VERMONT YANKEE NUCLEAR POWER CORPORATION

Ferry Road, Brattleboro, VT 05301-7002

REPLY TO
ENGINEERING OFFICE
580 MAIN STREET
BOLTON, MA 01740
(508) 779-6711

July 26, 1996
BVY 96-94

United States Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

References: (a) License No. DPR-28 (Docket No. 50-271)
(b) Letter, VYNPC to USNRC, BVY 96-58, dated May 28, 1996
(c) Letter, USNRC to VYNPC, NVY 96-117, dated June 28, 1996

Subject: Response to Request for Additional Information Regarding Vermont Yankee Request for Exemption from 10 CFR Part 50, Appendix R

In Reference (b), Vermont Yankee requested exemption from the requirements of 10CFR50, Appendix R, Section III.G, "Fire protection of safe shutdown capability," to permit use of Rockbestos Firezone®R fireproof cable in plant areas that require enclosing cables in a fire barrier having a 1-hour fire rating. The plant areas identified in the exemption request were the Cable Vault and the 280 foot elevation of the Reactor Building. Since submitting our exemption we have decided to implement a plant design modification which will eliminate reliance on the fire resistant cable in the Motor-Generator set area on the 280 foot elevation of the Reactor Building. As a result, the exemption request is now applicable to the routing of Rockbestos Firezone®R cable only in the Cable Vault.

In Reference (c), the NRC requested additional information needed to complete review of our exemption request. The requested information is attached.

We trust that the information provided is acceptable; however, should you have any questions, please contact this office.

Sincerely,

VERMONT YANKEE NUCLEAR POWER CORPORATION

010076

James J. Duffy

James J. Duffy
Licensing Engineer

A006

Attachments

c: USNRC Region I Administrator
USNRC Resident Inspector - VYNPS
USNRC Project Manager - VYNPS

Request for Additional Information
Vermont Yankee Nuclear Power Station

Request for Additional Information #1
Underwriter's Laboratory Report on Fire Resistant Cables, File R10925-1, dated April 10, 1984.

Vermont Yankee Response to Request for Additional Information #1
Subject report is included as Attachment 2.

Request for Additional Information #2
Fire Test Standard used to qualify the fire resistant cables.

Vermont Yankee Response to Request for Additional Information #2
As identified on page 1 of the Underwriter's Laboratory Report on Fire Resistant Cables (Attachment 2), "The floor assembly was subjected to fire exposure with the furnace temperatures controlled in accordance with the standard time-temperature curve outlined in the Standard for Fire Tests of Building Construction and Materials, ASTM E119 (UL 263, NFPA 251). Following the fire exposure, the assembly was subjected to the impact, erosion and cooling effect of a water hose stream test."

Request for Additional Information #3
Detailed drawings of the fire areas through which the cable is passing. Clearly mark the route of the cables, and clearly label all equipment and components that are in the fire areas.

Vermont Yankee Response to Request for Additional Information #3
As discussed in the cover letter, our exemption request has been revised such that the Cable Vault is the only fire area for which an exemption to use the fire resistant cable is being requested. Attachment 3 provides a mark-up of the Cable Vault with the route of the cables and all major equipment and components clearly identified.

Request for Additional Information #4
Describe how the cables are routed (e.g., type of raceway) and how the cables and raceways are supported.

Vermont Yankee Response to Request for Additional Information #4
The cables of concern consist of four stainless steel sheathed cables. The cables, which are grouped together throughout their run in the Cable Vault, enter through the floor of the Cable Vault along the east wall near panel DC-2. The cables rise vertically about 6 feet, travel about 45 feet horizontally to the south wall of the Cable Vault, and enter the Reactor Building through a block out. The cables are located between 16 inches and 30 inches below the ceiling throughout the horizontal run. The cables are not located in any cable trays and they are not attached to the side rails of any trays. One short section of cable tray at the north end of the horizontal run is routed perpendicular to, and over, the fire resistant

cables. Several conduits are also routed parallel to and over the fire resistant cables. The routing of the cables and methods of support are described below and depicted on Attachment 4.

The cables are attached to 12 gauge light metal framing members and associated hardware (i.e., unistrut type). Two supports, bolted directly to the east wall of the Cable Vault, are used in the vertical portion of the cable run. Eleven supports, spaced about four feet to five feet apart, are used in the horizontal portion of the run, with the cables attached to the top of short, horizontal members. The horizontal sections are bolted to vertical framing members which are attached to the floor, ceiling, or overhead conduits. Three of the vertical supports are bolted directly to the ceiling above. Four of the vertical supports are attached to conduits, and the conduits are attached to the ceiling by 3/8 inch (minimum) diameter threaded rods and concrete inserts. Three of the vertical supports also form part of the support system for the floor-to-ceiling cable trays that run parallel to and below the fire resistant cables. The three vertical supports that form part of the cable tray support system (which is described in more detail below) are bolted to the floor, with one of the supports also bolted to the ceiling. One support is framed into the block out where the cables penetrate through the south wall of the Cable Vault.

The floor-to-ceiling cable tray system running parallel to and under the fire resistant cables is supported by a total of nine vertical 12 gauge light metal framing members, spaced about 4 feet to 5 feet apart, on both sides of the tray system. Horizontal supports, provided underneath each cable tray, are bolted to the vertical members. The vertical members are all bolted to the floor and most are also bolted to the ceiling. Fire rated barriers are not required for any of the cables in the cable trays running parallel to the fire resistant cables.

<u>Request for Additional Information #5</u>
Verify that the cable supports and raceway supports will not fail if exposed to a fire.

<u>Request for Additional Information #6</u>
Verify that the failure under fire exposure of a structure, system or component in the vicinity of the cables will not damage the fire resistant cables.

<u>Vermont Yankee Responses to Request for Additional Information #5 & #6</u>
The response to RAI No. 5 and No. 6 is divided into two parts. The first evaluates the fire protection capabilities available in the Cable Vault to limit the severity of postulated fires such that failure of cable supports and structures, systems, or components in the area are not a likely event. Following this is a discussion of postulated sequences of cable support failures and failure of structures, systems, or components in the area and the likely impact of such failures on the capability of the fire resistant cables to perform their intended function. Each discussion is provided separately below.

<u>Evaluation of Fire Protection Capabilities</u>
The Cable Vault, a reinforced concrete structure, is a separate fire area contained within the control building. The Cable Vault contains instrumentation, control and power cables in cable trays and conduit that are relied on for safe shutdown of the plant. The fire loading consists predominantly of cable insulation in cable trays which results in an equivalent fire severity of under 3 hours. Alternate shutdown capability is provided to ensure safe shutdown given a Cable Vault fire.

Fire protection features in the Cable Vault are provided in accordance with defense-in-depth principles. Fire protection features include automatic detection and suppression systems and portable extinguishers in the Cable Vault, and a hose station outside the main entrance door, for fire brigade use. A fire of the duration and magnitude required to result in failure of supports for the cable tray system, overhead conduits, and/or the fire resistant cables is considered to be an unlikely event. The bases for this assessment are described below.

Cable Vault access is controlled by key card and is not a normal travel route to any other plant location. The Cable Vault is designated as a Fire Control Area per administrative procedures. A Fire Control Area requires a Fire Protection Control Permit for introduction of significant quantities of combustible or flammable materials into the area. A Fire Control Area also requires a Hot Work Control Permit for any hot work activity in the area. The possibility and impact of transient combustible material fires in the Cable Vault are, therefore, considered to be minimal.

Postulated fires in the Cable Vault would involve cable insulation in the cable tray system. Such a fire would develop slowly and generate a significant amount of smoke in the early stages of the fire.

The Cable Vault is provided with full area detection system coverage (27 ionization detectors mounted at ceiling level) that would detect a postulated fire in its incipient stages. Activation of a single detector transmits an alarm to the Control Room and sounds an alarm outside the room. Activation of a second detector initiates an evacuation alarm inside the room and a 75 second timer prior to discharge of the total flooding CO_2 extinguishing system. The CO_2 system can be manually activated from outside the main entrance door to the room, and a manually activated 100% reserve capability is also provided through a cross-connect with the West Switchgear Room system. Control Room alarms due to automatic or manual detection or CO_2 suppression system activation will result in prompt fire brigade response. Portable extinguishers are located in the Cable Vault, and a hose station is located outside the northwest entrance door to the room, for manual fire fighting purposes.

Reasonable assurance is therefore provided that postulated fires in the Cable Vault would be detected in the incipient stages, with actuation of the total flooding CO_2 suppression system to extinguish the fire. The fire brigade would respond rapidly to the Cable Vault upon receipt of an alarm in the Control Room to begin manual fire fighting activities as required. Based on the automatic detection and suppression systems provided for the area, and rapid fire brigade response for manual fire fighting activities, postulated fires in the Cable Vault would be detected, controlled, and extinguished prior to temperatures rising to a level that could challenge the structural support capabilities of the fire resistant cables, cable tray network, and overhead conduits. Additional bases for this position are provided in the following discussion.

<u>Evaluation of Structures, Systems, Components, and Cable Support Failures</u>

The fire resistant cable is somewhat flexible, not rigid. As documented in the test report of the fire resistant cable, the cables are able to support significant load without damage. The as-tested fire resistant cables were placed in the bottom of a ladder back cable tray, and the tray was then filled with standard cables to represent a typical fuel loading that could present an installed hazard to the cables. At about the 40 minute point in the fire test, the 16 gauge galvanized steel tray rungs began to separate from the side rails, and the 14 gauge side rails began to bow inwards. During the last 20 minutes of the test exposure, most of the tray rungs disengaged from the side rails. The fuel load cables in the tray on top of the fire resistant cables deflected downward, with most of the weight of the fuel load cables supported by the fire resistant cables. The test report documents that the stainless steel sheath on each of the fire resistant cables did not appear to be damaged by the applied stresses.

Failure of the conduit clips that attach the vertical run of the fire resistant cable to the supports, which are bolted to the east wall of the Cable Vault, could cause the cables to disengage from the wall and sag towards the first horizontal support. Failure of the conduit clips that attach the horizontal run of the cables to the supports will not adversely impact on the cables since they are supported on top of the supports to which they are attached. The conduit clips act to laterally support the horizontal run of the fire resistant cables in place during seismic events and do not provide any dead weight support. The applied stresses to the fire resistant cables by failure of the conduit clips would be bounded by the stresses applied by the fuel load cables in the fire test. Therefore, failure of the conduit clips during postulated fires will not adversely impact the capabilities of the fire resistant cables to perform their intended function.

The support failures that could be of concern are those that could cause gross collapse of the conduits and single cable tray that are above the fire resistant cables or gross collapse of the cable tray network in the Cable Vault. Collapse of the conduits and/or cable tray above the fire resistant cables could potentially cause physical damage to the cables. Collapse of the cable tray network could pull down the entire routing of the fire resistant cables, potentially damaging the cables and/or pulling the cables out of the barriers through which they pass.

Collapse of the overhead conduits or cable tray, or collapse of the cable tray network, are catastrophic failures that require a significant fire exposure in order to occur. As identified previously, the existing detection and suppression systems installed in the Cable Vault should detect, control, and extinguish postulated fires in the Cable Vault prior to temperatures reaching a level that would challenge the structural support capabilities of the fire resistant cables, cable tray network, and overhead conduits. Therefore, catastrophic failure of the support systems is considered to be unlikely.

Additional justification for this position is contained in the fire resistant cable test report. The test report documents that at about the 40 minute point in the test, the 16 gauge tray rungs began to separate from the side rails, and the 14 gauge side rails began to bow inwards. Typically, 12 gauge framing members bolted to the floor and/or ceiling is used in the Cable Vault to support cable trays. Minimum 3/8 inch diameter threaded rods used to support conduit are typically either embedded in or bolted to the concrete ceiling. The existing tray and conduit support system should be expected to last at least as long in an ASTM E119 exposure fire as the 16 gauge tray rungs and the 14 gauge side rails in the fire resistant cable fire test since the tray/conduit support systems are of a stronger gauge than the tray rungs and side rails included in the fire test. Therefore, postulated fires in the Cable Vault would have to intensify unimpeded for a significant period of time in order to cause gross failure and collapse of the cable tray or conduit support systems.

In summary, given the existing fire protection features and the layout of conduits, cable trays and the fire resistant cable support system in the Cable Vault, detection and suppression of postulated fires would occur well before any challenge to the support capabilities of conduits and cable trays in the vicinity of the fire resistant cables.

Attachment 2

Underwnter's Laboratory Report on Fire Resistant Cables

File R10925-1

dated April 10, 1984

8406140177 75PP

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

File R10925-1
Project 84NK2320

April 10, 1984

REPORT

on

FIRE RESISTANT CABLES

The Rockbestos Company,
Division of CEROCK Wire & Cable Group, Inc.
New Haven, Connecticut

In no event shall Underwriters Laboratories Inc. be responsible to anyone for whatever use or nonuse is made of the information contained in this Report and in no event shall Underwriters Laboratories Inc., its employees, or its agents incur any obligation or liability for damages, including, but not limited to, consequential damages, arising out of or in connection with the use, or inability to use, the information contained in this Report.

Information conveyed by this Report applies only to the specimens actually involved in these tests. Underwriters Laboratories Inc. has not established a factory follow-up service program to determine the conformance of subsequently produced material nor has any provision been established to apply any registered mark of Underwriters Laboratories Inc. to such material.

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

A B S T R A C T

This Report describes a testing program which was undertaken to develop information for the assessment of fire resistant cables in Redundant Safety Trains as outlined in "Fire Protection Program For Operating Nuclear Power Plants" (Appendix R to 10 CFR 50). The testing program consisted of a full-scale fire test investigation and an adjunct small-scale fire test. These tests provided data on the electrical characteristics of the fire resistant cable samples under controlled fire exposure conditions and during an extended cool-down period.

T A B L E O F C O N T E N T S

Abstract.......... i
Table Of Contents.......... ii
General.......... 1
Description.......... 4
    Materials.......... 4
        Full-Scale Test Assembly.......... 4
        Small-Scale Test Assembly.......... 8
    Erection Of Test Assemblies.......... 8
        Full-Scale Test Assembly.......... 8
        Small-Scale Test Assembly.......... 14
Test Record No. 1, Full-Scale Test Assembly.......... 15
    Fire Endurance Test.......... 15
        Sample.......... 15
        Method.......... 15
        Results.......... 17
            Character And Distribution Of Fire.......... 17
            Observations During Test.......... 17
            Circuit Integrity.......... 18
    Initial Hose Stream Test.......... 18
        Sample.......... 18
        Method.......... 19
        Results.......... 19
    Extended Cool-Down Period.......... 19
    Second Hose Stream Test.......... 20
        Sample.......... 20
        Method.......... 20
        Results.......... 20
    Observations After Tests.......... 20
    Discussion.......... 21
Test Record No. 2, Small-Scale Test Assembly.......... 25
    Fire Endurance Test.......... 25
        Sample.......... 25
        Method.......... 25
        Results.......... 26
            Character And Distribution Of Fire.......... 26
            Observations During Test.......... 27
            Temperatures Of The Cables.......... 27
            Leakage Current Measurements.......... 27
Summary.......... 30

A P P E N D I C E S

Appendix A, Electrical Circuit Measurements, Full-Scale Test Assembly.......... A1
Appendix B, Insulation Resistance Measurements, Full-Scale Test Assembly.......... B1
Appendix C, Dielectric Voltage-Withstand Tests, Full-Scale Test Assembly.......... C1

Appendix D, Cable Temperature Measurements,
Small-Scale Test Assembly.............................. D1
Location Of Thermocouples.......................... D1
Temperatures Of The Cables......................... D1
Appendix E, Instrument Calibration Records............. E1
Instruments Supplied By Underwriters
Laboratories Inc................................. E1
Full-Scale Test Assembly...................... E1
Furnace Temperature Recorder.............. E1
Automatic Data Logger..................... E1
Ammeter................................... E1
Voltage Source............................ E1
Water Pressure Gauge...................... E1
Small-Scale Test Assembly..................... E2
Furnace Temperature Recorder.............. E2
Cable Temperature Recorder................ E2
Instruments Supplied By The Rockbestos Co.......... E3
Full-Scale Test Assembly...................... E3
Digital Ammeter........................... E3
Meggering Equipment....................... E3
Small-Scale Test Assembly..................... E3
Digital Multimeters....................... E3

G E N E R A L

The subject of this Report is the fire test investigation of fire resistant electrical cables installed in cable trays, conduits and air drops beneath a floor assembly. The purpose of the investigation was to develop information which may be used to determine whether the electrical cables manufactured by The Rockbestos Company meet the specifications for Redundant Safety Trains outlined in "Fire Protection Program For Operating Nuclear Power Plants" (Appendix R to 10 CFR 50). We understand that the information developed in this investigation is to be submitted only to the United States Nuclear Regulatory Commission (NRC), American Nuclear Insurers (ANI), Nuclear Mutual Limited (NML) and firms concerned with utility installations for their consideration as to the use of the Rockbestos cables in redundant safety trains as specified in Appendix R to 10 CFR 50 for use in nuclear generating stations under the jurisdiction of the United States Nuclear Regulatory Commission.

The test program consisted of constructing a floor assembly with various cable tray and conduit systems containing fire resistant cables. In addition, nonfire resistant cables were installed in the cable tray systems to simulate the fuel loading which would be present in actual site installations. The floor assembly was subjected to fire exposure with the furnace temperatures controlled in accordance with the standard time-temperature curve outlined in the Standard for Fire Tests of Building Construction and Materials, ASTM E119 (UL 263, NFPA No. 251). Following the fire exposure, the assembly was subjected to the impact, erosion and cooling effect of a water hose stream test. After an extended cool-down period, the assembly was subjected to a second water hose stream test.

Immediately before the fire endurance test, the fire resistant cables were energized with predetermined steady-state ac electrical currents. The cables remained energized throughout the fire exposure except for a 10 s period immediately preceding an inrush current test on each fire resistant cable. Following the fire endurance test, the cables were deenergized for the water hose stream test. Following the water hose stream test, the cables were again energized with predetermined steady-state ac electrical currents. The cables remained energized throughout a 93 h extended cool-down period except for 10 s periods immediately preceding each of four supplemental inrush current tests. Following the 93 h extended cool-down period, the cables were deenergized for the second water hose stream test. Immediately following the second water hose stream test, the cables were subjected to a final inrush current test.

In addition to monitoring ac currents in each of the fire resistant cables, each conductor of each fire resistant cable was energized with a dc voltage and monitored for electrical faults.

A total of six fire resistant cable types were tested in a total of twelve configurations. Nine of the test configurations were included to develop information for consideration as to the use of the Rockbestos cables in redundant safety trains as specified in Appendix R to 10 CFR 50. The remaining three test configurations were included to develop engineering information of a preliminary nature for use by The Rockbestos Company. Only the data pertinent to the nine fire resistant cable configurations intended for consideration as to use in redundant safety trains, as specified in Appendix R to 10 CFR 50, are included herein. These nine fire resistant cable configurations are listed below:

1. 3/C-No. 14 AWG power cable with stainless steel sheath (Product Code E30-0211) in conduit-to-cable tray transition.

2. 3/C-No. 14 AWG power cable with stainless steel sheath (Product Code E30-0211) in cable tray.

3. 3/C-No. 14 AWG power cable without stainless steel sheath (Product Code E30-0208) in conduit.

4. 3/C-No. 6 AWG power cable with stainless steel sheath (Product Code E30-0210) in conduit-to-cable tray transition.

5. 3/C-No. 6 AWG power cable with stainless steel sheath (Product Code E30-0210) in cable tray.

6. 3/C-No. 6 AWG power cable without stainless steel sheath (Product Code E30-0204) in conduit.

7. 2/C-No. 14 AWG shielded twisted pair (S.T.P.) instrumentation cable with stainless steel sheath (Product Code E30-0212) in conduit-to-cable tray transition.

8. 2/C-No. 14 AWG S.T.P. instrumentation cable with stainless steel sheath (Product Code E30-0212) in cable tray.

9. 2/C-No. 14 AWG S.T.P. instrumentation cable without stainless steel sheath (Product Code E30-0209) in conduit.

Following the full-scale floor fire test investigation, a second fire test was conducted on two samples of the fire resistant cables installed beneath a 3 by 3 ft concrete floor slab. During the small-scale fire endurance test, each of the fire resistant cables was energized with rated voltage and monitored to measure leakage current.

The fire endurance and hose stream tests were supplemented with other tests and examinations which provided additional information relative to the electrical performance characteristics of the fire resistant cables.

D E S C R I P T I O N

MATERIALS:

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

FULL-SCALE TEST ASSEMBLY

Floor Assembly - The floor assembly consisted of five separate steel-reinforced vermiculite concrete slabs. Two of the slabs measured 5 ft, 2 in. by 13 ft, 8 in. by 8 in. thick. The remaining three slabs were 1 ft, 8 in. by 13 ft, 8 in. by 8 in. thick.

Cable Tray System - The nominal 24 in. wide open-ladder cable tray consisted of channel-shaped siderails and boxed-channel rungs. The siderails were 6-1/2 in. deep and were formed of 0.082 in. thick (No. 14 gauge) galvanized steel. The top and bottom flanges of the siderail were 1-1/4 in. wide. The boxed-channel rungs were 1-1/8 in. wide by 5/8 in. deep and were formed of 0.066 in. thick (No. 16 gauge) galvanized steel. The rungs were spaced 9 in. OC and were welded to the web of the siderails at each end. The loading depth of the tray was 5-3/4 in. The cable tray straight lengths were manufactured by Metal Products Division, United States Gypsum Company and designated "GLOBETRAY" (Catalog No. PLHD-SS09-2400-6-12).

The nominal 24 in. wide 90° inside vertical riser fittings used in the cable tray system each had an inside radius of 12 in., an outside radius of 18-1/2 in., and a tangent length of 3 in. The siderail members for each inside vertical riser were channel-shaped in cross-section with a web height of 6-1/2 in. and a top and bottom flange width of 1/2 in. The siderail members were formed of 0.082 in. thick (No. 14 gauge) galvanized steel. The inside vertical riser fittings were each provided with the same boxed-channel rungs used in the straight lengths. The rungs were spaced nominally 6 in. OC and were welded to the web of the siderails at each end. The inside vertical riser fittings were manufactured by Metal Products Division, United States Gypsum Company and designated "GLOBETRAY" (Catalog No. PLHD-IV90-2412-6).

The nominal 24 in. wide 90° outside vertical riser fitting used in the cable tray system had an inside radius of 12 in., an outside radius of 18-1/2 in. and a tangent length of 3 in. The siderail members were channel-shaped in cross-section with a web height of 6-1/2 in. and a top and bottom flange width of 1/2 in. The siderail members were formed of 0.082 in. thick (No. 14 gauge) galvanized steel. The outside vertical riser fitting was provided with the same boxed-channel rungs used in the straight lengths of cable tray. The rungs were spaced nominally 6 in. OC and were welded to the web of the siderails at each end. The outside vertical riser fitting was manufactured by Metal Products Division, United States Gypsum Company and designated "GLOBETRAY" (Catalog No. PLHD-OV90-2412-6).

The flat splice plates used to join the inside and outside vertical riser fittings with the cable tray straight sections consisted of 4 by 6 by 0.107 in. thick (No. 12 gauge) galvanized steel plates. Each splice plate was provided with eight 3/8 in. diameter by 5/8 in. long slots which aligned with the four 3/8 in. diameter holes drilled at each end of the vertical riser and straight section cable tray siderails. The splice plates were manufactured by Metal Products Division, United States Gypsum Company and designated "GLOBETRAY" (Catalog No. P-RSPST-6-H). Each splice plate was provided with 3/8 in. diameter truss-head ribbed shank bolts and serrated flanged nuts.

Steel Conduit Systems - The nominal 3 in. diameter Trade Size rigid steel conduits were 3.500 in. in diameter with a wall thickness of 0.216 in. Each of the three nominal 3 in. diameter rigid conduit systems consisted of two 90° elbows with threaded ends, one nominal 10 ft straight length with threaded ends, two straight lengths each having one threaded end, four threaded steel couplings and two set-screw fiber bushings.

The nominal 1-1/2 in. diameter Trade Size rigid steel conduit used in the conduit-to-cable tray transition was 1.900 in. in diameter with a wall thickness of 0.145 in. The conduit system consisted of one 90° elbow with threaded ends, a straight length having one threaded end, two threaded steel couplings and one set screw fiber bushing.

The nominal 3/4 in. diameter Trade Size rigid steel conduits used in the two conduit-to-cable tray transitions were 1.050 in. in diameter with a wall thickness of 0.113 in. Each of the two conduit systems consisted of one 90° elbow with threaded ends, one straight length having one threaded end, two threaded steel couplings and one set-screw insulated grounding bushing.

The conduits and elbows each bore the UL Listing Mark. The straight conduit lengths and couplings were supplied by GPU Nuclear Corporation, Parsippany, New Jersey. The conduit elbows and bushings were purchased locally.

Conduit Terminations - The conduit terminations used in conjunction with the nominal 1-1/2 in. and 3/4 in. diameter Trade Size rigid steel conduits for the conduit-to-cable tray transitions each consisted of a stainless steel compression shell, a brass grommet and a stainless steel coupling nut. The conduit termination fittings were manufactured by Rowe Industries, Toledo, Ohio and designated Type 3RT9006 (nominal 1-1/2 in. diameter Trade Size fitting) and Type 2RT9006 (nominal 3/4 in. diameter Trade Size fitting).

Trapeze Support - The trapeze supports each consisted of two nominal 1/2 in. diameter threaded steel rods, an L4x3x1/2 in. thick structural steel angle and steel nuts.

Fire Resistant Cables - Six types of fire resistant cables were included in the fire test assembly. The six cable types were: 3/C-No. 14 AWG with stainless steel sheath (Product Code E30-0211); 3/C-No. 6 AWG with stainless steel sheath (Product Code E30-0210); 2/C-No. 14 AWG shielded twisted pair (S.T.P.) with stainless steel sheath (Product Code E30-0212); 3/C-No. 14 AWG without stainless steel sheath (Product Code E30-0208); 3/C-No. 6 AWG without stainless steel sheath (Product Code E30-0204); and 2/C-No. 14 AWG S.T.P. without stainless steel sheath (Product Code E30-0209).

The six cable types, designated Firewall FR SR Class 1E Electric Cables, were manufactured by The Rockbestos Company, Division of CEROCK Wire & Cable Group, Inc., New Haven, Connecticut. No marking was present on the cable jackets or sheaths.

Fuel Loading Cables - Four types of fuel loading cables were used in the cable tray systems. The cable types used were 3/C-No. 2 AWG power cables, 9/C-No. 12 AWG control cables, 19/C-No. 12 AWG control cables and 37/C-No. 12 AWG control cables.

Each conductor of the 3/C-No. 2 AWG power cable consisted of seven 0.097 in. diameter copper strands stranded together and covered with a mylar wrap and cross-linked polyethylene (XLPE) insulation. The outside diameter of each conductor was 0.403 in. The fillers within the cable construction consisted of polyester strands. The fillers and conductors were encased in a tissue paper wrap and covered with a Hypalon jacket. The outside diameter of the cable was 1.036 in. The cable jacket was marked "2 AWG 3/C ROCKBESTOS R 600V FIREWALL R III XHHW NEC TYPE TC (UL)."

Each conductor of the 9/C-No. 12 AWG cable consisted of seven 0.031 in. diameter copper strands stranded together and covered with ethylene propylene rubber insulation and a hypalon jacket. The outside diameter of each conductor was 0.196 in. The fillers within the cable construction consisted of polyester strands. The fillers and conductors were encased in a scrim paper wrap and covered with a hypalon jacket. The outside diameter of the cable was 0.858 in. The cable jacket was marked "BOSTON INSULATED WIRE AND CABLE COMPANY, (1980) 9/C-12 AWG, EPR/HYP INSUL, HYPALON JKT. 600 V."

Each conductor of the 19/C-No. 12 AWG cable consisted of seven 0.029 in. diameter copper strands stranded together and covered with polyethylene insulation and a PVC jacket. The outside diameter of each conductor was 0.156 in. The conductors were encased in a mylar wrap and covered with a PVC jacket. The outside diameter of the cable was 0.935 in. The cable jacket was marked "ROME CT-B CONTROL CABLE 19/C 12 AWG CU 600 V."

Each conductor of the 37/C-No. 12 AWG cable consisted of seven 0.030 in. diameter copper strands stranded together and covered with XLPE insulation. The outside diameter of each conductor was 0.153 in. The conductors were encased in a mylar wrap and covered with a PVC jacket. The outside diameter of the cable was 1.250 in. The cable jacket was marked "ROME CABLE 37/C 12 AWG CU 600 V XLP TYPE B CONTROL CABLE."

The 19/C- and 37/C-No. 12 AWG control cables were purchased locally. The 3/C-No. 2 AWG and the 9/C-No. 12 AWG cables were supplied by GPU Nuclear Corporation, Parsippany, New Jersey. The reel containing the 3/C-No. 2 AWG cable bore a pressure-sensitive adhesive label reading "GPU NUCLEAR TMI, Reel Number #2, B/M____, Footage 896', P.O. Number ________, Date Received __________, S.S.N. 118-764-2900-1." The reel containing the 9/C-No. 12 AWG cable bore a pressure-sensitive adhesive label reading "GPU NUCLEAR TMI, Reel Number EJ0018, B/M FR-9JJ, Footage 593', P.O. Number 89145, Date Received 9-8-80, S.S.N. 118-753-7000-1."

Cable Ties - The ties used to secure the fire resistant and fuel loading cables in place consisted of No. 14 SWG (0.080 in. diameter) steel wire ties and stainless steel cable straps. The stainless steel cable straps were purchased from Metal Products Division, United States Gypsum Company (Catalog Nos. CT-2000-SS and CT-4375-SS).

SMALL-SCALE TEST ASSEMBLY

Floor Assembly - The floor assembly consisted of a nominal 36 by 36 by 2 in. thick steel-reinforced normal weight concrete slab.

Fire Resistant Cables - Two cable types were used in the test assembly. The cable types used were 3/C-No. 14 AWG cable with stainless steel sheath (Product Code E30-0211) and 2/C-No. 14 AWG S.T.P. cable with stainless steel sheath (Product Code E30-0212). The cable samples were cut from the same reels of cable used in the full-scale floor fire test assembly.

Cable Ties - The ties used to band the coils of fire resistant cables were stainless steel cable straps purchased from Metal Products Division, United States Gypsum Company (Catalog No. CT-4375-SS).

ERECTION OF TEST ASSEMBLIES:

FULL-SCALE TEST ASSEMBLY

The full-scale floor fire test assembly was constructed in accordance with the methods specified by the submittor, as shown in ILLS. 1 through 9. The construction of the test assembly was observed by members of the technical and engineering staff of Underwriters Laboratories Inc.

Nominal 6 by 6 by 1/2 in. thick structural steel angles were placed along the walls of the test frame such that the top of the horizontal leg was 8 in. below the top edges of the test frame. The five steel-reinforced vermiculite concrete floor slabs were then installed in the test frame. Prior to installation of the floor slabs, nominal 1-1/4 in. thick mineral-wool batts were placed over the structural steel angles to form a smoke and heat seal. The average bearing of each floor slab on the structural steel angles was 4-1/2 in. A 6 in. separation was maintained between adjacent floor slabs to accommodate the vertical legs of the cable tray and conduit systems.

Two W4x13 steel beams, 17 ft long, were placed over the top of the floor slabs. The beams rested on and were secured to the projecting steel reinforcement of each slab (bottom chord of inverted Type 8H2 steel joists) to prevent differential deflection of the various slabs during fire exposure.

The locations of the various cable trays and conduits in the floor assembly are shown in ILL. 1.

The trapeze supports for the cable trays and conduits were installed as shown in ILLS. 1, 2, 4 and 5.

The nominal 24 in. wide main cable tray system and the auxiliary cable tray receiving the tray-to-tray cable air drops were assembled and installed as shown in ILL. 2. The 24 in. wide main cable tray system was assembled with flat splice plates in conjunction with 3/8 in. diameter truss-head ribbed shank bolts and serrated flanged nuts. The main cable tray system and auxiliary cable tray were suspended from the trapeze supports. In addition, the cable tray system was suspended by means of nominal 2 by 2 by 1/4 in. thick steel angles, 24 in. long, spanning across the projecting steel reinforcement of the floor slabs (bottom chord of inverted Type 8H2 steel joists) and welded to the cable tray siderails.

The three nominal 3 in. diameter rigid steel conduit systems were assembled and installed as shown in ILL. 4. The three conduit systems rested on the trapeze supports and were additionally supported by means of nominal 2 by 2 by 1/4 in. thick steel angles, 24 in. long, spanning across the projecting steel reinforcement of the floor slabs and welded to the sides of the conduits.

Prior to installation of the main cable tray system, auxiliary cable tray and the three nominal 3 in. diameter rigid steel conduits, a nominal 1 in. thickness of ceramic fiber blanket was placed on the 3 in. wide bearing leg of the trapeze support angle such that the cable raceways did not rest directly upon the steel trapeze supports.

The two nominal 3/4 in. diameter rigid steel conduits and the nominal 1-1/2 in. rigid steel conduits for the conduit-to-cable tray transitions were installed as shown ILL. 5. The elbow of each conduit rested on and was welded to the 3 in. leg of the trapeze support angle. Each conduit was additionally supported by means of nominal 2 by 2 by 1/4 in. thick steel angles, 24 in. long, spanning across the projecting steel reinforcement of the floor slabs and welded to the conduits.

The 6 ft, 9 in. long auxiliary cable tray was provided with a 41.5 percent fill of randomly-laid fuel loading cables. Each cable was cut into a 6 ft, 9 in. length and was laid flat in the cable tray. The type and quantity of fuel loading cables in the auxiliary cable tray are tabulated below:

Cable Type	Cable Insulation Material	Cable Jacket Material	Cable OD	Quantity
3/C-No. 2 AWG	XLP	HYP	1.036 in.	16 pieces
9/C-No. 12 AWG	EPR-HYP	HYP	0.858 in.	16 pieces
19/C-No. 12 AWG	PE	PVC	0.935 in.	36 pieces
37/C-No. 12 AWG	XLP	PVC	1.250 in.	8 pieces

The 3/C-No. 14 AWG, 3/C-No. 6 AWG and the 2/C-No. 14 AWG S.T.P. cables with the stainless steel sheaths (Product Code E30-0211, -0210 and -0212, respectively) were installed in the bottom of the main cable tray system and air-dropped into the auxiliary cable tray as shown in ILLS. 1, 2 and 3. The stainless steel sheathed cables were secured to the rungs of the main cable tray system and to the top layer of fuel loading cables in the auxiliary cable tray with stainless steel cable straps. The 3/C-No. 6 AWG cable and the 2/C-No. 14 AWG S.T.P. cable were installed such that the stainless steel sheath was in contact with the siderail of both the main cable tray system and auxiliary cable tray. The 3/C-No. 14 AWG cable was installed along the longitudinal centerline of the main cable tray system and auxiliary cable tray.

After installation of the stainless steel sheathed cables, a 41.5 percent fill of randomly-laid fuel loading cables was installed in the main cable tray system. The type and quantity of fuel loading cables in the main cable tray system was identical to that installed in the auxiliary cable tray. The fuel loading cables were installed along the entire length of the cable tray system beneath the floor and terminated approximately 2 in. below the underside of the floor. The vertical runs of cable in the main cable tray system were secured to the cable tray rungs with stainless steel cable straps and steel wire ties.

Each of the three fire resistant cables in the main cable tray system passed through the floor and projected above the top of the floor.

Three fire resistant cables without stainless steel sheaths were installed in each of the three nominal 3 in. diameter conduit systems, as shown in ILL. 4. The west conduit system contained three 2/C-No. 14 AWG S.T.P. cables (Product Code E30-0209). The center conduit contained two 3/C-No. 14 AWG cables and one 3/C-No. 6 AWG cable (Product Code E30-0208 and -0204, respectively). The east conduit contained two 3/C-No. 6 AWG cables and one 3/C-No. 14 AWG cable (Product Code E30-0204 and -0208, respectively). Each cable was installed along the entire length of each conduit system and projected approximately 2 ft beyond each end of each conduit system. After installation of the cables, the ends of each conduit on the unexposed side of the assembly were stuffed with pieces of ceramic fiber blanket to minimize convective heat loss and smoke issuing from the conduit during the fire test.

One fire resistant cable was installed in each of the two nominal 3/4 in. diameter rigid steel conduits and in the nominal 1-1/2 in. diameter rigid steel conduit, as shown in ILL. 5. The fire resistant cable installed in the nominal 1-1/2 in. diameter rigid steel conduit was a 3/C-No. 6 AWG stainless steel sheathed cable (Product Code E30-0210). The fire resistant cable installed in the west nominal 3/4 in. diameter rigid steel conduit was a 3/C-No. 14 AWG stainless steel sheathed cable (Product Code E30-0211). The fire resistant cable installed in the east nominal 3/4 in. diameter rigid steel conduit was a 2/C-No. 14 AWG S.T.P. stainless steel sheathed cable (Product Code E30-0212). The portion of each fire resistant cable which entered the rigid steel conduit was stripped of its stainless steel sheath. The stainless steel sheathed portion of each fire resistant cable protruding from the rigid steel conduit extended through the air and entered the main cable tray system as shown in ILL. 1. At its entrance into the main cable tray system, each fire resistant cable was secured to the top layer of fuel loading cables using stainless steel cable straps. The fire resistant cables extended through the floor and projected above the top surface of the floor, with the ends of the cable secured to the rungs of the main cable tray system with stainless steel cable straps. The conduit-to-cable tray transitions were accomplished using compression-type conduit terminations. For each transition, the conduit termination compression shell was threaded into the conduit coupling at the end of the conduit elbow. The fire resistant cable, with stainless steel sheath removed and with the conduit termination coupling nut and grommet in place, was inserted into the conduit through the opening in the compression shell. The cut end of the stainless steel sheath projected approximately 7/8 in. into the open end of the compression shell. The small end of the brass grommet was flush with the end of the stainless steel sheath. While restraining the compression shell from rotating, the coupling nut was brought forward and tightened onto the compression shell to 150 ft-lb. The unsheathed portion of each fire resistant cable extended approximately 2 ft beyond the ends of the conduits on the unexposed side of the assembly. After installation of the fire resistant cables, the end of each conduit on the unexposed side of the assembly was stuffed with pieces of ceramic fiber blanket to minimize convective heat loss and smoke issuing from the conduit during the fire test.

After installation of the cable trays, conduits and cables, the nominal 6 in. wide slots in the floor assembly containing the vertical legs of the various systems were filled with vermiculite concrete as a firestop. First, each of the fire resistant cables exiting the floor from the main cable tray system (three cable ends at north end of assembly and six cable ends at south end of assembly) were individually wrapped with a nominal 1 in. thick by 4 in. wide piece of ceramic fiber blanket. The ceramic fiber blanket was secured in place with steel wire ties and was installed such that the bottom edge of the ceramic fiber blanket wrap was flush with the bottom surface of the floor. Removeable forms were placed beneath each slot, flush with the underside of the floor slab. Small pieces of ceramic fiber blanket were stuffed between the edges of the forms and the cables to minimize leakage of the vermiculite concrete. Nominal 7 in. lengths of nominal 1/2 in. diameter deformed steel rods were wedged into each slot to act as reinforcement. The vermiculite concrete, composed of five parts expanded vermiculite aggregate to one part Portland cement, by bulk volume, and mixed with water, was pumped into the slots and struck with a trowel. After drying for 24 h, the forms were removed from the underside of the assembly.

As a final step, the underside of the floor assembly and the horizontal and vertical members of the trapeze supports beneath the floor assembly were protected. The protection on the nominal 1/2 in. diameter threaded steel rods acting as the vertical members of the trapeze supports were each wrapped with a nominal 1 in. thickness of ceramic fiber blanket held in place with steel wire ties. The ceramic fiber blanket was then wrapped with a layer of expanded steel lath to act as a mechanical key for the protection material. The protection material applied to the expanded steel lath consisted of a nominal 1 in. thickness of Zonolite Type MK-5 cementitious mixture which was mixed with water and applied by hand. The protection on the L4x3x1/2 in. thick structural steel angles forming the horizontal member of the trapeze support consisted of a nominal 1/2 in. thickness of the Type MK-5 cementitious mixture applied to all exposed faces of the steel angle. The protection on the underside of the floor assembly consisted of a nominal 3/4 to 1 in. thickness of spray-applied Type MK-5 cementitious mixture.

The appearance of the exposed surface before the fire endurance test is shown in ILLS. 6, 7 and 8. The appearance of the unexposed surface before the fire endurance test is shown in ILL. 9.

SMALL-SCALE TEST ASSEMBLY

The small-scale floor fire test assembly was constructed in accordance with the methods specified by the submitter, as shown in ILL. 20. The construction of the test assembly was observed by members of the technical and engineering staff of Underwriters Laboratories Inc.

Nominal 25 ft lengths of the 3/C-No. 14 AWG and 2/C-No. 14 AWG S.T.P. stainless steel sheathed cables (Product Code E30-0211 and -0212, respectively) were each formed into a coil having an outside diameter of approximately 28 in. and containing three coils of cable. Each coil was formed and held in position with four stainless steel cable straps, as shown in ILL. 20.

Four nominal 1 in. diameter holes were drilled in the nominal 2 in. thick concrete slab to accommodate the four ends of the two cable coils. The free ends of the cable coils were inserted in the holes as shown in ILL. 20. Two nominal 3/8 in. diameter holes were drilled in the nominal 2 in. thick concrete slab and a No. 8 SWG (0.162 in. diameter) galvanized steel wire was threaded through the holes and through the two coils of cable with the two ends of the wire twisted together on the top (unexposed) side of the concrete slab to suspend the coiled cables. The four cable ends were additionally supported on the top side of the floor by means of short lengths of steel channel in conjunction with steel wire ties. Each of the six holes in the concrete slab was stuffed with small pieces of ceramic fiber blanket.

The end of each cable projected approximately 30 in. above the top surface of the floor.

TEST RECORD NO. 1

FULL-SCALE TEST ASSEMBLY

FIRE ENDURANCE TEST:

The fire endurance test was conducted with the furnace temperatures controlled in accordance with the Standard for Fire Tests of Building Construction and Materials, ASTM E119 (UL 263, NFPA No. 251).

SAMPLE

The fire endurance test was conducted on the full-scale test assembly constructed as previously described in this Report under the section entitled "Erection Of Test Assemblies" and as shown in ILLS. 1 through 9.

The installation of the cable raceways, conduits, fire resistant cables and fuel loading cables was completed approximately seven days before the fire endurance test was conducted.

METHOD

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

The temperatures of the furnace chamber were measured by 16 thermocouples which were placed 12 in. from the underside of the floor assembly, located as shown in ILL. 10.

Each conductor of the nine fire resistant cable configurations was energized with a low voltage ac electrical current and monitored during the fire endurance test. The electrical current driving and metering plan for each fire resistant cable is shown in ILL. 11. Each conductor of the three conductor power cables (Product Code E30-0204, -0208, -0210 and -0211) was provided with a jumper between its two ends which was fitted with a driver transformer set and a metering transformer, as shown in ILLS. 12 and 13. The characteristics of the driver transformer circuit and its associated variable transformer were such that all conductors of each three conductor cable had a common driver transformer set controlled by a single variable transformer, as shown in ILLS. 15 and 16. The control range was such that currents in the range of 3 to 21 A could be achieved on the 3/C-No. 14 AWG cables and 20 to 120 A could be achieved on the 3/C-No. 6 AWG cables. The 2/C-No. 14 AWG S.T.P. instrumentation cables (Product Code E30-0209 and -0212) were similarly connected. However, the conductors of all of the two conductor cables were driven by a common transformer (three test sample cables plus one engineering sample cable for a total of eight conductors), as shown in ILLS. 14, 15 and 16.

The predetermined steady-state and inrush current values for the 3/C-No. 14 AWG power cables were 3.4A and 21A, respectively. The predetermined steady-state and inrush current values for the 3/C-No. 6 AWG power cables were 19.8A and 120A, respectively. The 2/C-No. 14 AWG S.T.P. instrumentation cables were each energized with a simulated "pilot" current in the approximate range of 1 to 2 A.

Before the start of the fire endurance test, each cable was energized at its predetermined steady-state current. As the fire endurance test proceeded, the output of the variable transformer was increased to maintain the steady-state currents as compensation for the increase in circuit resistance caused by the normal resistance versus temperature characteristics of the conductor exposed to the fire. During the last 15 min of the fire portion of the test, each three conductor power cable was deenergized for 10 s. After 10 s, the current was reapplied and rapidly adjusted to an inrush value. The inrush current was held for 30 s and then rapidly decreased to the predetermined steady-state value.

In addition to the low voltage ac electrical current applied to each conductor of the nine fire resistant cable configurations, each fire resistant cable was energized with a dc voltage and monitored continuously for electrical faults (conductor-to-conductor, conductor-to-sheath/ground, conductor-to-shield and shield-to-sheath/ground). The details of the electrical fault monitor circuitry are shown schematically in ILL. 17. The electrical fault monitor panel was connected to an automatic data logger which scanned each circuit and provided a printed record to show electrical faults.

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 resistant cables with special reference to circuit integrity.

RESULTS

Character And Distribution Of Fire - The fire was luminous and well-distributed. As shown in ILL. 10, the furnace temperatures followed the standard time-temperature curve as outlined in the Standard, ASTM E119 (UL 263, NFPA No. 251) during the first 10 min of fire exposure. Thereafter, the heat contributed from the burning fuel loading cables in the main cable tray system and the auxiliary cable tray caused the furnace temperatures to exceed the standard time-temperature curve.

Observations During Test - On the exposed side of the test assembly, the fuel loading cables in the auxiliary cable tray ignited at 40 s. The fuel loading cables in the main cable tray system were smoking at 1 min, 30 s and, at 2 min, 15 s, the cables ignited. By 3 min, 30 s, the fuel loading cables in the main cable tray system and auxiliary cable tray were engulfed in flame and were smoking profusely. The profuse flaming and smoking of the fuel loading cables continued throughout the fire exposure test. At 40 min, it was noted that the galvanized coating on the cable trays and conduits was oxidized. During the final 20 min of fire exposure, the cable tray siderails bowed inward and several of the cable tray rungs disengaged from the cable tray siderails and allowed the fuel loading cables to deflect downward.

On the unexposed side of the test assembly, white smoke commenced issuing from the ends of the fire resistant cables at 4 min. The smoking continued until 30 min. Thereafter, no significant changes occurred on the unexposed side of the test assembly. The furnace fire was extinguished at 60 min.

Circuit Integrity - During the fire exposure test, each conductor of each fire resistant cable carried its steady-state electrical current. During the fire exposure, it was necessary to "trim" the variable transformer to maintain the test current. Commencing at 47 min, each three conductor power cable was deenergized for 10 s. The current was then reapplied to each cable and rapidly adjusted to the maximum current attainable and held for 30 s. The voltage output from the variable transformer was not sufficient to attain the predetermined inrush current level in any of the power cables due to the increased resistance of the conductors. After the 30 s inrush current test, the current was reduced to its steady-state value. The electrical current measurements recorded during the fire endurance test are contained in Appendix A.

During the fire endurance test, some of the light emitting diodes (LED's) in the electrical fault monitor panel commenced glowing visibly after 12 min of fire exposure. By 25 min, all of the LED's were illuminated at various degrees of brightness. However, at that time, no electrical faults were indicated by the automatic data logger monitoring current flow through the LED's. As the test progressed, the brightness of the LED's increased and the current flow through the LED's registered on the automatic data logger.

Following the fire endurance test, the electrical fault monitoring circuitry was analyzed. Based on this analysis described in the section of this Test Record entitled "Discussion," it was determined that no electrical faults occurred in any of the nine fire resistant cable configurations during the fire endurance test. Rather, it was determined that the illumination of the LED's during the fire endurance test was an indication of leakage currents caused by the temperature effect on insulation resistance.

INITIAL HOSE STREAM TEST:

SAMPLE

The hose stream was applied to the exposed surface of the floor assembly. The hose stream test commenced approximately 5 min, 30 s after the furnace fire was extinguished.

METHOD

At the conclusion of the fire exposure, the fire resistant cables were deenergized and the test assembly was lifted from the furnace and moved to the hose stream area.

The cable trays, conduits and cables were subjected to the action of a water hose stream applied for a duration of 90 s. The hose stream was applied with an electrically-safe fog nozzle (set at a 30° included angle) at a perpendicular distance of approximately 17 ft, 3 in. from the center of the test assembly and on a line approximately 27° from a line normal to the center of the assembly. The water pressure measured at the inlet of the 1-1/2 in. diameter hose 50 ft upstream of the nozzle was 105 psi.

Following the 90 s water hose stream test, subsequent applications of water were necessary to suppress flaming of the fuel loading cables in the main cable tray system and in the auxiliary cable tray.

RESULTS

Upon suppression of all flaming of the fuel loading cables, current was applied to each of the nine fire resistant cable configurations. Each conductor of each fire resistant cable carried its steady-state electrical current.

At the conclusion of the fire endurance test, all of the electrical fault monitoring circuits had been switched off. Following the water hose stream test, all of the electrical fault monitoring circuits were reenergized. At that time, a low current (1 mA) electrical fault (dim LED) was indicated between the shield and sheath of the 2/C-No. 14 AWG S.T.P. instrumentation cable with stainless steel sheath in the main cable tray system. No other electrical faults were indicated.

<u>EXTENDED COOL-DOWN PERIOD:</u>

At the conclusion of the fire endurance test and initial water hose stream test, the predetermined steady-state electrical currents were reapplied to each of the nine fire resistant cable configurations. The cables remained energized throughout a 93 h extended cool-down period except for 10 s periods immediately preceding each of four supplemental inrush current tests. The electrical current measurements recorded during the extended cool-down period are contained in Appendix A.

In addition to monitoring current in each of the nine fire resistant cable configurations, each fire resistant cable was energized with a dc voltage and monitored for electrical faults during the 93 h extended cool-down period. To monitor circuit integrity in the absence of an operator (at night), the electrical fault monitor panel was connected to an automatic data logger which scanned each circuit at 55 min intervals and provided a printed record to show electrical faults. No electrical faults occurred during the extended cool-down period.

SECOND HOSE STREAM TEST:

SAMPLE

The hose stream was applied to the exposed surface of the floor assembly. The hose stream test commenced approximately 93 h after the fire endurance test was completed.

METHOD

At the conclusion of the 93 h extended cool-down period, the fire resistant cables were deenergized (except for dc voltage used to monitor cables for electrical faults) and the cable trays, conduits and cables were subjected to the action of a water hose stream applied for a duration of 90 s. The hose stream was applied with an electrically-safe fog nozzle (set at a 30° included angle) at a maximum distance of 5 ft from each of the cable trays, conduits and cables. The water pressure measured at the inlet of the 1-1/2 in. diameter hose 50 ft upstream of the nozzle was 100 psi.

RESULTS

During the hose stream test, no electrical faults occurred in the fire resistant cables.

Upon completion of the hose stream test, current was applied to each of the nine fire resistant cable configurations. Each conductor of each fire resistant cable carried its steady-state electrical current. A final inrush current test was conducted approximately 3 min after the hose stream test was completed. The electrical current measurements recorded during the final inrush current test are contained in Appendix A.

OBSERVATIONS AFTER TESTS:

The appearance of the exposed surface of the test assembly after all testing was completed is shown in ILLS. 18 and 19.

On the exposed side of the assembly, the three nominal 3 in. diameter rigid steel conduit systems and the three conduits used for the conduit-to-cable tray transitions were oxidized but were otherwise unchanged.

The main cable tray system and auxiliary cable tray were essentially destroyed. A majority of the cable tray rungs were disengaged from the cable tray siderails at one or both ends such that the mass of fuel loading cables was supported by the trapeze supports and by the fire resistant cables which penetrated the floor assembly at the two ends of the main cable tray system. Approximately 80 percent of the insulation and jacketing materials on the fuel loading cables had been consumed during the fire endurance test.

The stainless steel sheathed fire resistant cables in the main cable tray system and in the conduit-to-cable tray transition were displaced due to the disengagement of the cable tray rungs and the resultant downward movement of the fuel loading cable mass. With the loss of support from the cable tray rungs, the fuel loading cable mass along most of the main cable tray system run was suspended from the stainless steel sheathed fire resistant cables. The stainless steel sheath on each of the fire resistant cables did not appear to be damaged by the applied stresses.

The cementitious mixture protection material on the underside of the floor assembly and on the trapeze supports was partially dislodged by the water hose stream tests. Beneath the protection material, the floor assembly and trapeze supports remained structurally sound.

Other than discoloration of the fire resistant cable ends and the vertical legs of the cable raceways, no changes were noted in the appearance of the unexposed surface of the test assembly.

DISCUSSION:

During the fire endurance test, some of the light emitting diodes (LED's) in the electrical fault monitoring panel commenced glowing visibly after 12 min of fire exposure. By 25 min, all of the LED's were illuminated at various degrees of brightness. However, at that time, no electrical faults were indicated by the automatic data logger which monitored current flow through the LED's. As the test progressed, the brightness of the LED's increased and the current flow through the LED's became sufficiently high to register on the automatic data logger.

Following the fire endurance test and the initial water hose stream test, the only electrical fault indicated on the electrical fault monitoring panel was a dim glow of the LED's associated with the shield and sheath of the 2/C-No. 14 AWG S.T.P. instrumentation cable in the main cable tray system. The current flow through the two LED's was not sufficient to register on the automatic data logger.

During the extended cool-down period, the electrical fault monitoring circuitry was analyzed to discern the cause of the anomalous electrical fault indications during the fire endurance test.

The electrical fault monitoring circuitry is depicted schematically in ILL. 17. As shown, a dc voltage of 120 V is connected to a voltage divider. Two LED's are connected to the voltage divider at multiple points. The forward diode is yellow and the reverse diode is red. The outboard end of the diodes is connected to the test points (i.e., conductor, shield, sheath and/or ground). When an ohmic path is established between any two test points, the associated current flows between the LED's to indicate the nature of the electrical fault. Dependent upon the orientation of the LED's along the voltage divider, the level of current flowing between the LED's associated with two test points ranges between 17 and 104 mA under electrical fault conditions.

The automatic data logger monitoring current flow through the LED's was configured to indicate 0 percent up to 4 mA, 100 percent at 20 mA and "overrange" at anything over 20 mA in the forward direction. Over 20 mA in the reverse direction would also indicate an "overrange" condition.

Based on technical information provided by the manufacturer of the LED's used in the electrical fault monitoring panel, it was thought that a dc current in the range of 16 to 45 mA was required to illuminate the LED's. However, it was found that a dc current of 0.1 mA was sufficient to cause a visible glow in the LED's.

Based on the above in conjunction with a review of the printed record of current flow through the LED's during the fire endurance test, it was determined that no electrical faults occurred in any of the nine fire resistant cable configurations. Rather, the illumination of the LED's during the fire endurance test was determined to be an indication of leakage currents caused by the temperature effect on insulation resistance. Since the decrease in insulation resistance with temperature is reversible, no illumination of the LED's occurred after the assembly had been cooled by the water hose stream test. The only exception was the LED's associated with the shield and sheath of the 2/C-No. 14 AWG S.T.P. instrumentation cable in the main cable tray system.

As indicated earlier in this discussion, the LED's associated with the shield and sheath of the 2/C-No. 14 AWG S.T.P. instrumentation cable in the main cable tray system continued to glow visibly following the initial water hose stream test. Approximately 24 h after the fire endurance test was completed, the current flow through the LED's was measured with a Simpson Model 260 Volt-Ohm-Milliammeter and was found to be 1 mA. Approximately 72 h after the fire endurance test had been completed, the illumination of the LED's was still perceptible but was very faint. The measured current flow through the LED's at that time was 0.1 mA.

The level of current flowing between the LED's associated with the shield and sheath of the 2/C-No. 14 AWG S.T.P. instrumentation cable in the main cable tray system under mechanically induced electrical fault conditions was in excess of 20 mA. However, the measured current flow through the LED's in question was only 1 mA. Upon further cooling and drying of the assembly, the measured current flow through the LED's in question had dropped to 0.1 mA. These observations tend to substantiate the determination that no electrical faults occurred in the 2/C-No. 14 AWG S.T.P. instrumentation cable and that the illumination of the LED's in question reflected leakage current between the shield and sheath.

To further substantiate the determination that no electrical faults were present in the nine fire resistant cable configurations, insulation resistance and dielectric voltage-withstand tests were conducted on each conductor of the nine cables. The results of the insulation resistance and dielectric voltage-withstand tests are contained in Appendices B and C, respectively.

Because of the scale of the test assembly and safety considerations involved, it was deemed inadvisable to conduct the full-scale fire test investigation with the cables energized at rated voltage. Instead, the cables were energized only at rated current with a supplemental low voltage dc electrical fault monitoring circuit. In order to determine the levels of leakage current present in the fire resistant cables under fire exposure conditions with the cables energized at rated voltage, a second fire test investigation was conducted, as described in Test Record No. 2.

TEST RECORD NO. 2

SMALL-SCALE TEST ASSEMBLY

FIRE ENDURANCE TEST:

The fire endurance test was conducted with the furnace temperatures controlled in accordance with the Standard for Fire Tests Of Building Construction And Materials, ASTM E119 (UL 263, NFPA No. 251).

SAMPLE

The fire endurance test was conducted on the small-scale test assembly constructed as described previously in this Report under the section entitled "Erection Of Test Assemblies" and as shown in ILL. 20.

The installation of the fire resistant cables in the concrete floor slab was completed approximately 18 h before the fire test was conducted. The humidity of the concrete slab was less than 75 percent at the time of the fire test.

METHOD

The assembly was tested on a horizontal exposure furnace, as shown in ILL. 21. The furnace temperatures were measured by three thermocouples symmetrically located 12 in. below the exposed surface of the floor slab.

The temperatures of each coil of fire resistant cable were measured by two thermocouples affixed to the stainless steel sheath with stainless steel cable straps and located as shown in Appendix D, ILL. D1.

The fire resistant cables were connected to a test panel and three-phase power supply as shown in ILLS. 22, 23 and 24. The power supply was adjusted to provide three-phase Y voltages of 480/277 V ac. At room temperature (approximately 70 °F) the circuit was energized and charging currents were measured. Since only one test panel was available, the 3/C-No. 14 AWG power cable was energized continuously throughout the fire endurance test except for brief periods when it was disconnected to make measurements on the 2/C-No. 14 AWG S.T.P. instrumentation cable.

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 resistant cables.

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 the Standard, ASTM E119 (UL 263, NFPA No. 251), and as shown in the following table:

Test Time, min	Temperature, °F (ASTM E119 Time-Temperature Curve)	Average Furnace Temperature, °F
1	285	400
2	500	645
3	670	725
4	860	760
5	1000	1000
6	1110	1145
7	1180	1180
8	1230	1240
9	1260	1270
10	1300	1300
15	1399	1400
20	1462	1445
25	1510	1500
30	1550	1550
35	1584	1580
40	1613	1620
45	1638	1640
50	1661	1670
55	1681	1690
60	1700	1700
65	1718	1710
70	1735	1735
75	1750	1750
78	1759	1760

Observations During Test - On the exposed side of the test assembly, no changes were noted in the appearance of the fire resistant cables other than discoloration of the stainless steel sheaths.

On the unexposed side of the test assembly, white smoke commenced issuing from the ends of the fire resistant cables at 3 min. The smoking continued until 30 min. Other than discoloration of the cable ends and a slight "dishing" of the concrete floor slab, no significant changes were noted in the appearance of the unexposed surface during the remainder of the fire test. The furnace fire was extinguished at 78 min.

Temperatures Of The Cables - The temperatures measured by the various thermocouples on the fire resistant cables were measured at 1 min intervals during the fire test. These temperatures are tabulated in Appendix D, ILLS. D2, D3 and D4.

Leakage Current Measurements - During the fire endurance test and after the fire endurance test was completed, the leakage currents in each fire resistant cable were measured while energized at rated voltage. The applied voltages and leakage currents were measured using four Beckman 3010 Digital Multimeters supplied by The Rockbestos Company. After 1 h of fire exposure, each cable was subjected to an overvoltage condition (960 V ac phase-to-phase) for a minimum of 2 min and supplemental leakage current measurements were obtained. The leakage current measurements recorded during the fire test investigation are shown in the following tables:

LEAKAGE CURRENT MEASUREMENTS

(Applied Voltage - 480 V ac 3-Phase Y, 277 V ac - Ground)

3/C - No. 14 AWG Power Cable W/Stainless Steel Sheath (E30-0211)

Test Time min	Avg. Furnace Temp., °F	Leakage Current, Phase-Ground Red Cndr.	Leakage Current, Phase-Ground White Cndr.	Leakage Current, Phase-Ground Black Cndr	Leakage Current, Phase-Delta Red Cndr.	Leakage Current, Phase-Delta White Cndr.	Leakage Current, Phase-Delta Black Cndr.
0	70	72.6uA	74.9uA	74.9uA	94.6uA	97.4uA	97.7uA
6	1145	-	-	-	150uA	152uA	158uA
12	1345	0.19mA	0.21mA	1.5mA	0.19mA	0.25mA	0.5mA
18	1430	-	-	-	0.34mA	0.35mA	0.45mA
20	1445	0.43mA	0.45mA	0.46mA	0.44mA	0.45mA	0.47mA
31	1555	1.08mA	1.09mA	1.11mA	0.99mA	1.04mA	1.07mA
40	1620	7.16mA	7.45mA	5.49mA	6.91mA	7.13mA	5.30mA
47	1660	13.8mA	13.0mA	10.2mA	12.8mA	12.8mA	9.69mA
54	1680	24.2mA	23.7mA	18.3mA	23.9mA	23.4mA	18.0mA
63	1705	42.7mA	42.3mA	32.9mA	42.1mA	41.4mA	32.4mA
97+	650	110uA	114uA	64uA	114uA	125uA	73uA

2/C - No. 14 AWG S.T.P. Instrumentation Cable W/Stainless Steel Sheath (E30-0212)

Test Time, min	Avg. Furnace Temp., °F	Leakage Current, Cndr. - Shield White Conductor	Leakage Current, Cndr. - Shield Black Conductor	Leakage Current, Cndr. - Cndr. White Conductor	Leakage Current, Cndr. - Cndr. Black Conductor
0	70	97.6uA	95.1uA	110uA	110uA
26	1505	0.96mA	0.84mA	0.92mA	0.83mA
35	1580	4.21mA	3.65mA	4.06mA	3.58mA
49	1670	23.2mA	21.3mA	22.9mA	21.0mA
65	1710	60.9mA	59.6mA	60.4mA	59.1mA
103+	600	100uA	103uA	112uA	112uA

+ - Furnace fire extinguished at 78 min. Leakage current measurements taken with test sample located in furnace.

SUPPLEMENTAL LEAKAGE CURRENT MEASUREMENTS

(Applied Voltage - 960 V ac 3-Phase Y, 555 V ac - Ground)++

3/C - No. 14 AWG Power Cable W/Stainless Steel Sheath (E30-0211)

Test Time, min	Avg. Furnace Temp., °F	Leakage Current, Phase-Ground Red Cndr.	Leakage Current, Phase-Ground White Cndr.	Leakage Current, Phase-Ground Black Cndr.	Leakage Current, Phase-Delta Red Cndr.	Leakage Current, Phase-Delta White Cndr.	Leakage Current, Phase-Delta Black Cndr.
68	1725	127mA	138mA	99mA	108mA	110mA	84mA

2/C - No. 14 AWG S.T.P. Instrumentation Cable W/Stainless Steel Sheath (E30-0212)

Test Time, min	Avg. Furnace Temp, °F	Leakage Current, Cndr. - Shield		Leakage Current, Cndr. - Cndr.	
		White Conductor	Black Conductor	White Conductor	Black Conductor
75	1750	163mA	162mA	138mA	138mA

++ - High voltage applied and held for minimum 2 min for each leakage current measurement.

As a supplement to the above, the leakage current between the shield and the sheath of the 2/C-No. 14 AWG S.T.P. instrumentation cable was measured after approximately 75 min of fire exposure. With an applied voltage of 10 V ac, the leakage current was 113 mA. With an applied voltage of 180 V ac, the leakage current was 2000 mA.

In addition, the insulation resistance between the shield and sheath of the 2/C-No. 14 AWG S.T.P. instrumentation cable was measured during and after the fire endurance test. The insulation resistance measurements recorded during the fire test investigation are shown in the following table:

Test Time, min	Average Furnace Temperature, °F	Shield-Sheath Insulation Resistance
27	1525	17 kilohms
56	1695	2.1 kilohms
75	1750	3.5 kilohms
103	600	100 kilohms

S U M M A R Y

In consideration of the nature of this investigation, the foregoing Report is to be construed as information only and should not be regarded as conveying any conclusions or recommendations on the part of Underwriters Laboratories Inc. regarding the acceptability of the fire resistant cables for use in redundant safety trains, as specified in Appendix R to 10 CFR 50, or for any other purpose.

A total of six fire resistant cable types were installed in a total of nine configurations beneath a full-scale floor assembly. The nine fire resistant cable configurations are listed below:

1. 3/C-No. 14 AWG power cable with stainless steel sheath (Product Code E30-0211) in conduit-to-cable tray transition.

2. 3/C-No. 14 AWG power cable with stainless steel sheath (Product Code E30-0211) in cable tray.

3. 3/C-No. 14 AWG power cable without stainless steel sheath (Product Code E30-0208) in conduit.

4. 3/C-No. 6 AWG power cable with stainless steel sheath (Product Code E30-0210) in conduit-to-cable tray transition.

5. 3/C-No. 6 AWG power cable with stainless steel sheath (Product Code E30-0210) in cable tray.

6. 3/C-No. 6 AWG power cable without stainless steel sheath (Product Code E30-0204) in conduit.

7. 2/C-No. 14 AWG shielded twisted pair (S.T.P.) instrumentation cable with stainless steel sheath (Product Code E30-0212) in conduit-to-cable tray transition.

8. 2/C-No. 14 AWG S.T.P. instrumentation cable with stainless steel sheath (Product Code E30-0212) in cable tray.

9. 2/C-No. 14 AWG S.T.P. instrumentation cable without stainless steel sheath (Product Code E30-0209) in conduit.

On February 21, 1984, the full-scale floor assembly containing the nine fire resistant cable configurations was subjected to a 1 h fire endurance test. The fire endurance test was conducted with the furnace temperatures controlled in accordance with the standard time-temperature curve specified in ASTM Standard E119 (UL 263, NFPA No. 251). During the fire endurance test, each of the fire resistant cables was energized with a steady-state electrical current. Commencing after 47 min of fire exposure, each cable was deenergized for 10 s and an inrush current was applied to each cable and held for 30 s. After the 30 s inrush, the current levels were reduced to the steady-state values.

Immediately following the 1 h fire endurance test, the fire resistant cables were deenergized, the test assembly was removed from the furnace and the underside of the test assembly was subjected to the impact, erosion and cooling effect of a water hose stream applied for a duration of 90 s. Following additional water application to suppress flaming of the fuel loading cables in the cable tray systems, the fire resistant cables were again energized with steady-state electrical currents for an extended cool-down period totaling 93 h.

During the initial 79 h of the extended cool-down period, inrush current levels were applied to the test cables four times. Following the 79 h extended cool-down period, the cables remained energized with their steady-state electrical currents for an additional 14 h, after which they were deenergized and subjected to a second water hose stream test. Following the second water hose stream test, the cables were reenergized and a final inrush current test was conducted.

The electrical current measurements recorded during the full-scale test investigation are contained in Appendix A.

The insulation resistance of each fire resistant cable conductor was measured before the fire test, 24 h after the fire test and approximately 96 h after the fire test immediately following the second water hose stream. The insulation resistance measurements are contained in Appendix B.

On March 9, 1984 (17 days after the full-scale fire test), test potentials were applied to each fire resistant cable to determine "trip" voltage and voltage withstand between each conductor and all other conductors plus the shield, sheath or ground. The "trip" voltage and sustained voltage measurements are contained in Appendix C.

As evidenced from the tables in Appendices A, B and C, each of the nine fire resistant cable configurations in the full-scale test assembly remained electrically functional during the fire endurance test and during the extended cool-down period.

During the fire endurance test of the full-scale test assembly, all of the light emitting diodes (LED's) in the electrical fault monitoring panel illuminated. Based upon an analysis of the electrical fault monitoring circuitry and a review of the recorded data, it was determined that no electrical faults occurred in the nine fire resistant cable configurations and that the illumination of the LED's during the fire endurance test was an indication of leakage current caused by the temperature effect on insulation resistance. To determine the levels of leakage current present in the fire resistant cables during fire exposure conditions, a second fire endurance test was conducted on nominal 20 ft lengths of the stainless steel sheathed 3/C-No. 14 AWG power cable (Product Code E30-0211) and the stainless steel sheathed 2/C-No. 14 AWG shielded twisted pair (S.T.P.) instrumentation cable (Product Code E30-0212) installed beneath a small-scale floor assembly.

On March 9, 1984, the small-scale floor assembly was subjected to a 78 min fire exposure with the furnace temperatures controlled in accordance with the ASTM Standard E119 (UL 263, NFPA No. 251). During the fire endurance test, the cables were connected to a three phase power supply adjusted to provide three phase Y voltages of 480/277 V and 960/555 V ac. The leakage current measurements recorded during the small-scale test investigation are contained in Test Record No. 2. The temperatures measured on the stainless steel sheath of each fire resistant cable during the small-scale test investigation are contained in Appendix D.

The calibration records of the instrumentation used in the investigation are contained in Appendix E.

Report by:

C. J. Johnson

C. J. JOHNSON
Engineering Associate
Fire Protection Department

Reviewed by:

R. M. Berhinig

R. M. BERHINIG
Engineering Group Leader
Fire Protection Department

K. W. Howell

K. W. HOWELL
Associate Managing Engineer
Fire Protection Department

J R Beyreis

J. R. BEYREIS
Managing Engineer
Fire Protection Department

CJJ/RMB:pr
RPTS3

APPENDIX A

ELECTRICAL CURRENT MEASUREMENTS

FULL-SCALE TEST ASSEMBLY

The electrical current in each cable circuit was measured using a General Electric Model 750X93G metering transformer in conjunction with a General Electric Model 25034 panel ammeter having a range of 0-5 A ac. The stepdown ratios of the metering transformers were calibrated to obtain the required current(s) as a percentage of full scale deflection of the panel ammeters.

The three panel ammeters associated with each three-conductor power cable and the two panel ammeters associated with the two-conductor shielded twisted pair (S.T.P.) instrumentation cables were arranged in vertical rows, as shown in ILL. 16. It was expected that some variation in the current readings would be present in the individual panel ammeters associated with each cable due to the small variations in circuit impedance inherent in applications of three phase loads. Accordingly, the center panel ammeter associated with the white conductor of the individual three-conductor power cables was chosen to represent the desired current in each power cable.

The metering transformer and panel ammeter associated with the white conductor (center panel ammeter) of each three-conductor power cable and with each group of conductors of the two-conductor S.T.P. cables were calibrated against a reference ammeter. The reference ammeter used to check the calibration of the metering transformers and panel ammeters was an Amprobe Model ACD-1 hand-held clamp-on digital ammeter supplied by The Rockbestos Company. The calibration of the digital ammeter was checked against a calibrated General Electric 0-800A, 0-750 V hand-held clamp-on ammeter.

The actual electrical current associated with the panel ammeter reading of each circuit at the desired test current(s) is shown in the following table:

CURRENT MEASUREMENT CALIBRATION

Fire Resistant Cable Type	Cable Location	Steady-State Current Meter Reading, A	Steady-State Current Actual Current, A	Inrush Current Meter Reading, A	Inrush Current Actual Current, A
3/C-No. 14 AWG w/Stainless Steel Sheath (E30-0211)	Conduit-to-Cable Tray Transition	0.8	4.7	4	19.9
3/C-No. 14 AWG w/Stainless Steel Sheath (E30-0211)	Cable Tray-to-Cable Tray Transition	0.8	4.1	4	19.4
3/C-No. 14 AWG w/o Stainless Steel Sheath (E30-0208)	Nom. 3 in. Diameter Conduit System	0.8	3.8	4.2	20.1
3/C-No. 6 AWG w/Stainless Steel Sheath (E30-0210)	Conduit-to-Cable Tray Transition	1.0	30.0	4.0	118
3/C-No. 6 AWG w/Stainless Steel Sheath (E30-0210)	Cable Tray-to-Cable Tray Transition	1.0	30.3	4.0	116
3/C-No. 6 AWG w/o Stainless Steel Sheath (E30-0204)	Nom. 3 in. Diameter Conduit System	1.0	29.1	4.0	120
2/C-No. 14 AWG S.T.P. w/ & w/o Stainless Steel Sheath (E30-0212 & -0209)	All (4 White Cndrs)	3.5	6.7	N.A.	N.A.
	All (4 Black Cndrs)	4.0	7.7	N.A.	N.A.

The steady-state electrical current in each cable circuit and the inrush electrical current in each power cable circuit were recorded at various times during the fire endurance test and during the extended cool-down period, as shown in the following tables. In each table, the test time (Hr:Min) is the elapsed time from initiation of the fire endurance test.

During the fire endurance test and, in some instances, during the extended cool-down period, the voltage output from the variable transformers to their associated driver transformers was not sufficient to attain the desired inrush currents due to leakage currents. In cases where the desired inrush current was not attainable, the maximum attainable inrush current was applied and held for a duration of 30 to 32 s rather than the prescribed 15 s duration.

ELECTRICAL CURRENT MEASUREMENTS

Cable Type - 3/C-No. 14 AWG power cable w/stainless steel sheath (Product Code E30-0211)

Cable Location - Conduit-to-cable tray transition.

Test Time,	Red Conductor		White Conductor		Black Conductor		Inrush Current
Hr:Min	Meter Reading, A	Actual Current, A	Meter Reading, A	Actual Current, A	Meter Reading, A	Actual Current, A	Duration
0:00	0.9	5.3	0.8	4.7	1.0	5.9	-
0:18	0.8	4.7	0.6	3.5	0.8	4.7	-
0:32	0.8	4.7	0.7	4.1	0.9	5.3	-
0:43	0.9	5.3	0.9	5.3	0.9	5.3	-
0:47	3.4	16.9	3.2	15.9	3.3	16.4	30 s
0:58	1.0	5.9	0.9	5.3	0.8	4.7	-
1:44	0.8	4.7	0.7	4.1	0.9	5.3	-
2:20	4.0	19.9	4.0	19.9	4.0	19.9	17 s
27:34	1.0	5.9	0.9	5.3	1.0	5.9	-
27:39	4.2	20.9	4.1	20.4	4.1	20.4	16 s
48:40	0.9	5.3	0.8	4.7	1.0	5.9	-
49:10	4.1	20.4	4.0	19.9	4.0	19.9	15 s
76:00	0.9	5.3	0.8	4.7	1.0	5.9	-
79:30	4.1	20.4	4.0	19.9	4.0	19.9	16 s
94:05	4.1	20.4	4.0	19.9	4.0	19.9	15 s

Cable Type - 3/C-No. 14 AWG power cable w/stainless steel sheath (Product Code E30-0211)

Cable Location - Cable tray-to-cable tray transition.

Test Time,	Red Conductor		White Conductor		Black Conductor		Inrush Current
Hr:Min	Meter Reading, A	Actual Current, A	Meter Reading, A	Actual Current, A	Meter Reading, A	Actual Current, A	Duration
0:00	0.8	4.1	0.8	4.1	0.8	4.1	-
0:18	0.8	4.1	0.8	4.1	0.8	4.1	-
0:32	0.8	4.1	0.8	4.1	0.8	4.1	-
0:43	0.8	4.1	0.8	4.1	0.8	4.1	-
0:47	3.6	17.5	3.7	17.9	3.6	17.5	30 s
0:58	0.9	4.6	0.9	4.6	0.9	4.6	-
1:44	0.9	4.6	0.9	4.6	0.9	4.6	-
2:20	4.0	19.4	4.0	19.4	3.9	18.9	17 s
27:34	0.9	4.6	0.9	4.6	0.9	4.6	-
27:39	4.0	19.4	4.0	19.4	3.9	18.9	15 s
48:40	0.8	4.1	0.8	4.1	0.8	4.1	-
49:10	4.0	19.4	4.0	19.4	3.9	18.9	15 s
76:00	0.9	4.6	0.8	4.1	0.8	4.1	-
79:30	4.0	19.4	4.1	19.9	4.0	19.4	21 s
94:05	4.0	19.4	4.0	19.4	3.9	18.9	16 s

Cable Type - 3/C-No. 14 AWG power cable w/o stainless steel sheath (Product Code E30-0208)

Cable Location - Nominal 3 in. diameter rigid steel conduit system.

Test Time, Hr:Min	Red Conductor Meter Reading, A	Red Conductor Actual Current, A	White Conductor Meter Reading, A	White Conductor Actual Current, A	Black Conductor Meter Reading, A	Black Conductor Actual Current, A	Inrush Current Duration
0:00	0.8	3.8	0.8	3.8	0.8	3.8	-
0:18	0.7	3.3	0.7	3.3	0.7	3.3	-
0:32	0.8	3.8	0.8	3.8	0.9	4.3	-
0:43	0.8	3.8	0.8	3.8	0.9	4.3	-
0:47	3.5	16.8	3.5	16.8	3.6	17.2	30 s
0:58	0.8	3.8	0.8	3.8	0.9	4.3	-
1:44	0.9	4.3	0.9	4.3	0.9	4.3	-
2:20	4.0	19.1	4.0	19.1	4.1	19.6	20 s
27:34	0.8	3.8	0.8	3.8	0.9	4.3	-
27:39	4.0	19.1	4.0	19.1	4.1	19.6	15 s
48:40	0.8	3.8	0.8	3.8	0.9	4.3	-
49:10	4.0	19.1	4.0	19.1	4.1	19.6	15 s
76:00	0.8	3.8	0.8	3.8	0.8	3.8	-
79:30	4.0	19.1	4.0	19.1	4.1	19.6	15 s
94:05	4.0	19.1	4.0	19.1	4.1	19.6	15 s

Cable Type - 3/C-No. 6 AWG power cable w/stainless steel sheath (Product Code E30-0210)

Cable Location - Conduit-to-cable tray transition.

Test Time, Hr:Min	Red Conductor Meter Reading, A	Red Conductor Actual Current, A	White Conductor Meter Reading, A	White Conductor Actual Current, A	Black Conductor Meter Reading, A	Black Conductor Actual Current, A	Inrush Current Duration
0:00	0.8	24.0	0.8	24.0	0.8	24.0	-
0:18	0.6	18.0	0.6	18.0	0.7	21.0	-
0:32	-	-	- (Not Recorded) -		-	-	-
0:43	0.8	24.0	0.8	24.0	0.9	27.0	-
0:47	2.5	73.8	2.4	70.8	2.5	73.8	30 s
0:58	0.8	24.0	0.6	18.0	0.8	24.0	-
1:44	0.9	27.0	0.9	27.0	0.9	27.0	-
2:20	3.7	109.1	3.7	109.1	3.7	109.1	17 s
27:34	0.8	24.0	0.8	24.0	0.8	24.0	-
27:39	3.8	112.1	3.8	112.1	3.8	112.1	31 s
48:40	0.8	24.0	0.7	21.0	0.8	24.0	-
49:10	3.8	112.1	3.8	112.1	3.9	115.1	30 s
76:00	0.8	24.0	0.7	21.0	0.8	24.0	-
79:30	3.8	112.1	3.8	112.1	3.9	115.1	31 s
94:05	3.8	112.1	3.9	115.1	3.9	115.1	30 s

Cable Type - 3/C-No. 6 AWG power cable w/stainless steel sheath (Product Code E30-0210)

Cable Location - Cable tray-to-cable tray transition.

Test Time, Hr:Min	Red Conductor Meter Reading, A	Red Conductor Actual Current, A	White Conductor Meter Reading, A	White Conductor Actual Current, A	Black Conductor Meter Reading, A	Black Conductor Actual Current, A	Inrush Current Duration
0:00	0.8	24.2	0.8	24.2	0.8	24.2	-
0:18	0.8	24.2	0.7	21.2	0.7	21.2	-
0:32	0.7	21.2	0.7	21.2	0.7	21.2	-
0:43	0.8	24.2	0.7	21.2	0.7	21.2	-
0:47	3.1	89.9	3.0	87.0	3.0	87.0	30 s
0:58	0.9	27.3	0.9	27.3	0.9	27.3	-
1:44	0.9	27.3	0.8	24.2	0.9	27.3	-
2:20	4.0	116.0	4.0	116.0	4.0	116.0	20 s
27:34	0.9	27.3	0.6	18.2	0.7	21.2	-
27:39	4.0	116.0	4.0	116.0	4.0	116.0	15 s
48:40	0.8	24.2	0.7	21.2	0.8	24.2	-
49:10	4.0	116.0	4.0	116.0	4.0	116.0	15 s
76:00	0.8	24.2	0.7	21.2	0.7	21.2	-
79:30	4.0	116.0	4.0	116.0	4.0	116.0	15 s
94:05	4.0	116.0	4.0	116.0	4.0	116.0	15 s

Cable Type - 3/C-No. 6 AWG power cable w/o stainless steel sheath (Product Code E30-0204)

Cable Location - Nominal 3 in. diameter rigid steel conduit system.

Test Time, Hr:Min	Red Conductor Meter Reading, A	Red Conductor Actual Current, A	White Conductor Meter Reading, A	White Conductor Actual Current, A	Black Conductor Meter Reading, A	Black Conductor Actual Current, A	Inrush Current Duration
0:00	0.8	23.4	0.8	23.4	0.8	23.4	-
0:18	0.8	23.4	0.8	23.4	0.8	23.4	-
0:32	0.8	23.4	0.8	23.4	0.8	23.4	-
0:43	0.7	20.4	0.7	20.4	0.7	20.4	-
0:47	2.9	87.0	2.9	87.0	2.9	87.0	30 s
0:58	0.9	26.2	0.9	26.2	0.9	26.2	-
1:44	0.8	23.4	0.8	23.4	0.8	23.4	-
2:20	3.1	93.0	3.1	93.0	3.1	93.0	30 s
27:34	0.8	23.4	0.8	23.4	0.8	23.4	-
27:39	3.2	96.0	3.2	96.0	3.2	96.0	31 s
48:40	0.7	20.4	0.7	20.4	0.7	20.4	-
49:10	3.2	96.0	3.2	96.0	3.2	96.0	30 s
76:00	0.7	20.4	0.7	20.4	0.7	20.4	-
79:30	3.2	96.0	3.2	96.0	3.2	96.0	31 s
94:05	3.2	96.0	3.2	96.0	3.3	99.0	32 s

Cable Types - 2/C-No. 14 AWG shielded twisted pair (S.T.P.) instrumentation cables with and without stainless steel sheath (Product Codes E30-0212 and -0209, respectively).

Cable Locations - All.

Test Time, Hr:Min	White Conductors (4) Meter Reading, A	White Conductors (4) Actual Current, A	Black Conductors (4) Meter Reading, A	Black Conductors (4) Actual Current, A
0:00	4.1	7.8	4.1	7.9
0:18	4.3	8.2	4.3	8.3
0:32	4.2	8.0	4.1	7.9
0:43	4.0	7.7	4.0	7.7
0:58	4.0	7.7	4.0	7.7
1:44	4.0	7.7	4.0	7.7
27:34	4.0	7.7	4.0	7.7
48:40	4.1	7.8	4.1	7.9
76:00	4.1	7.8	4.1	7.9

APPENDIX B

INSULATION RESISTANCE MEASUREMENTS

FULL-SCALE TEST ASSEMBLY

The insulation resistance (I.R.) of each power cable conductor (one conductor to all others plus sheath/ground) and each shielded twisted pair (S.T.P.) instrumentation cable (conductor to conductor plus shield and shield to sheath/ground) were measured using a General Radio Model 1864 Megohmmeter and a Simpson Model 260 Volt-Ohm-Milliammeter supplied by The Rockbestos Company.

The initial I.R. test was conducted approximately 18 h before the fire endurance test with the jumpers disconnected. The interim I.R. test was conducted approximately 24 h after completion of the fire endurance test with the jumpers in place and with the cables energized with their steady-state electrical currents. The final I.R. test was conducted approximately 96 h after completion of the fire endurance test with the jumpers disconnected.

The results of the I.R. tests are shown in the following table:

INSULATION RESISTANCE MEASUREMENTS

Cable Tray	Cable Location	Cable Cndr.	Initial I.R., Ohms+ (1000Vdc-1 Min)	Interim I.R., Ohms+ (500Vdc-1 Min)	Final I.R., Ohms+ (1000Vdc-1 Min)
3/C-No. 14 AWG	Conduit-To-	Red	140G	26G	13G
w/Stnls. Steel	Cable Tray	White	140G	6G	4.5G
Sheath (E30-0211)	Transition	Black	160G	14G	6.8G
3/C-No. 14 AWG	Cable Tray-	Red	90G	12G	12G
w/Stnls. Steel	To-Cable Tray	White	140G	8.8G	7.6G
Sheath (E30-0211)	Transition	Black	150G	9.4G	8.6G
3/C-No. 14 AWG	Nom. 3 in.	Red	200G	120G	180G
w/o Stnls. Steel	Diam.Conduit	White	200G	110G	200G
Sheath (E30-0208)	System	Black	180G	130G	160G
3/C-No. 6 AWG	Conduit-To-	Red	170G	7.2G	40G
w/Stnls. Steel	Cable Tray	White	100G	6.8G	50M
Sheath (E30-0210)	Transition	Black	130G	7G	6.4G

Cable Tray	Cable Location	Cable Cndr.	Initial I.R., Ohms+ (1000Vdc-1 Min)	Interim I.R., Ohms+ (500Vdc-1 Min)	Final I.R., Ohms+ (1000Vdc-1 Min)
3/C-No. 6 AWG	Cable Tray-	Red	130G	56G	120G
w/Stnls. Steel	To-Cable Tray	White	130G	80G	54G
Sheath (E30-0210)	Transition	Black	110G	82G	64G
3/C-No. 6 AWG	Nom. 3 in.	Red	200G	170G	180G
w/o Stnls. Steel	Diam.Conduit	White	150G	130G	160G
Sheath (E30-0204)	System	Black	160G	170G	180G
2/C-No. 14 AWG	Conduit-To-	White	52G	58G	45G
S.T.P. w/Stnls.	Cable Tray	Black	65G	30G	30G
Steel Sheath	Transition	Shield	26G++	380k+++	350k
(E30-0212)					
2/C No. 14 AWG	Cable Tray-	White	60G	40G	50M
S.T.P. w/Stnls.	To-Cable Tray	Black	66G	22G	200M
Steel Sheath	Transition	Shield	45G++	34k+++	200k
(E30-0212)					
2/C No. 14 AWG	Nom. 3 in.	White	68G	110G	95G
S.T.P.w/o Stnls.	Diam. Conduit	Black	66G	110G	100G
Steel Sheath	System	Shield	110G++	1.2M+++	5M
(E30-0209)					

\+ - G = Gigaohms (1×10^9 ohms)
M = Megohms (1×10^6 ohms)
k = Kilohms (1×10^3 ohms)

++ - Shield-to-sheath/ground at 50Vdc-1 Min.

+++ - Measurements made with Simpson Model 260 Volt-Ohm-Milliammeter. All other measurements made with General Radio Model 1864 Megohmmeter.

APPENDIX C

DIELECTRIC VOLTAGE WITHSTAND TESTS

FULL-SCALE TEST ASSEMBLY

On March 9, 1984 (17 days after fire endurance test of full-scale test assembly), test potentials were applied to each fire resistant cable to determine "trip" voltage and voltage withstand between each conductor and all other conductors plus the shield, sheath or ground. The test potentials were applied and measured using an Associated Research, Inc. AC Hypot Junior Model 4025 voltage source.

The AC Hypot Junior Model 4025 is a nondestructive tester featuring a high reactance type transformer designed so that the output voltage will collapse should the current output exceed a given value. The instrument used for the dielectric voltage-withstand tests described herein was configured to "trip" at a current output (leakage current, charging current, corona and/or break-down current) of 1 mA.

The results of the dielectric voltage-withstand tests are shown in the following table.

DIELECTRIC VOLTAGE-WITHSTAND MEASUREMENTS

Cable Tray	Cable Location	Cable Condr.	"Trip" Voltage, kVac	Two Minute Sustained Voltage, kVac
3/C-No. 14 AWG w/	Conduit-To	Red	1.6	1.5
Stainless Steel	Cable Tray	White	2.4	2.0
Sheath (E30-0211)	Transition	Black	2.2	2.0
3/C-NO.14 AWG w/	Cable Tray-To-	Red	2.2	2.0
Stainless Steel	Cable Tray	White	2.1	2.0
Sheath (E30-0211)	Transition	Black	2.2	2.0
3/C-No. 14 AWG w/o	Nom. 3 in.	Red	1.7	1.5
Stainless Steel	Diam. Conduit	White	1.7	1.5
Sheath (E30-0208)	System	Black	1.55	1.5
3/C-No. 6 AWG w/	Conduit-To-	Red	1.5	1.4
Stainless Steel	Cable Tray	White	1.5	1.4
Sheath (E30-0210)	Transition	Black	1.5	1.4

Cable Tray	Cable Location	Cable Condr.	"Trip" Voltage, kVac	Two Minute Sustained Voltage, kVac
3/C-No. 6 AWG w/	Cable Tray-To-	Red	1.3	1.0
Stainless Steel	Cable Tray	White	1.1	1.0
Sheath (E30-0210)	Transition	Black	1.1	1.0
3/C-NO.6 AWG w/o	Nom. 3 in.	Red	1.7	1.5
Stainless Steel	Diam. Conduit	White	1.7	1.5
Sheath (E30-0204)	System	Black	1.8	1.5
3/C-No. 14 AWG S.T.P.	Conduit-To-	White	2.1	2.0
w/Stainless Steel	Cable Tray	Black	2.2	2.0
Sheath (E30-0212)	Transition			
2/C-No. 14 AWG S.T.P.	Cable Tray-To-	White	2.1	2.0
w/Stainless Steel	Cable Tray	Black	1.9	1.8
Sheath (E30-0212)	Transition			
2/C No. 14 AWG S.T.P.	Nom. 3 in.	White	2.1	2.0
w/o Stainless Steel	Diam. Conduit	Black	2.2	2.0
Sheath (E30-0209)	System			

APPENDIX D

CABLE TEMPERATURE MEASUREMENTS

SMALL-SCALE TEST ASSEMBLY

LOCATION OF THERMOCOUPLES:

The temperatures of each coil of fire resistant cable were measured by two inconel-sheathed chromel-alumel thermocouples having a time constant of 0.5 s. The thermocouples were affixed to the stainless steel sheath of each cable with stainless steel cable straps and were located as shown in ILL. D1.

TEMPERATURES OF THE CABLES:

The temperatures measured by the various thermocouples on the fire resistant cables were measured at 1 min intervals during the fire test. These temperatures are tabulated in ILLS. D2, D3 and D4.

APPENDIX E

INSTRUMENT CALIBRATION RECORDS

The instruments used to monitor environment, input electrical characteristics and electrical characteristics of the fire resistant cables during the test program were provided by both Underwriters Laboratories Inc. and The Rockbestos Company. Each of the instruments supplied by Underwriters Laboratories Inc. was calibrated against an instrument having calibration traceable to the National Bureau of Standards. The calibration records of each instrument are on file at Underwriters Laboratories Inc. With the exception of the new Amprobe Model ACD-1 digital ammeter, each of the instruments supplied by The Rockbestos Company bore a pressure-sensitive adhesive label indicating recent calibration.

INSTRUMENTS SUPPLIED BY UNDERWRITERS LABORATORIES INC.:

The following instruments were used in the test program.

FULL-SCALE TEST ASSEMBLY

Furnace Temperature Recorder - The temperature recorder used to measure the furnace temperatures was Leeds & Northrup, Model G, UL Instrument No. 6FB5TR.

Automatic Data Logger - The digital data acquisition system used to monitor elapsed time and current flow through the LED's of the electrical fault monitoring panel was Acurex Corporation, Model Autodata Ten/10, UL Instrument No. 8FI5DAS.

Ammeter - The hand-held clamp-on ammeter used to check the calibration of the Amprobe Model ACD-1 digital ammeter supplied by The Rockbestos Company was General Electric Company, 0-800 A, 0-750 V, UL Asset Identification No. 65 289.

Voltage Source - The voltage source used to measure dielectric voltage-withstand was Associated Research, Inc., Model 4025 AC Hypot Junior, UL Instrument No. 1FD5HP.

Water Pressure Gauge - The gauge used to measure the water pressure during the two hose stream tests was HTL, Perma-Cal, 0-300 psi, UL Instrument No. 83FA.

SMALL-SCALE TEST ASSEMBLY

Furnace Temperature Recorder - The temperature recorder used to measure the furnace temperature was Honeywell Brown Electronik, Model 152P15-PSH-296-III-55, UL Instrument No. 11FB5TR.

Cable Temperature Recorder - The digital data acquisition system used to measure cable temperatures was Leeds & Northrup, Model Trendscan 1000, UL Instrument No. 2FB5DAS.

INSTRUMENTS SUPPLIED BY THE ROCKBESTOS COMPANY:

The following instruments were used in the test program.

FULL-SCALE TEST ASSEMBLY

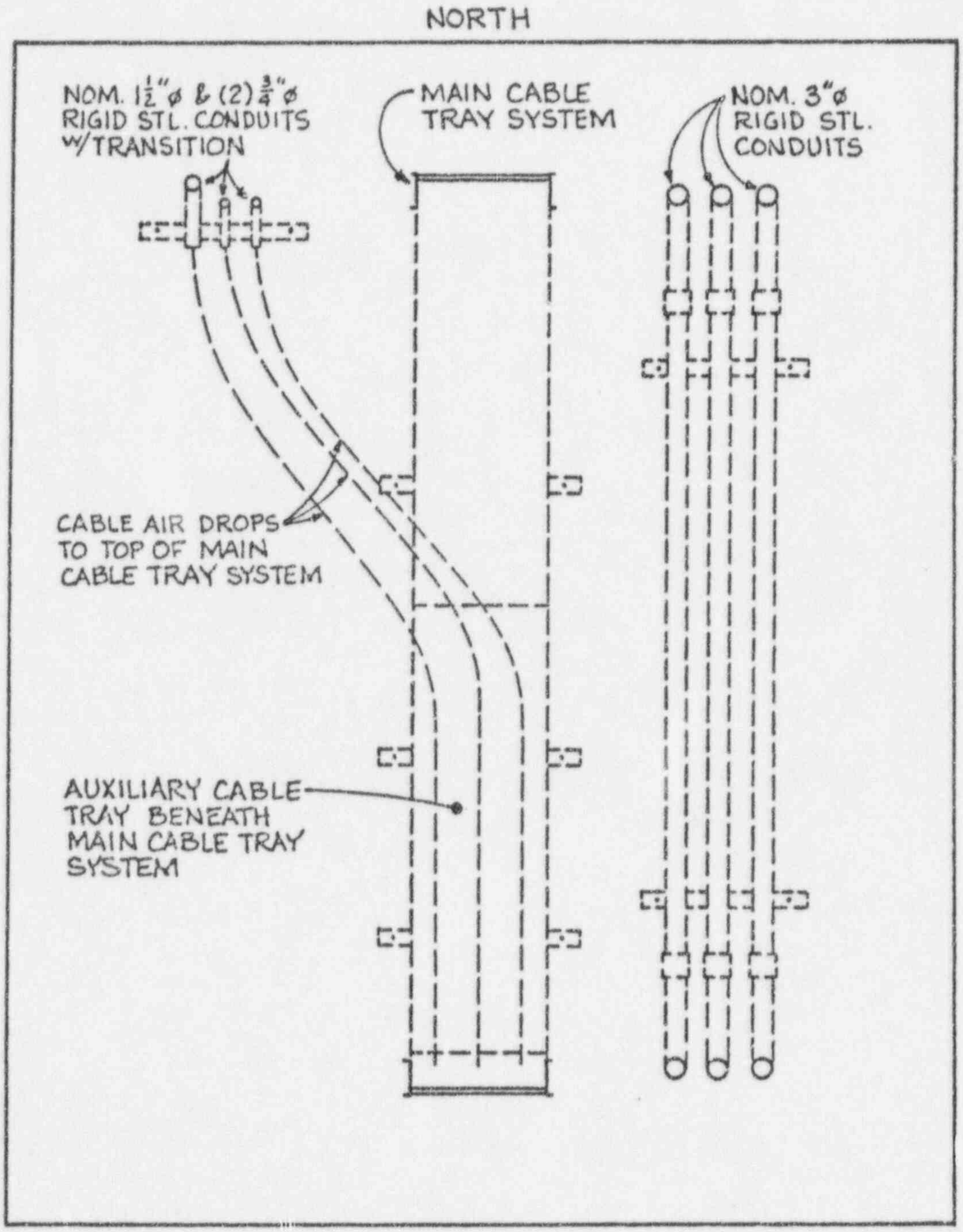
Digital Ammeter - The reference ammeter used to check the calibration of the metering transformers and panel ammeters was an Amprobe Model ACD-1 (Serial No. 833852) hand-held clamp-on digital ammeter. The digital ammeter was new and did not bear a calibration sticker.

Meggering Equipment - The equipment used to measure insulation resistance was a General Radio Model 1864 Megohmmeter bearing a calibration sticker reading "I.R. Set, Serial No. 2311, Checked 4-20-83 by Electrical Calibration Laboratory" and a Simpson 260 Volt-Ohm-Milliammeter bearing a calibration sticker reading "I.R. Set, Serial No. 712397, Checked 4-18-83 by Electrical Calibration Laboratory."

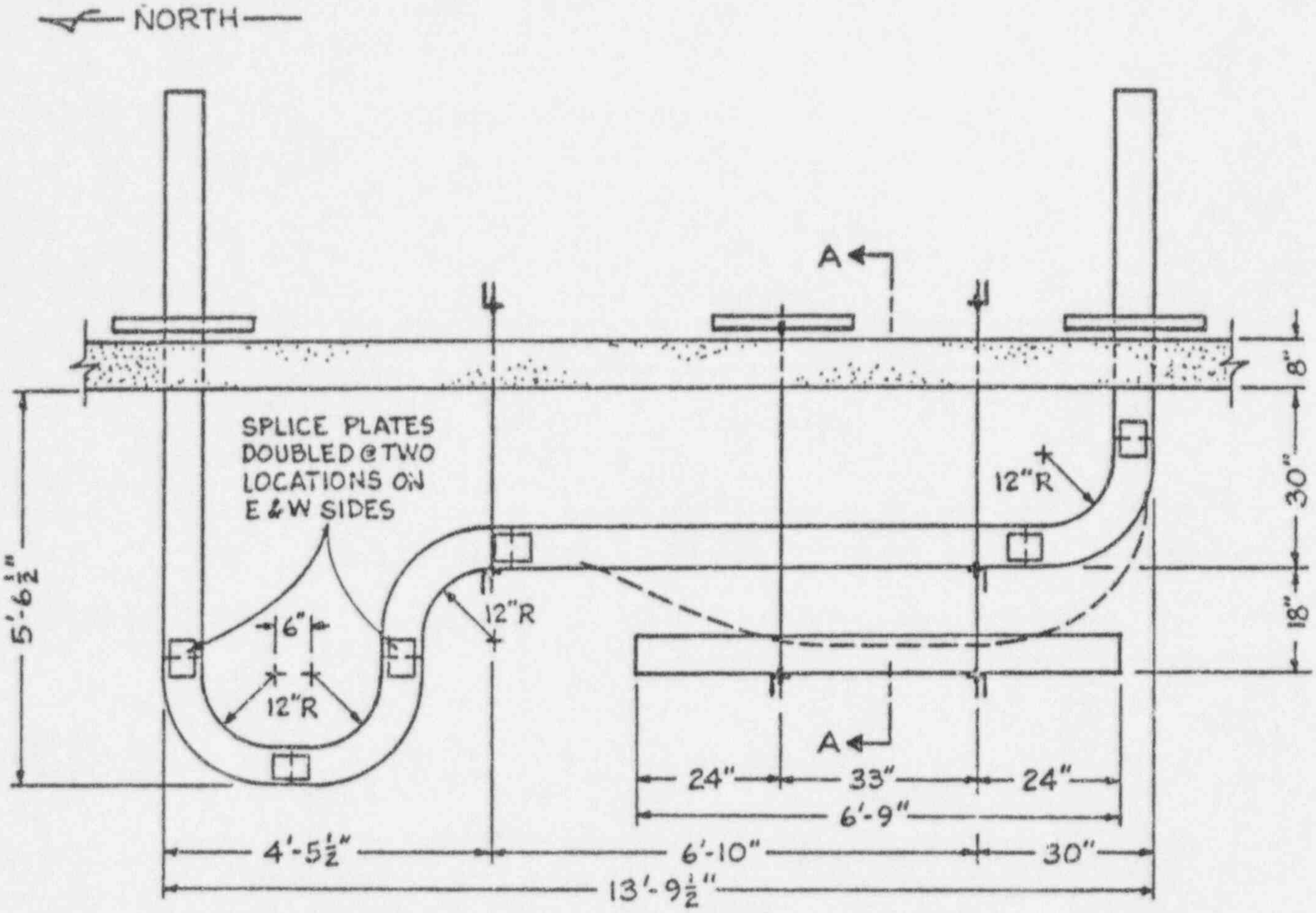
SMALL-SCALE TEST ASSEMBLY

Digital Multimeters - The four digital multimeters used to measure voltage and current were Beckman 3010 Digital Multimeters. Each digital multimeter (Units DMM-31027035, -31027364, -31027435 and -31027447) bore a calibration sticker reading "(Unit Number), Calibrated 3-7-84 by Robt. A. Gehm, New Equipment-Factory Calibrated-Checked AC Amp Ranges."

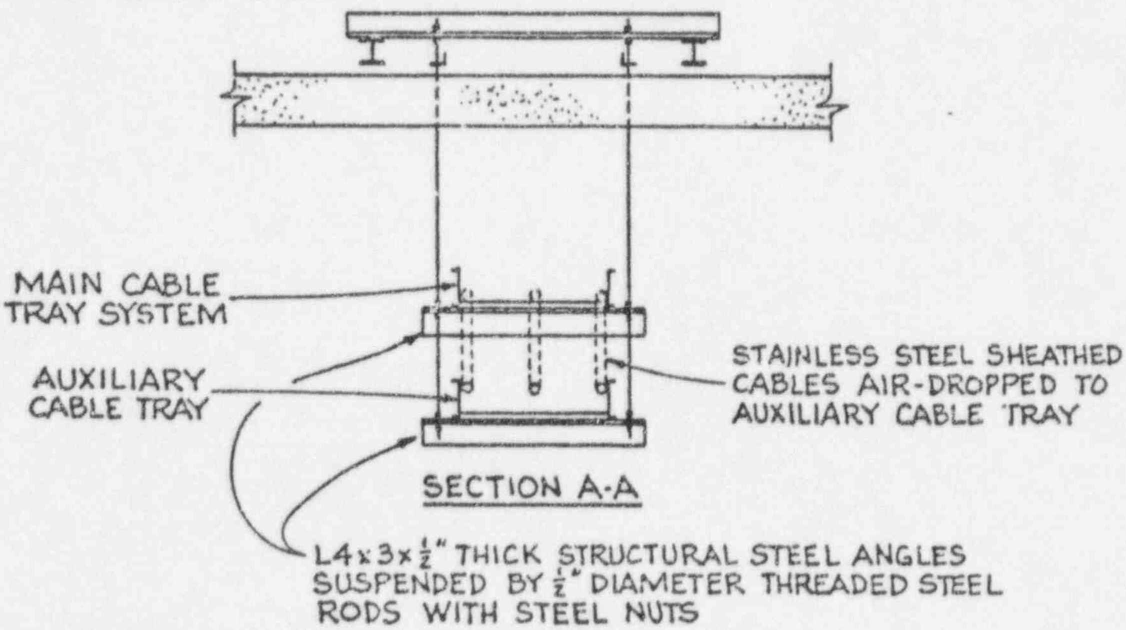
PLAN VIEW OF TEST ASSEMBLY



R10925-1
ILL. 1



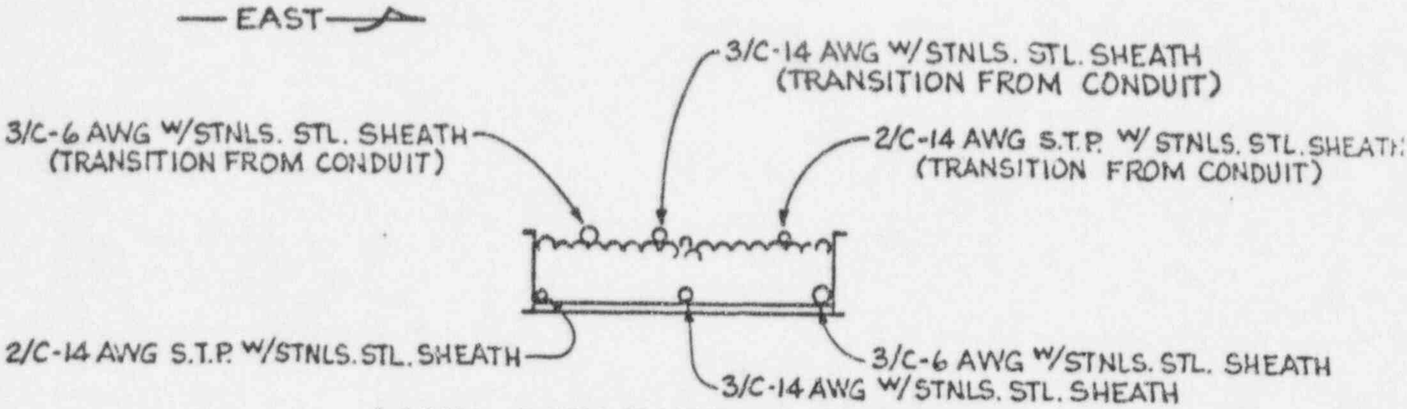
CABLE TRAYS, ELBOWS & SPLICE PLATES MANUFACTURED BY METAL PRODS. DIV. OF U.S. GYPSUM CO. & DESIGNATED "GLOBETRAY®". CABLE TRAYS & ELBOWS NOM. 6" DEEP (ACTUAL 6¼" DEEP W/ 5¾" CABLE LOADING DEPTH), 24" WIDE (INSIDE WIDTH) W/ 14 GA. GALV. STL. SIDERAILS & 16 GA. GALV. STL. RUNGS SPACED 9" O.C.



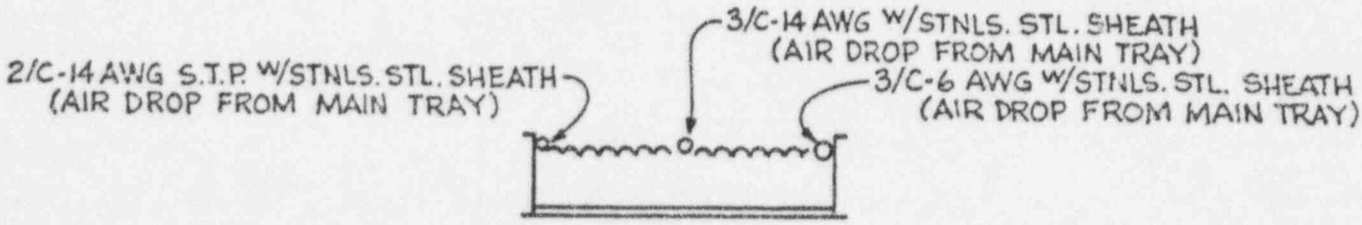
SECTION A-A

CABLE TRAY SYSTEM DETAILS

R10925-1
ILL. 2



MAIN CABLE TRAY SYSTEM



AUXILIARY CABLE TRAY

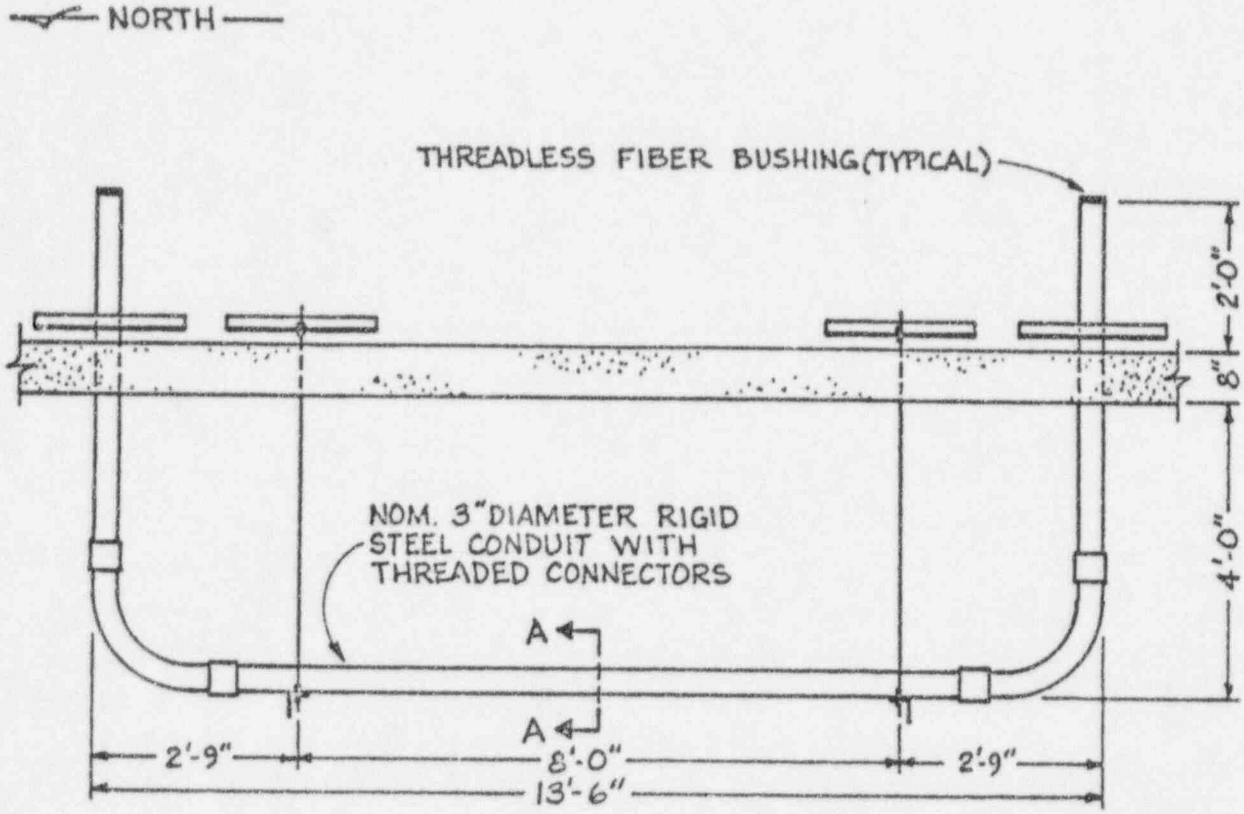
FUEL LOADING CABLES:

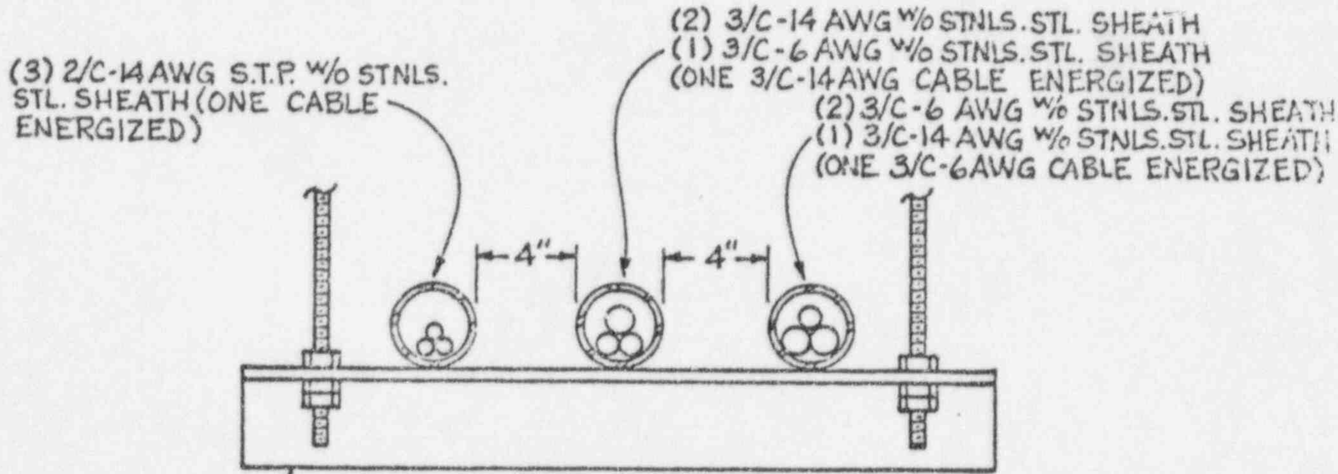
MAIN CABLE TRAY SYSTEM AND AUXILIARY CABLE TRAY EACH PROVIDED W/ RANDOMLY-LAID 41.5% FILL OF FUEL LOADING CABLES. PERCENT FILL BASED ON 24" CABLE TRAY WIDTH, 5¼" CABLE LOADING DEPTH AND AGGREGATE CROSS-SECTIONAL AREA OF 57.29 SQ. IN. FOR FUEL LOADING CABLES. FUEL LOADING CABLES IN MAIN CABLE TRAY SYSTEM TERMINATE AT UNDERSIDE OF FLOOR.

THE TYPE AND QUANTITY OF FUEL LOADING CABLES IN EACH CABLE TRAY ARE TABULATED BELOW:

CABLE TYPE	CABLE INSUL. MAT'L.	CABLE JACKET MAT'L.	CABLE O.D.	QUANTITY
9/C-12AWG	EPR/HYP	HYP	0.858"	16 PCS.
3/C-2AWG	XLP	HYP	1.036"	16 PCS.
37/C-12AWG	XLP	PVC	1.250"	8 PCS.
19/C-12AWG	PE	PVC	0.935"	36 PCS.

SAMPLE LOCATION IN CABLE TRAYS



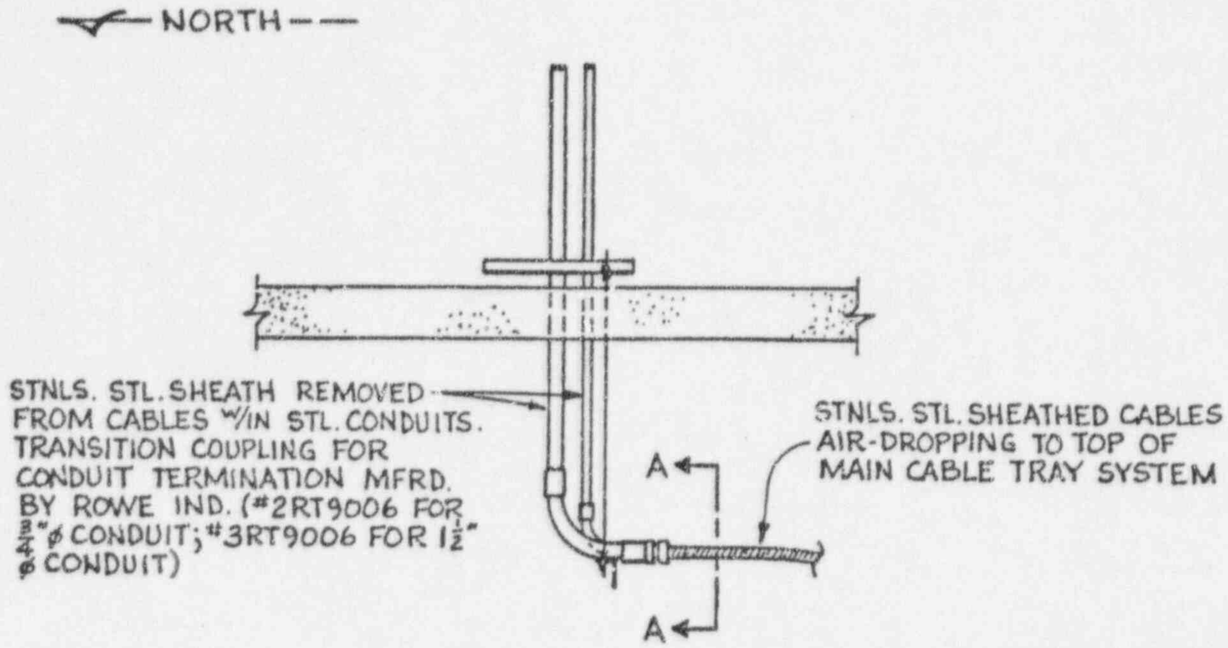


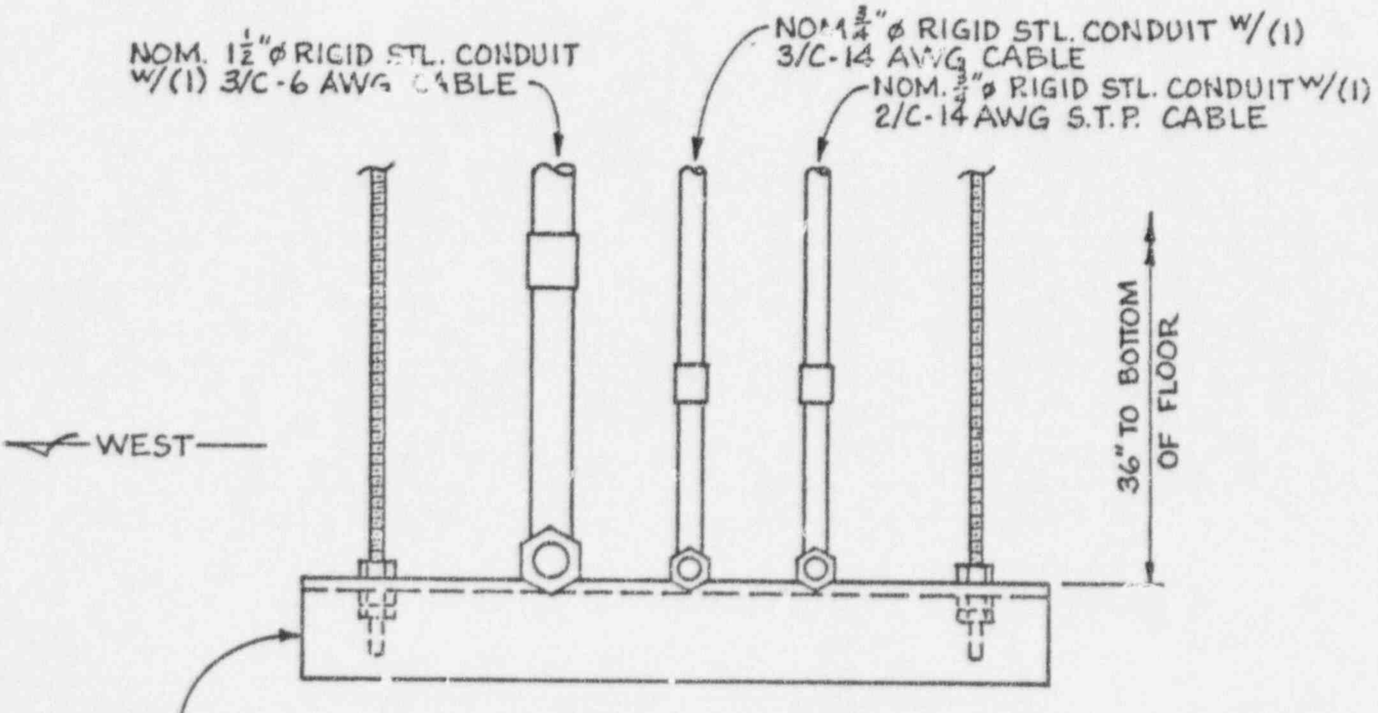
SECTION A-A

L4 x 3 x $\frac{1}{2}$" THICK, STRUCTURAL STEEL ANGLE SUSPENDED BY $\frac{1}{2}$" DIAMETER THREADED STEEL RODS WITH STEEL NUTS

CONDUIT SYSTEM DETAILS

R10925-1
ILL. 4

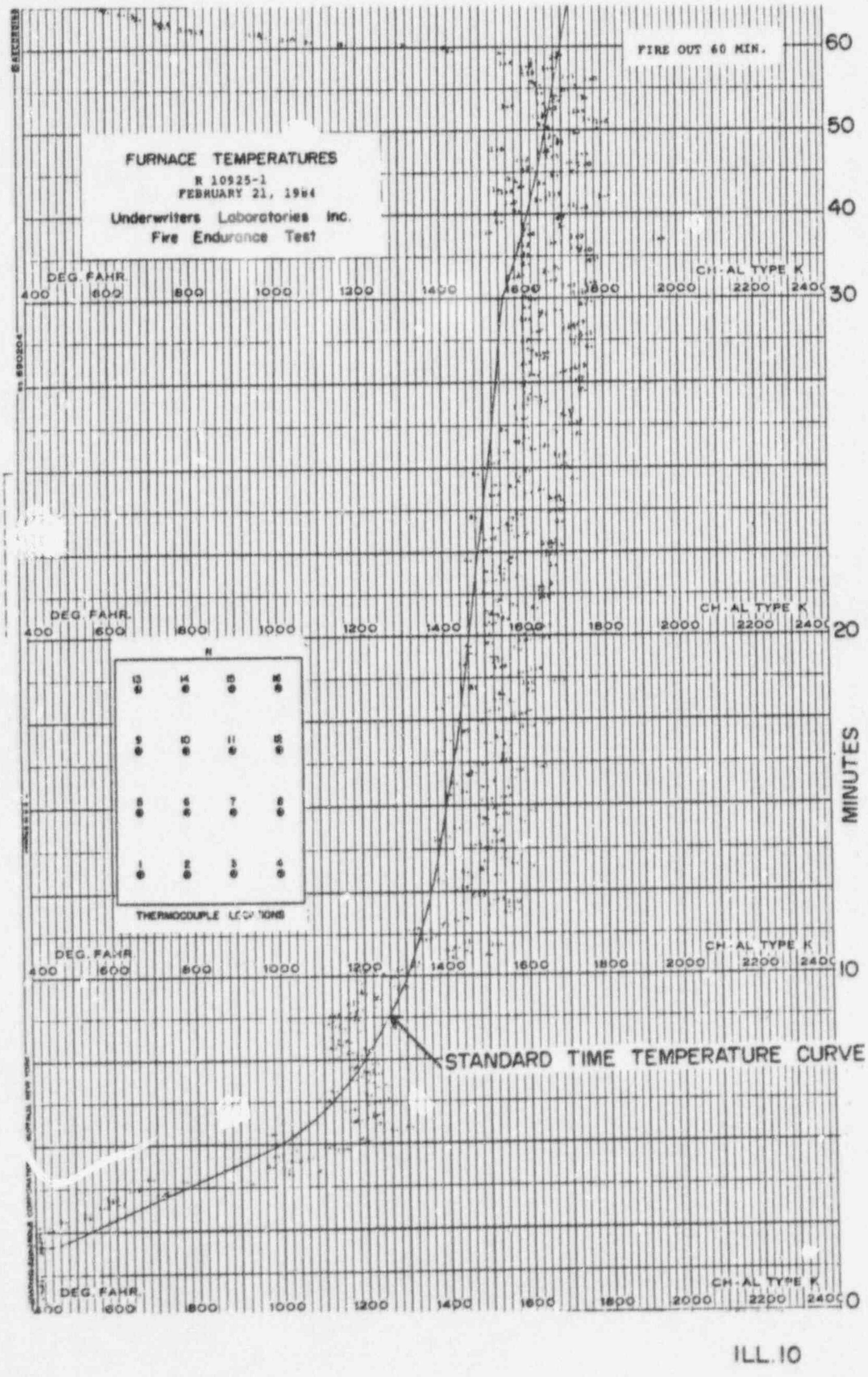




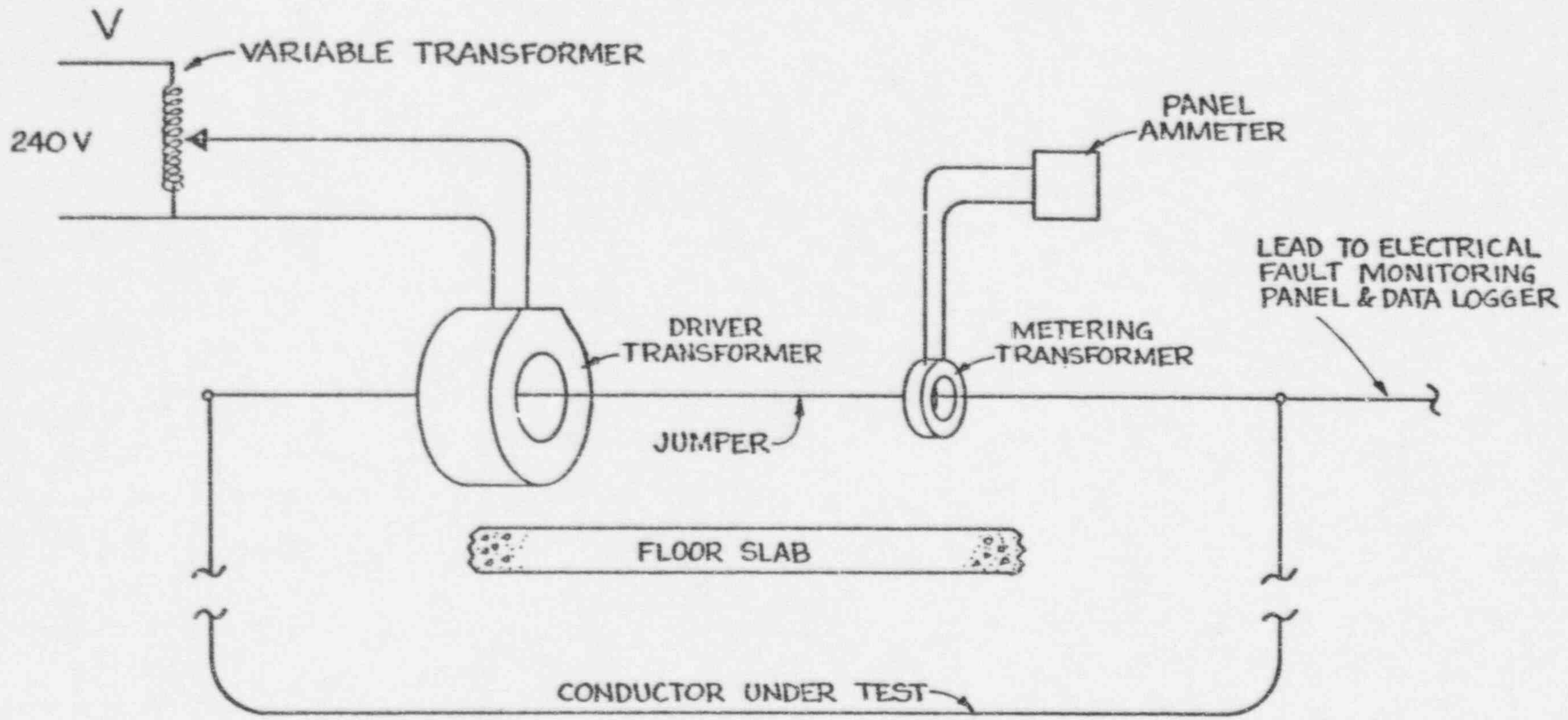
SECTION A-A

TRANSITION DETAILS

R10925-1
ILL. 5

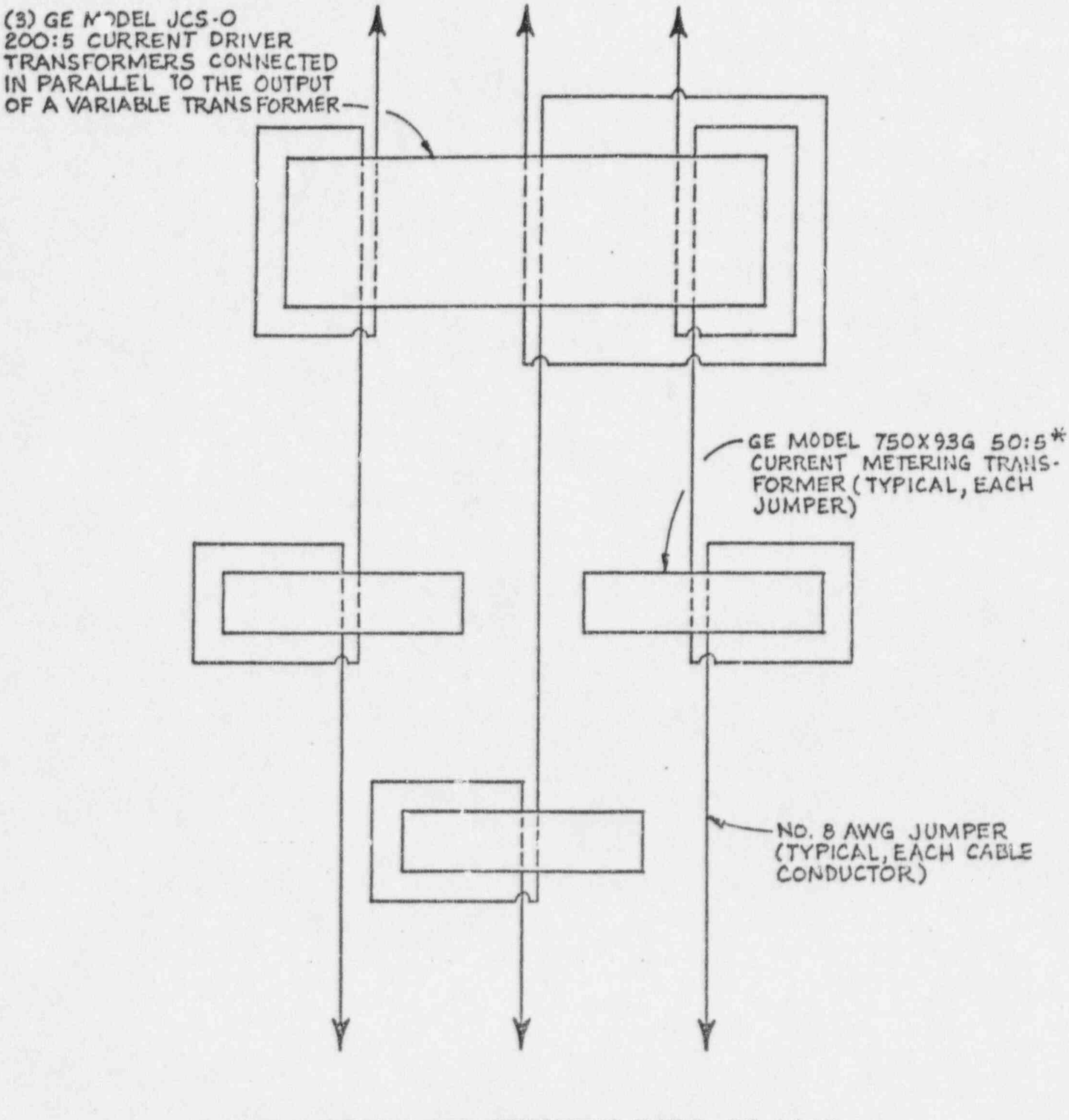

FURNACE TEMPERATURES
R 10925-1
FEBRUARY 21, 1984
Underwriters Laboratories Inc.
Fire Endurance Test
FIRE OUT 60 MIN.
DEG. FAHR.
CH-AL TYPE K
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
0
10
20
30
40
50
60
MINUTES
THERMOCOUPLE LOCATIONS
STANDARD TIME TEMPERATURE CURVE

ILL. 10



ELECTRICAL CURRENT DRIVING & METERING PLAN

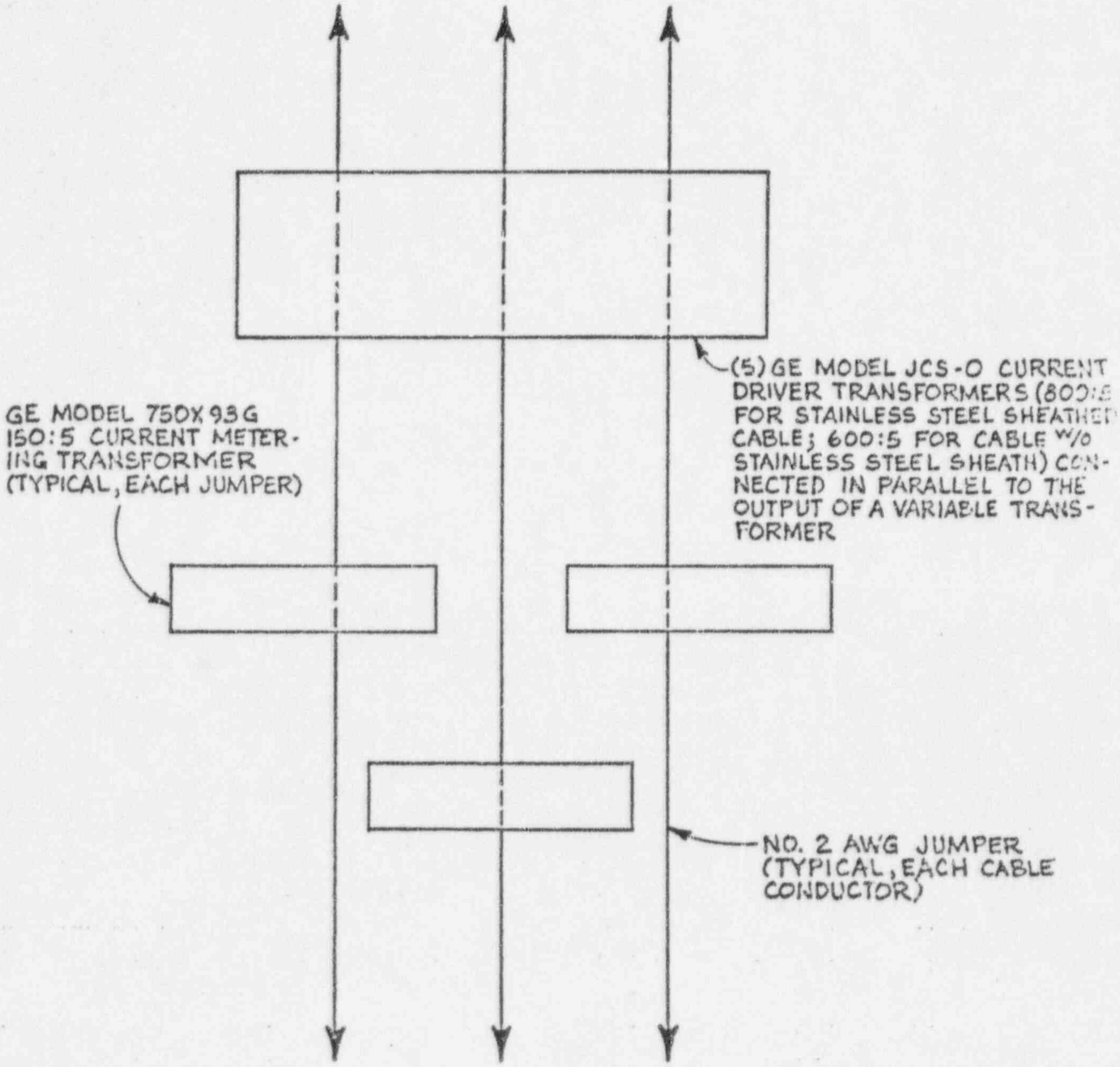
R10925-1
ILL. 11



* WITH ADDED LOOP, EFFECTIVE RATIO OF EACH CURRENT METERING TRANSFORMER IS 5:1

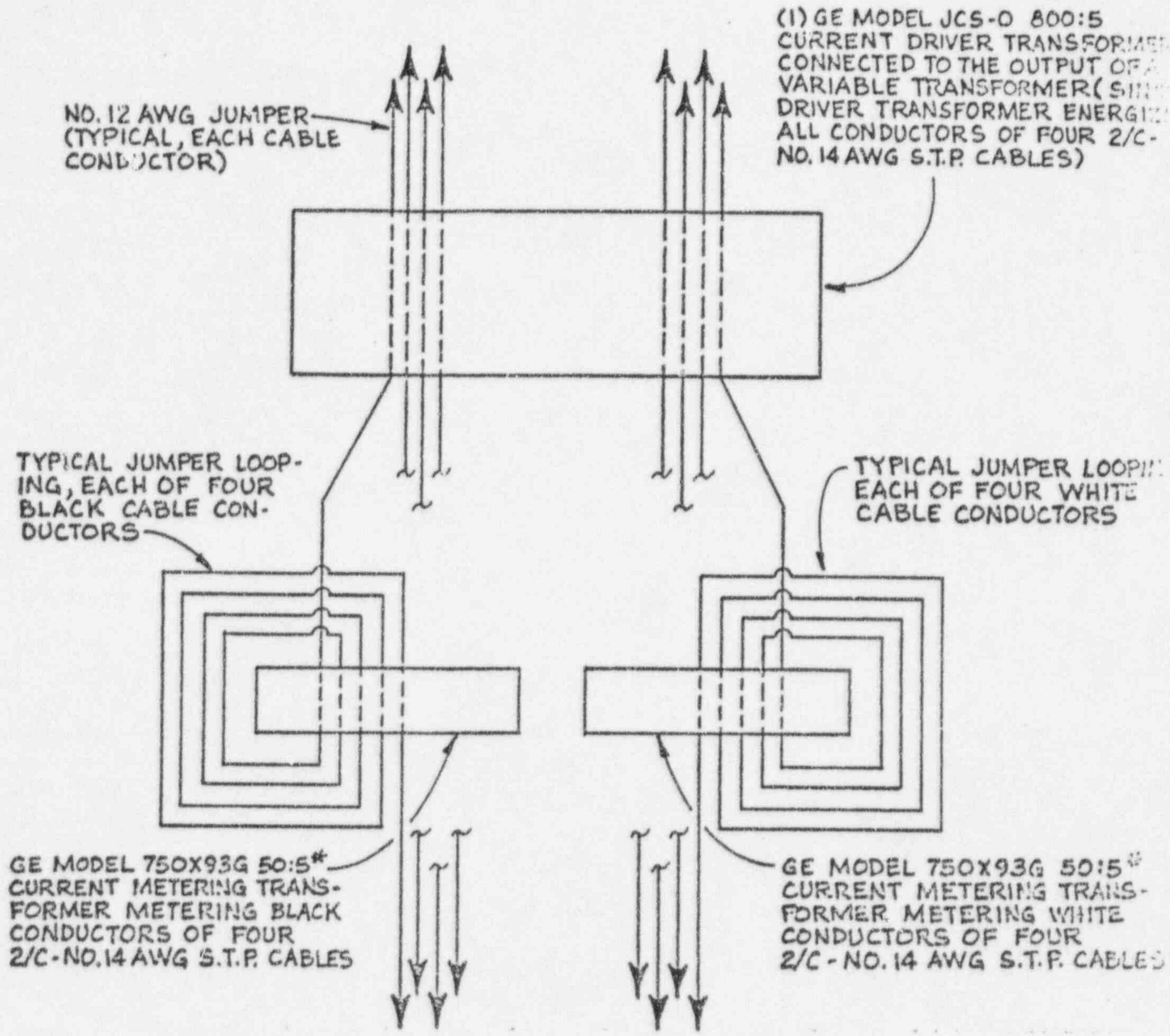
CURRENT DRIVER AND METERING TRANSFORMERS FOR 3/C-NO. 14 AWG POWER CABLE

R10925-1
III 12



CURRENT DRIVER AND METERING TRANSFORMERS
FOR 3/C-NO. 6 AWG POWER CABLE

R10925-1
ILL. 13

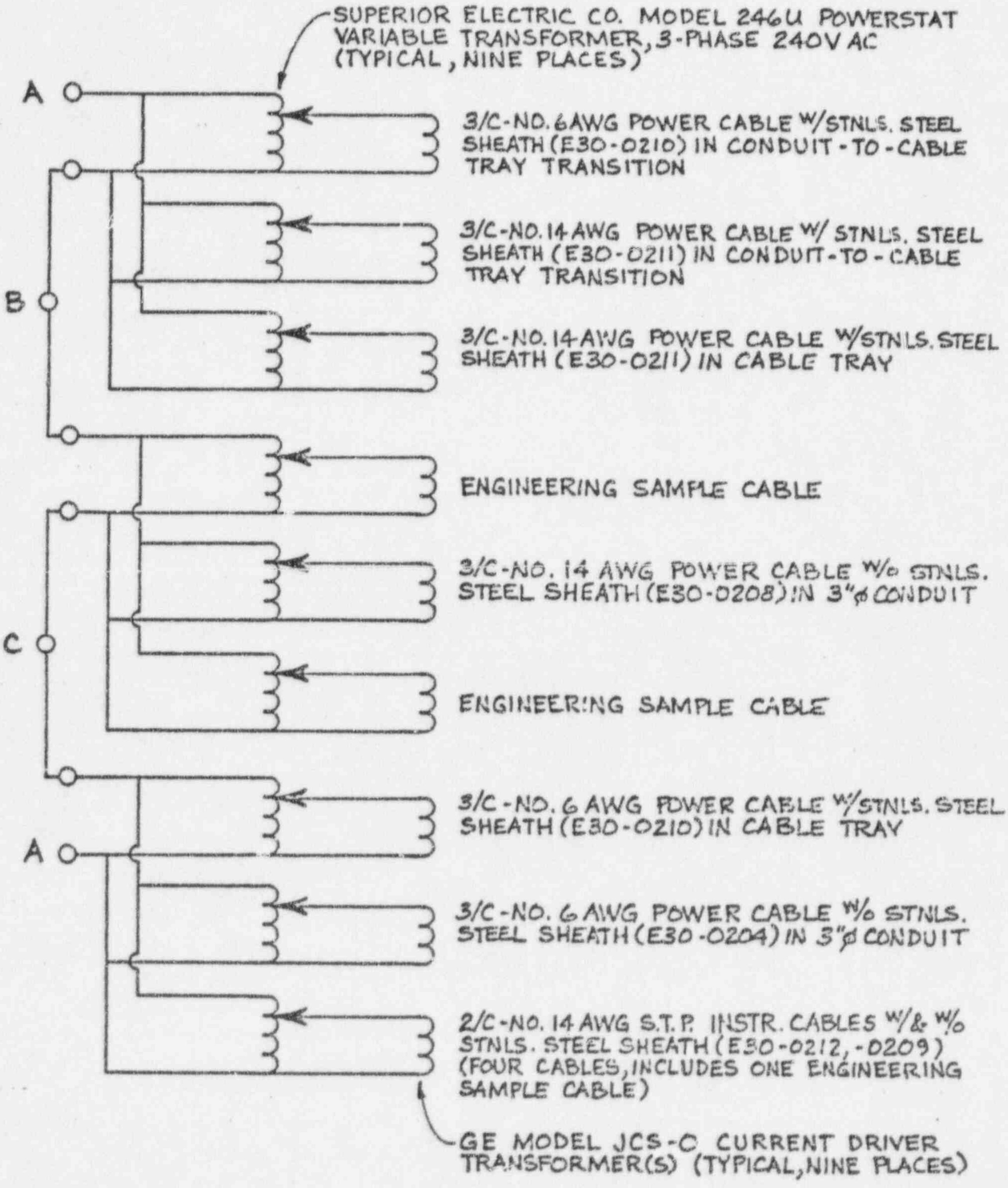


* WITH FOUR ADDED LOOPS, EFFECTIVE RATIO OF EACH CURRENT METERING TRANSFORMER IS 2:1

CURRENT DRIVER AND METERING TRANSFORMERS FOR 2/C-NO. 14 AWG S.T.P. INSTRUMENTATION CABLES

(INCLUDES ONE ENGINEERING SAMPLE CABLE)

R10925-1
ILL. 14

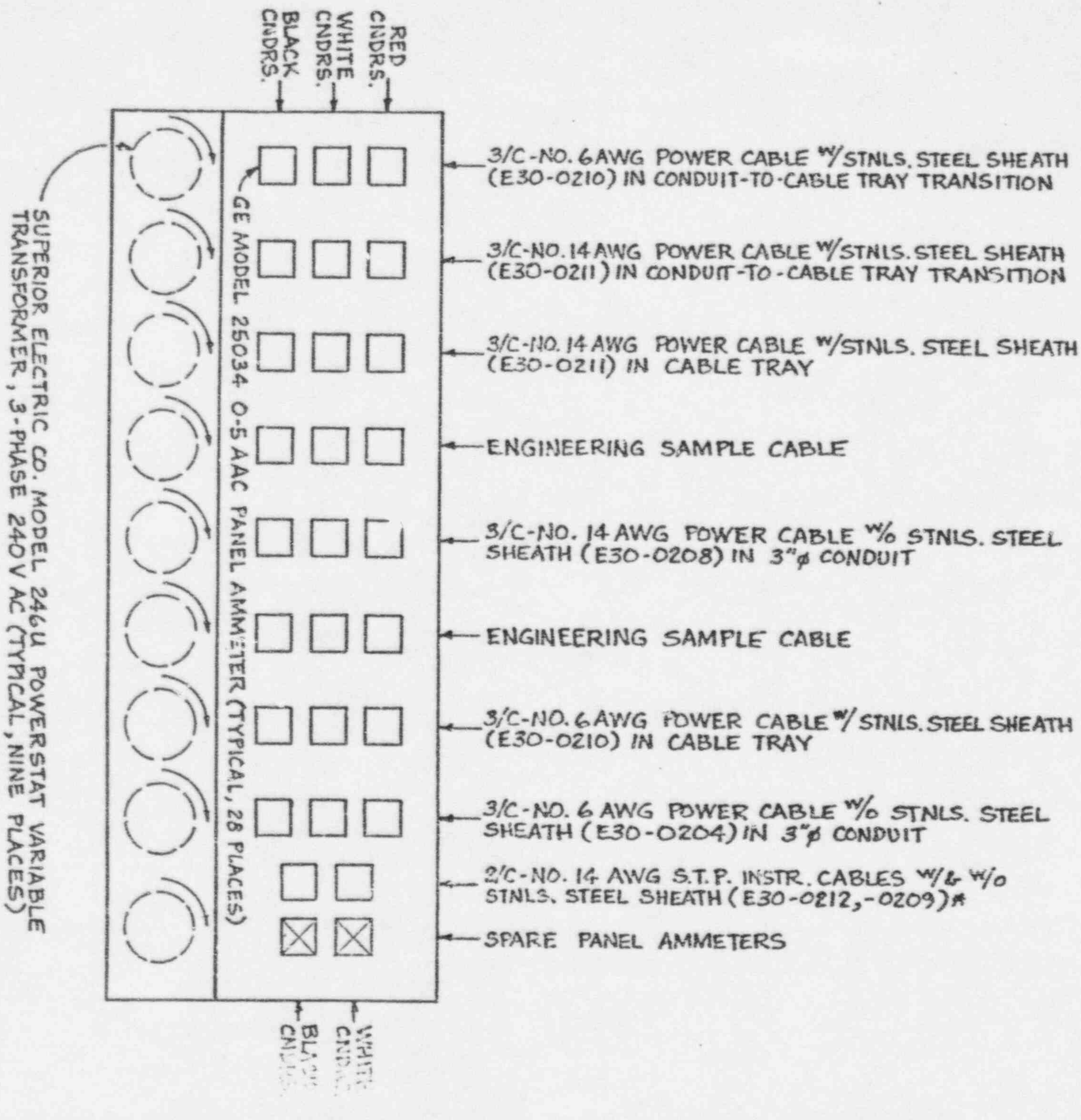


A/B/C THREE-PHASE 240 V AC, 30 A/PHASE
(PHASE-TO-PHASE)

WIRING DIAGRAM FOR VARIABLE TRANSFORMERS

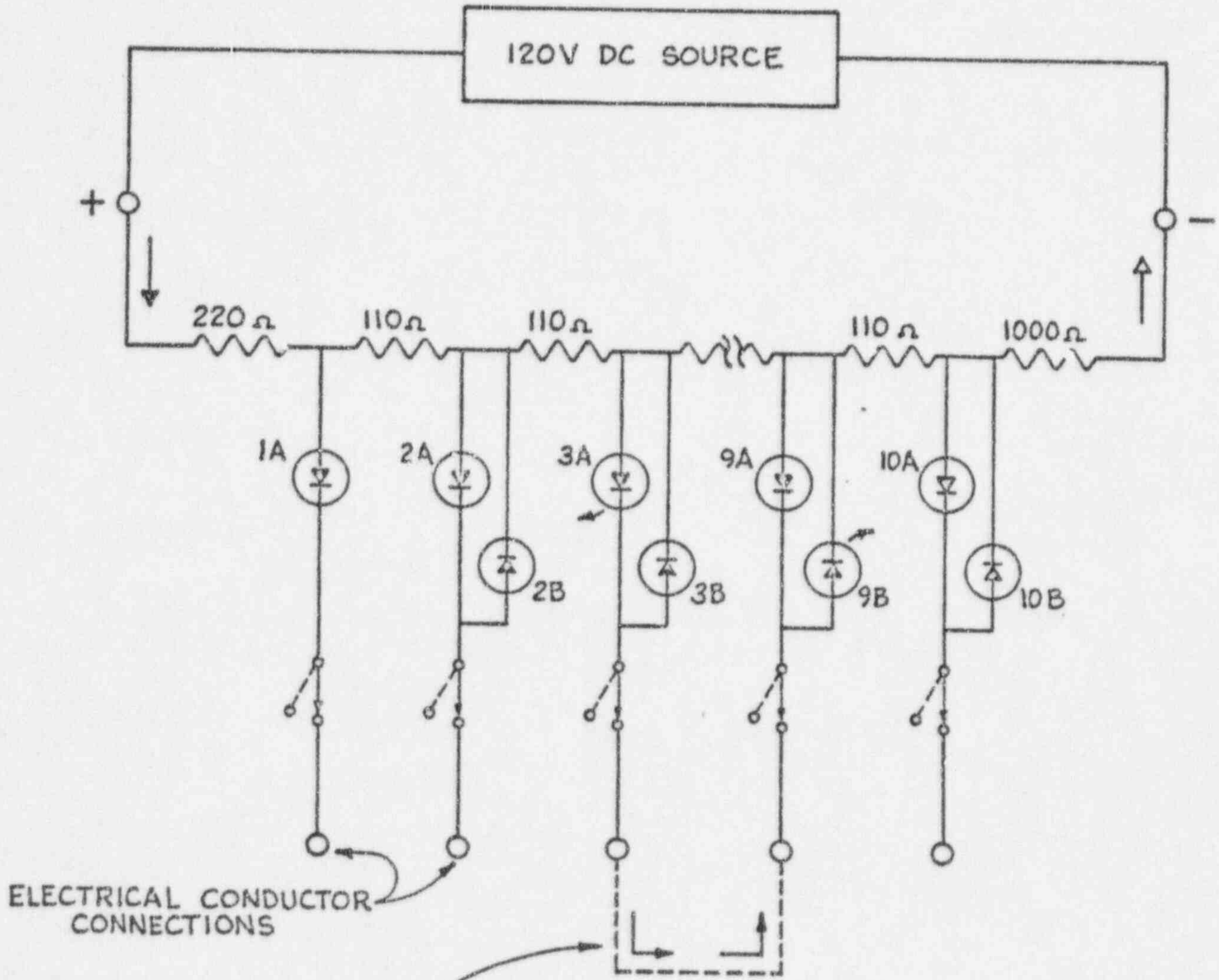
R10925-i
ILL. 15

CURRENT METERING PANEL



* FOUR CABLES, INCLUDING ONE ENGINEERING SAMPLE CABLE

R1C925-1
ILL. 16

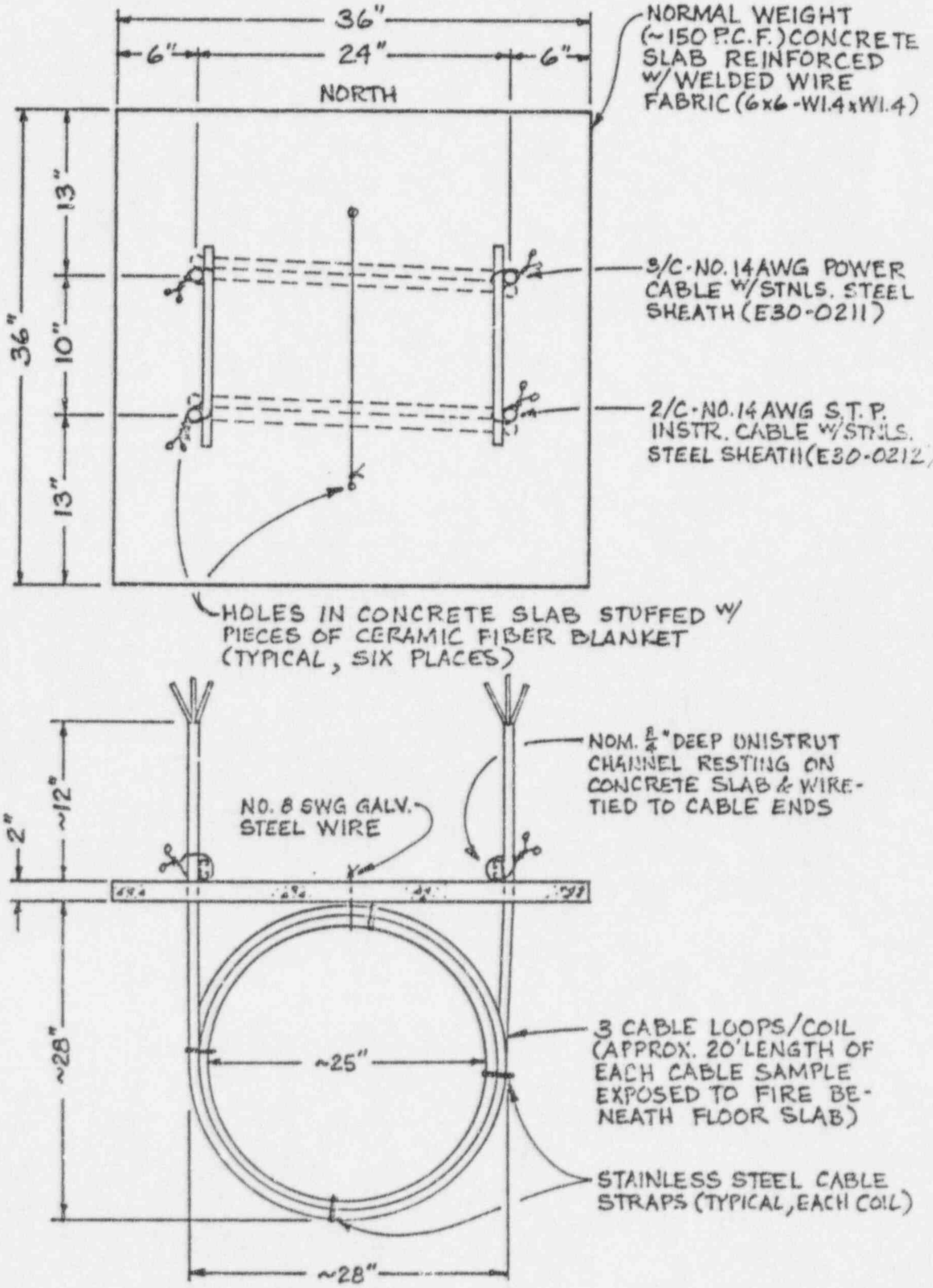


IF A FAULT OCCURS BETWEEN TWO ELECTRICAL CONDUCTORS, CURRENT WILL FLOW THROUGH THE YELLOW L.E.D. (3A) AND RETURN THROUGH THE RED L.E.D. (9B). THE FAULT BETWEEN THE ELECTRICAL CONDUCTORS IS INDICATED BY THE L.E.D.'S AND RECORDED BY A DIGITAL DATA ACQUISITION SYSTEM MONITORING CURRENT FLOW THROUGH THE L.E.D.'S.

<u>ELECTRICAL FAULT MONITORING SCHEMATIC</u>

(TYPICAL-EACH CIRCUIT)

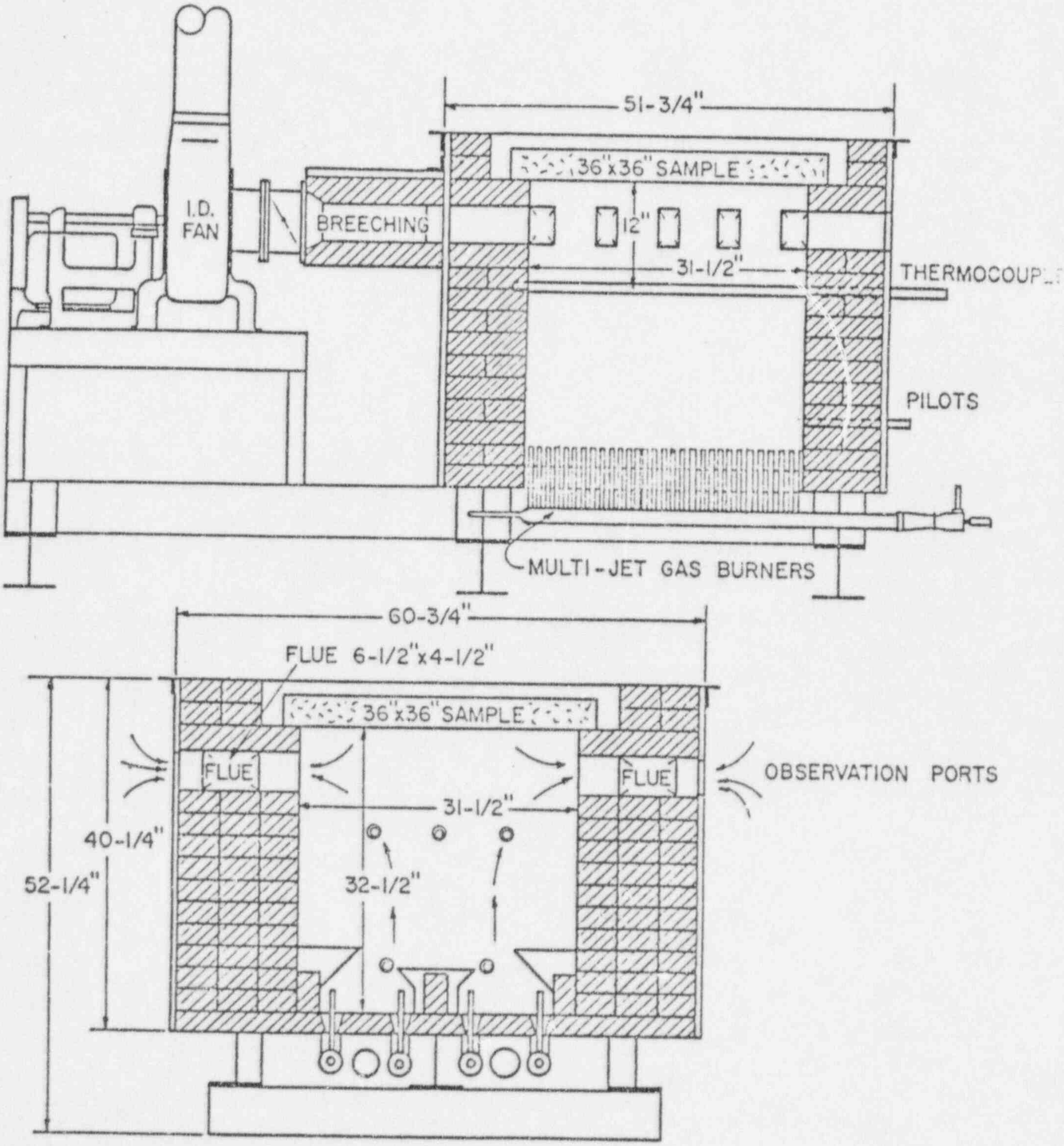
R10925-1
ILL. 17



SMALL-SCALE TEST ASSEMBLY

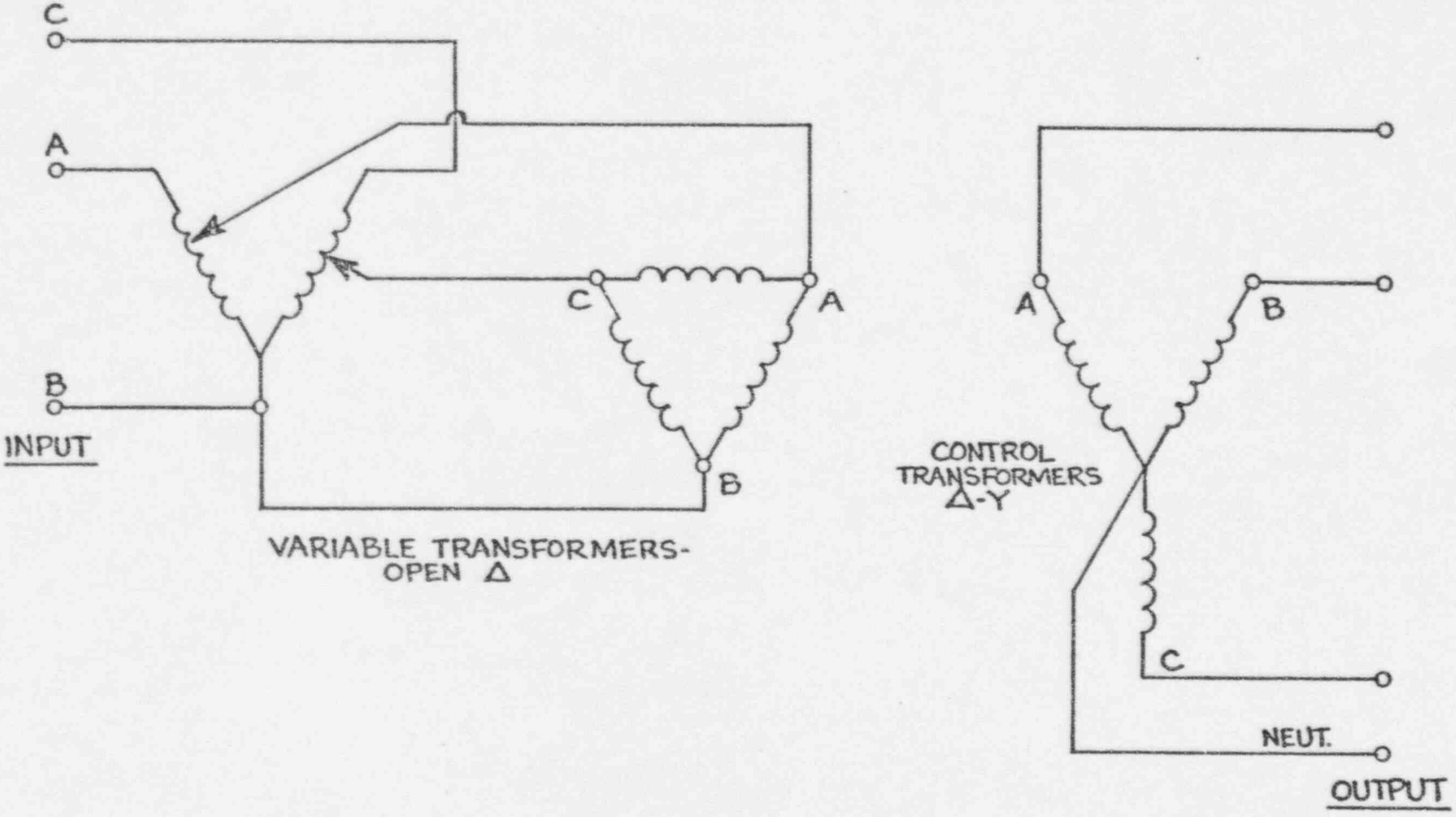
R10925-1
ILL. 20

SMALL SCALE HORIZONTAL EXPOSURE FURNACE



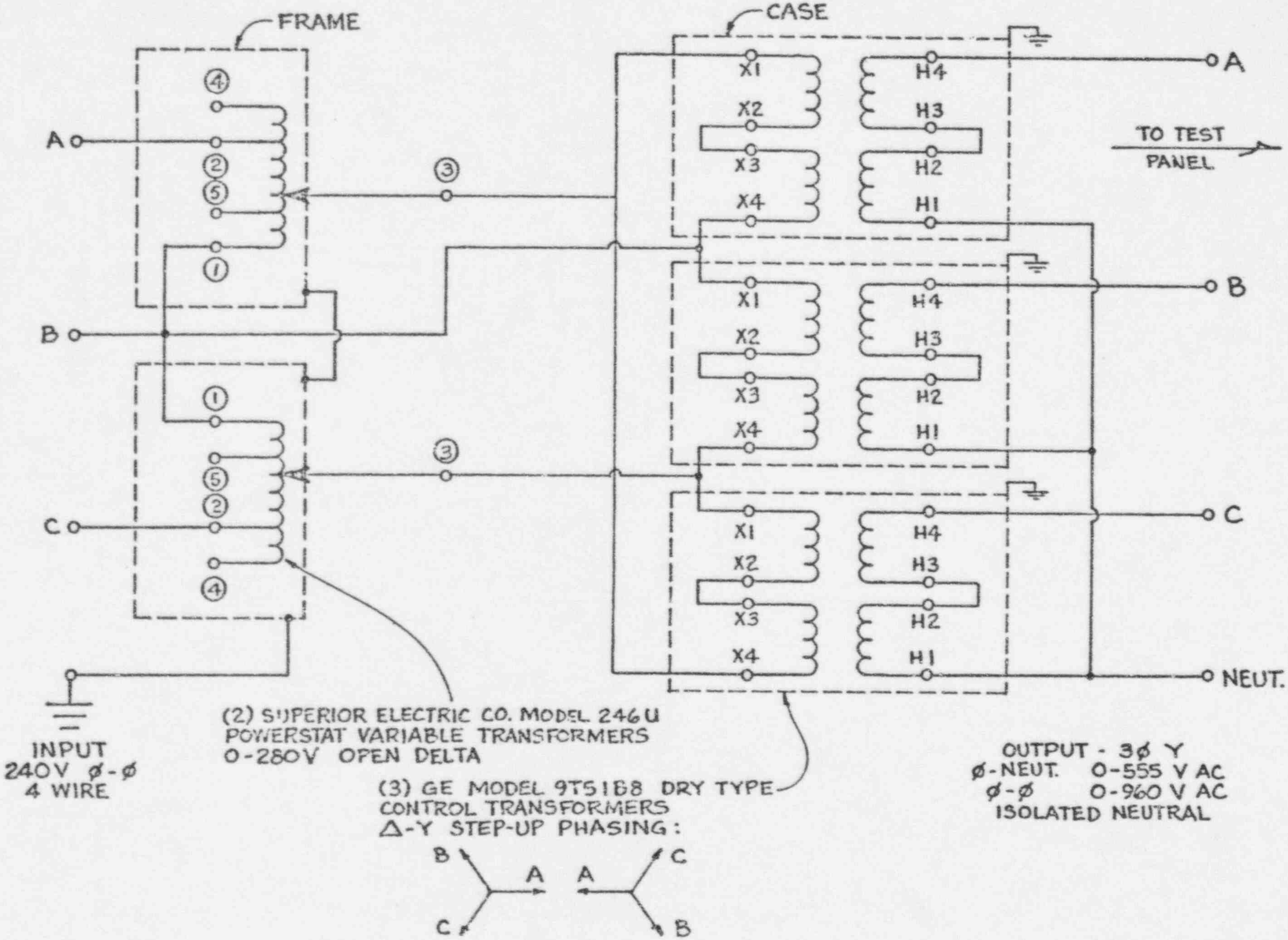
R10925-1
ILL. 21

SCHEMATIC



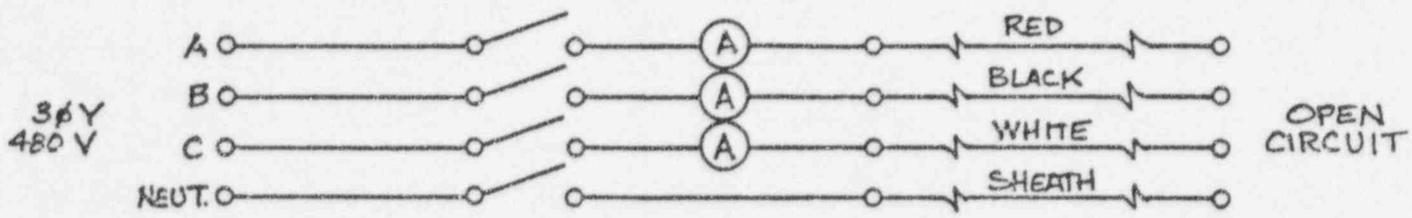
R10925-1
ILL. 22

WIRING DIAGRAM



R10925-1
ILL. 23

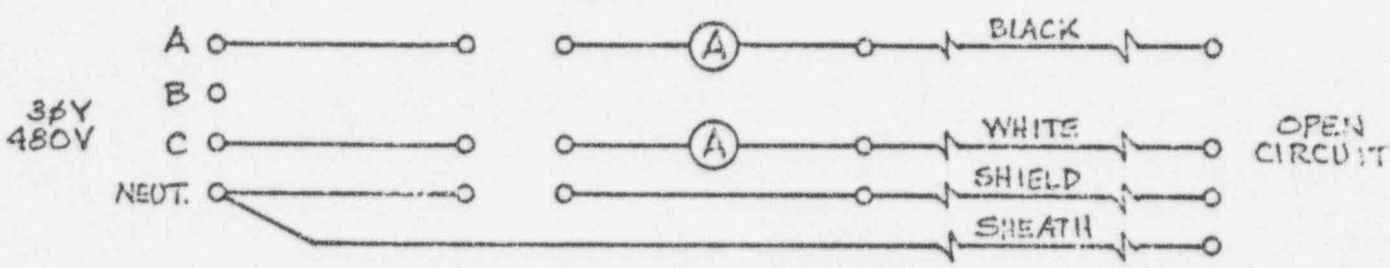
3/C-NO. 14 AWG



WITH ALL SWITCHES CLOSED, METERS READ THE SUMMATION OF 3ϕ LEAKAGE (CHARGING) CURRENTS

WITH A AND NEUT. SWITCH CLOSED, B AND C OPEN, METER READS INDIVIDUAL LEAKAGE TO GROUND

2/C-NO. 14 AWG S.T.P.



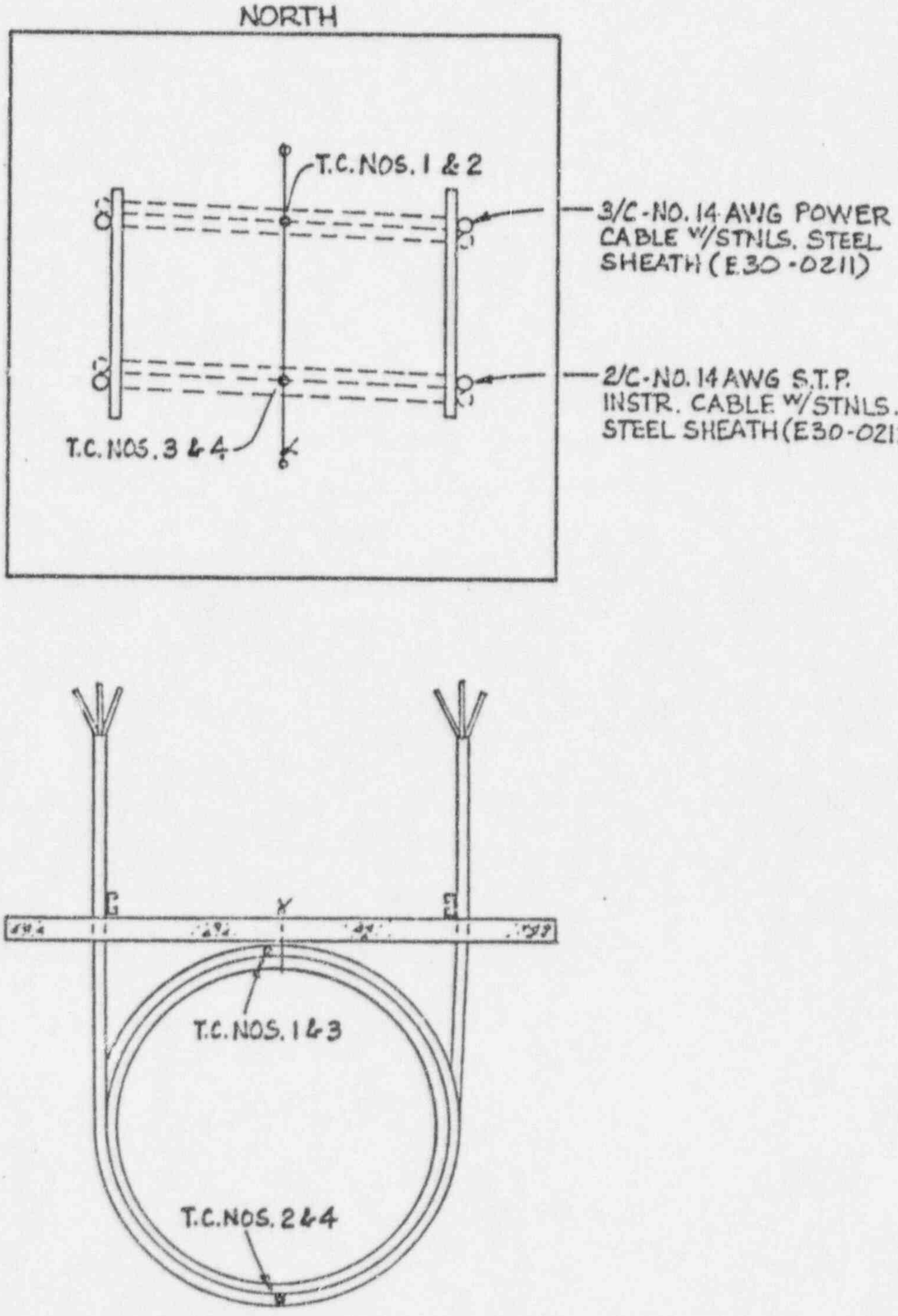
WITH ALL SWITCHES CLOSED, METERS READ THE CONDUCTOR-TO-CONDUCTOR LEAKAGE (CHARGING) CURRENTS

WITH A AND NEUT. SWITCH CLOSED AND C OPEN, METER READS INDIVIDUAL LEAKAGE TO GROUND

NOTE: CHARGING CURRENT IS 90° OUT OF PHASE WITH VOLTAGE BUT LEAKAGE CURRENT IS IN PHASE.

SCHEMATIC OF TEST MEASUREMENTS

R10925-1
ILL. 24



THERMOCOUPLE LOCATIONS

R10925-1
ILL. D1

THE ROCKBESTOS CO. DIV. OF
CEROCK WIRE&CABLE GROUP INC.
3-9-84 SMALL-SCALE FIRE ENDURANCE TEST

FILE# R10925
PROJECT# 84NK2

THERMOCOUPLE (NO'S)	1	2	3	4
TIME (MIN'S)				
1	841.6	465.7	738.3	1105.2
2	846.3	463.8	781.2	960.5
3	782.1	407.5	748.0	873.0
4	802.0	422.5	757.0	906.7
5	1049.7	644.0	944.7	1277.0
6	1095.2	725.5	1014.2	1273.5
7	1081.4	707.8	1005.4	1226.2
8	1146.7	803.4	1065.3	1316.2
9	1170.9	849.2	1102.2	1331.2
10	1180.0	882.3	1124.6	1366.9
11	1192.6	919.7	1138.5	1376.8
12	1216.1	953.6	1161.6	1412.3
13	1233.9	996.6	1177.5	1432.1
14	1262.3	1036.5	1204.0	1455.9
15	1285.3	1062.6	1217.7	1461.7
16	1302.5	1093.1	1234.4	1474.1
17	1305.7	1108.7	1246.8	1481.0
18	1317.0	1131.9	1257.6	1486.2
19	1319.4	1145.2	1257.9	1493.9
20	1328.6	1165.2	1272.8	1505.9
21	1350.9	1196.1	1285.6	1525.6
22	1370.8	1209.0	1312.5	1530.5
23	1381.6	1225.1	1314.3	1534.5
24	1381.3	1237.1	1314.9	1530.3
25	1390.2	1254.7	1332.5	1543.1
26	1403.1	1276.4	1345.0	1556.3
27	1417.2	1293.3	1352.6	1557.4
28	1425.9	1305.4	1360.8	1564.2
29	1444.8	1321.1	1374.6	1572.5
30	1456.4	1338.2	1391.2	1584.4
31	1473.2	1353.6	1406.9	1594.4
32	1488.1	1367.1	1418.6	1599.4

R10925-1
ILL. D2

THE ROCKBESTOS CO. DIV. OF
CEROCK WIRE&CABLE GROUP INC.
3-9-84 SMALL-SCALE FIRE ENDURANCE TEST

FILE# R10925
PROJECT# 84NK2

THERMOCOUPLE (NO'S)	1	2	3	4
TIME (MIN'S)				
33	1493.0	1376.6	1429.9	1606.2
34	1488.0	1384.4	1428.5	1606.5
35	1495.4	1396.3	1441.5	1615.2
36	1520.5	1406.7	1454.3	1624.9
37	1520.1	1421.9	1456.9	1630.6
38	1525.8	1432.9	1471.0	1633.8
39	1527.8	1444.2	1467.6	1638.7
40	1545.3	1457.2	1490.0	1646.5
41	1549.0	1465.3	1496.5	1651.5
42	1558.0	1472.4	1495.0	1658.3
43	1559.9	1478.8	1503.5	1661.4
44	1560.4	1485.9	1505.6	1664.4
45	1555.9	1497.0	1489.2	1674.9
46	1568.9	1510.4	1503.9	1684.0
47	1585.6	1524.7	1519.5	1691.9
48	1597.9	1533.2	1535.7	1695.0
49	1590.3	1532.0	1532.1	1697.4
50	1593.1	1536.8	1535.1	1700.3
51	1604.8	1543.0	1545.0	1703.6
52	1612.7	1547.3	1546.6	1708.3
53	1603.5	1555.7	1538.4	1715.4
54	1607.1	1562.3	1541.5	1719.6
55	1610.1	1568.1	1545.8	1717.3
56	1615.4	1577.9	1547.8	1722.9
57	1627.0	1580.6	1556.1	1729.6
58	1627.4	1583.0	1556.6	1734.3
59	1633.8	1590.2	1565.4	1733.6
60	1627.0	1583.4	1566.0	1728.2
61	1622.5	1582.0	1561.2	1729.7
62	1632.3	1593.3	1560.0	1730.9
63	1645.5	1604.7	1576.3	1744.2
64	1652.5	1616.0	1587.5	1748.6

R10925-1
III D3

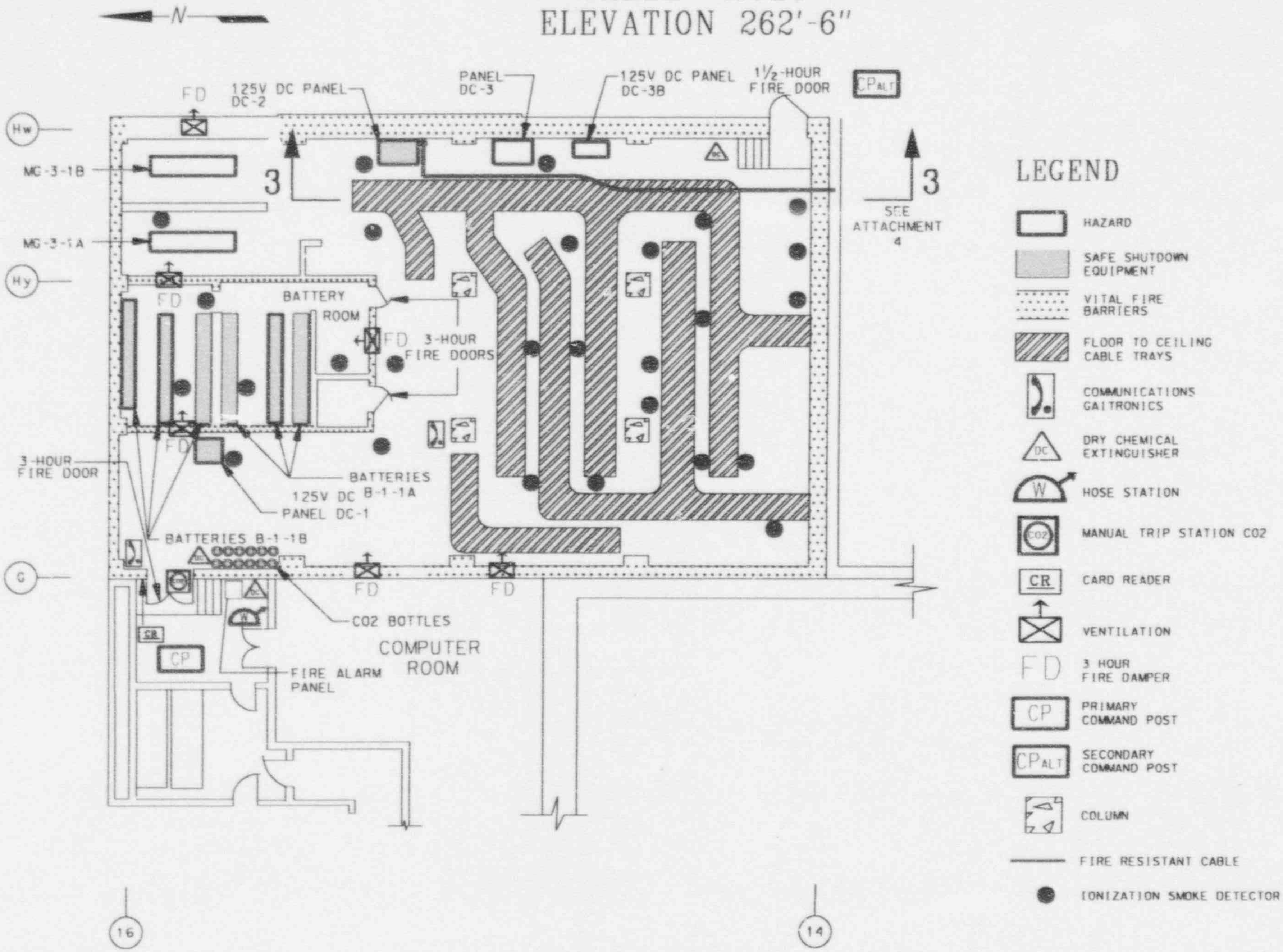
THE ROCKBESTOS CO. DIV. OF
CEROCK WIRE&CABLE GROUP INC.
3-9-84 SMALL-SCALE FIRE ENDURANCE TEST

FILE# R10925
PROJECT# 84NK2

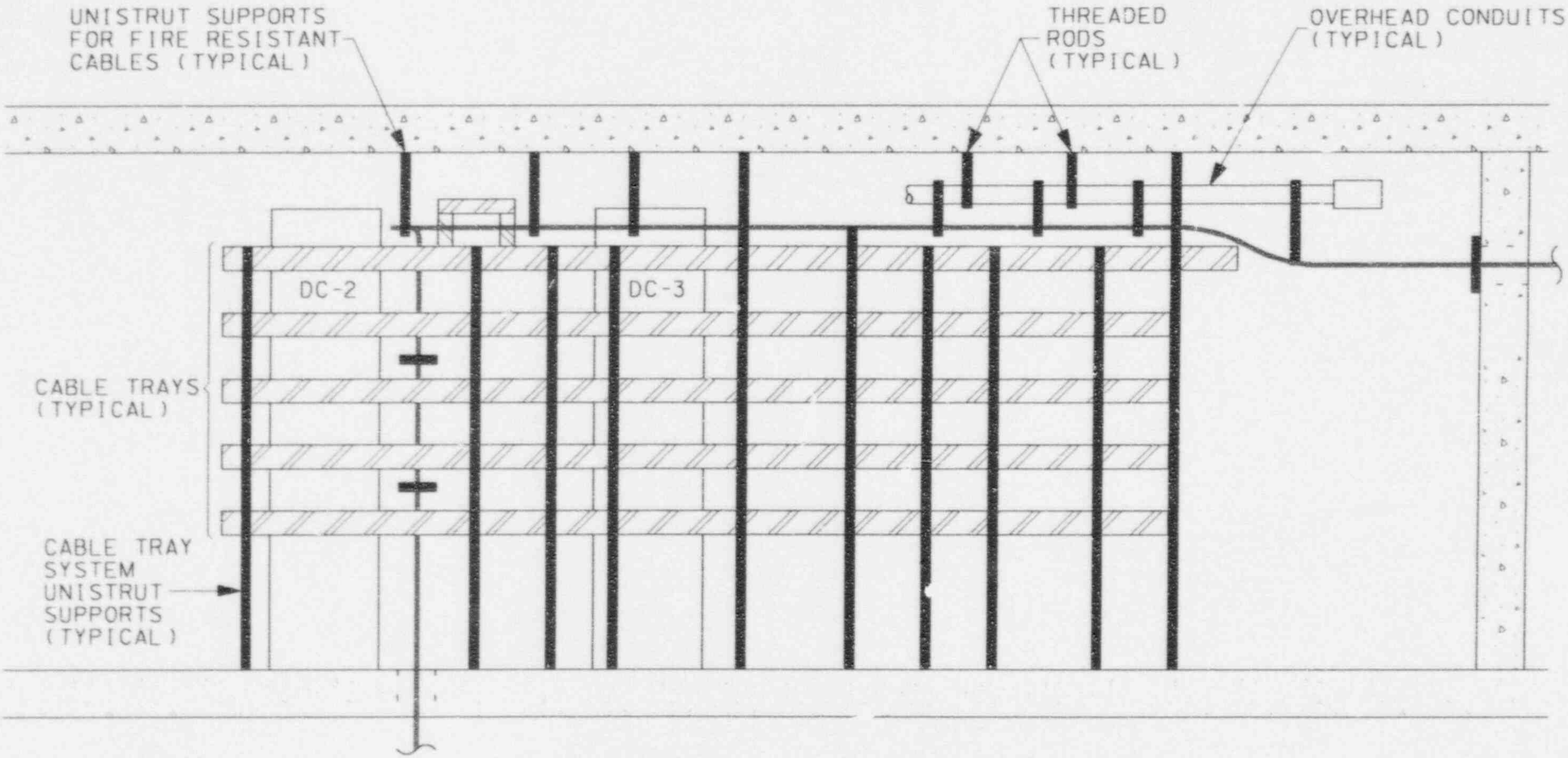
THERMOCOUPLE (NO'S)	1	2	3	4
TIME (MIN'S)				
65	1646.2	1611.6	1579.3	1749.7
66	1645.0	1612.5	1578.5	1748.2
67	1649.0	1617.2	1581.8	1751.7
68	1659.3	1626.3	1594.8	1760.0
69	1673.4	1630.6	1609.3	1763.2
70	1671.9	1634.8	1605.1	1768.4

R10925-1
ILL. D4

ATTACHMENT 3
CABLE VAULT
ELEVATION 262'-6"



ATTACHMENT 4
CABLE VAULT
ELEVATION 262'-6"



SECTION 3-3 LOOKING EAST