shown in Figs. 7 through 9. used on the nominal diameter conduit measured while the used on the and nominal diameter conduits measured . All had . Holes were punched in selected for instrumentation of the or conduit. were and conformed to the National Electrical Manufacturers Association (NEMA) standards for and were attached to conduit using two with the between the . The outside the had a

All , and and conduits that required a used that had and . Some of the and all of the conduit were not or could not be In these cases, with were used to provide a means of attachment for the that completed the

Lengths of and conduit were purchased in standard lengths. Several of the conduits in the test assembly required lengths in excess of and thus required For the conduits, were used. To form a more positive seal, the outer surface of the and adjacent conduit were coated with For the conduits, lengths were used to complete the lengths. were used for the conduits.

Location of the were, in general, approximately above the unexposed surface of the concrete slab. Figures 3 through 14 show actual and locations of the conduits.

Table 1 defines test parameters including conduit and conduit and the furnace. condition, and nominal of cable conductors. Table 2 is a list of hardware used for conduit closure and coupling mechanisms.

Table 1

Table 1

TABLE 2

Conduit Cable

Each conduit was required to contain a nominal percentage fill of cable conductors consisting of a combination of and/or cable conductors. Conduits with and nominal diameters were filled with approximately equal amounts of each type of cable. Conduits with and nominal diameters were filled with either cables and/or cables or exclusively cables. For the diameter conduits, it was impractical to use amounts of the cable conductor types.

In general, the percentage of cable conductors was specified as either or (total cross-sectional area of cable conductors compared to total cross-sectional area of conduit open run). Table 3 gives the total cross-sectional area of each type of cable used in each conduit and compares the actual conduit percentage with the required nominal percentage. Table 4 reports the total number of each type of cable used in each conduit.

The cables consisted of copper conductors with insulation. The types of cable conductors used in this test are listed below:

1.

2.

3.

4.

Table 3

Table 3 (Continued)

Table 4 C

Test Setup Assembly Procedure

After sufficient curing of the concrete slab, the slab was lowered into the beam/wall furnace, heated to a uniform temperature of , and maintained at that temperature for . This was done to reduce internal relative humidity of the concrete to acceptable levels for testing purposes.

The concrete slab was then placed on top of the beam/wall furnace in the CTL Fire/Thermal Research Laboratory. All conduits were installed in provided in the slab at appropriate locations. The and conduits were placed within the and then in place.

After conduits were all placed, condulets and junction boxes were installed. Cables were cut to length and bundled. Cable bundles that required thermocouples along the length of the conduit had the thermocouples assembled with the cable bundle. Cable bundles were banded together and pulled through conduits individually. conduits were subsequently and prepared for testing.

INSTRUMENTATION

A total of thermocouples were used for measuring temperatures of cable conductor bundles. These locations included the of the conduit run on the of the concrete slab and selected conduits the surface of the concrete slab the conduit cable bundles. Typical thermocouple locations are shown in Fig. 16. Figures A1 through A12, contained in Appendix A, show actual thermocouple locations for each of the conduits.

FIRE TEST FACILITIES

The test assembly was subjected to 3-hr fire exposure on the beam/wall furnace at CTL. The specimen was placed in a horizontal position on top of the beam/wall furnace. Fire exposure followed the time/temperature relationship defined in ASTM Designation: E 119. Furnace atmosphere temperatures were measured by thermocouples located below the exposed surface of the concrete test slab and were monitored throughout the 3-hr test.

A tabulation listing furnace temperatures and variations from those of the standard ASTM Designation: E 119 relationship is given in Appendix A.

Variation of the measured furnace temperatures from the standard was approximately based on comparison of total area under the time-temperature relationship. This is within the ± 5.00% variation permitted by ASTM Desgination: E119. Average furnace draft pressure was of water.

TEST RESULTS

The test assembly containing conduits was subjected to a 3-hr fire exposure on November 13, 1986. The following sections describe data and observations recorded during the fire test.

Fig. 16.

Temperature Test Data

As discussed previously, the test assembly was instrumented with thermocouples. A listing of conduit thermocouple locations and temperatures is given in Appendix A. It should be noted that a temperature drop at some thermocouple locations between test time and is probably due to the opening of the laboratory garage door during the test. It was necessary to open the door to vent the laboratory because of smoke produced during the hour of the test. Conduits located at the east end of the test assembly were most susceptible to the of from the The door was shut after a majority of the smoke cleared from the laboratory.

Observations of Unexposed Side

Observations of the unexposed side of the test assembly were made by representatives of CTL throughout the 3-hr fire test. Cameras were set-up at three locations to videotape the unexposed side of the test assembly during the fire test. Cameras and recorders were positioned at the upper west end, the upper southeast corner, and the lower southeast corner of the test assembly. Due to a mechanical malfunction the camera at the upper southwest corner of the test assembly failed to record the test. Copies of the videotapes from the remaining two cameras were forwarded to Mr. Kenneth Dungan of PLC on December 3, 1986. Each conduit run was flagged with its identification number prior to the start of the fire test.

During the first of the test, observations were made at intervals no greater than by observers. Each observer was assigned a group of conduits. Notes were made regarding the characteristics of the from specific conduits and any other changes in the conditions of the test assembly. In order to standardize the terminology used to describe the observed during the test the following criteria were used:

1.

2.

3.

4.

observed during the test was unless noted otherwise. Summaries of the observer's test notes are given in Appendix B.

At approximately minutes into the fire test the to make observations. At this time, was into the following conduits having conditions on the side of the test assembly:

these conduits with some of the and allowed observer to the side of the test assembly throughout the the test. After the

, the following conduits, which had their

side . had the

It should be noted that no passage or propagation of flame occurred through any of the conduits during the 3-hr fire test.

POST-TEST EXAMINATION

Post-test inspections of all conduits from PLC fire test on November 13, 1986 were performed on November 18, 20, 21 and 26, 1986 by representatives of CTL. The purpose of the inspection was to observe the extent of damage to cables within the conduits, to conduits, and to condulets or junction boxes. Observations were made on both the exposed and unexposed sides of the test assembly. Notes were kept and a form was completed for each of the conduits. These forms are provided for reference in Appendix C.

The following sections describe the procedure for recording observations of the various components of the test assembly, and also general observations made during the post-test examination.

Conduits

Conduit runs were first viewed externally and then removed from the test slab. Observations were made on the unexposed side to evaluate the presence of especially on the conduits with conditions. The presence or evidence of was also noted on the conduits with conditions.

Junction Boxes/Condulets

Initially, observations were made on the exterior condition of junction boxes and condulets on both the exposed and unexposed sides of the test assembly. Next, cover plates were removed and the condition of gasket seals was noted. Residue present in the junction boxes or condulets was noted. The pH of the residue was determined and the nature of any solids present was noted, i.e., charred cable jacket, molten copper, etc. Measurement of pH levels of residue in junction boxes or condulets was performed using indicating litmus paper.

As noted on the forms contained in Appendix C, all condulets or junction boxes and conduits were on the exposed side of the test assembly. The majority of these also showed signs of and the of a . Figure 17 shows the exposed side condulet for conduit run This figure shows outlined above. All junction boxes for the and conduits these same on the exposed side. In addition, the cover plates for these junction boxes the as shown in Fig. 18. The exception to this were conduits Nos. and where cover plates the . Fig. 18 also shows the junction box for conduit run No. with the gasket in place. The remaining junction boxes, i.e.

Fig. 18.

, contained varying amounts of cable jacket, cable, and cable as shown in Fig. 19. Residues within the condulets/junction boxes on the exposed side were and generally did not lend themselves to pH testing.

On the unexposed side of the test assembly condulets/ junction boxes contained varying degrees of Fig. 20 shows the on the unexposed side of conduit run This residue had a measured pH of to

Cables

Inspection of cables in conduits was performed by disassembling junction boxes or condulets and conduits from around the cables. was observed and when present checked for pH level. The extent of burned and/or melted cable was recorded for both the exposed and unexposed sides of the test assembly. The unexposed concrete surface of the test slab was used as a reference point for all measurements of cable damage. Most cables exhibited a typical characterized by the following:

1. A area where all cable jacketing Cable ends were and showed evidence of such as of metal. Some cable jacketing was present.
2. An area of cable where most if not all cable jacketing had . Any jacketing

Fig. 20.

was and to the cable. Metallic wrap found on instrument type cables was but still . Cables themselves were either or beginning to

3. An area of cable . where jacketing was either or Cables were intact but some showed

An example of a typical burn pattern is shown in Fig. 21 for the cable in Conduit .

SUMMARY

This report details the fabrication, testing and analysis of a test assembly containing conduits exposed to a 3-hr fire test. None of the conduits tested allowed the spread of fire to the unexposed side of the test assembly. This report summarizes test data and observations as well as post-test observations.

LABORATORY RESPONSIBILITY

The Construction Technology Laboratories is a division of the Portland Cement Association. Personnel of CTL make no judgment of the suitability of the materials or seal systems for particular end-point uses. Acceptance of the test results for guidance for field installation is the prerogative of the authority having jurisdiction.

Fig. 21.

Appendix A

TABULATION OF TEMPERATURES