Program Plan
For
Hemyc (1-Hour) and M.T. (3-Hour)
Fire Protective Wrap Performance Testing

Final

January 16, 2003

1 Purpose and Scope

Section 50.48, “Fire Protection,” of 10 CFR Part 50 requires that each operating nuclear power plant have a fire protection plan that satisfies General Design Criterion 3 of Appendix A to 10 CFR Part 50. Section 50.48 also requires that all plants with operating licenses issued prior to January 1, 1979, satisfy the requirements Sections of III.G, III.J, and III.O of Appendix R to 10 CFR Part 50. (Post 1979 plants (per 10 CFR Part 50.48) have to comply with the provisions of their licenses.)

Section III.G of Appendix R, which addresses fire protection of safe shutdown capability, requires that fire protection features be provided such that one train of systems necessary to achieve hot shutdown conditions remains free of fire damage. One acceptable means of satisfying this requirement is to separate cables and equipment and associated non-safety circuits of redundant systems necessary to achieve and maintain hot shutdown conditions located in the same fire area by a fire barrier having a 3-hour fire rating (Section III.G.2.a). Another means is to enclose cables and equipment and associated non-safety circuits of one redundant train in a fire barrier having a 1-hour fire rating and install fire detectors and an automatic fire suppression system in the fire area (Section III.G.2.c).

The scope of this document is to describe the overall program for investigating the fire protection rating of Hemyc (1-hour) and M.T. (3-hour) fire wraps. The primary approach will be to perform a series of ASTM E 119 furnace tests on a number of cable raceway types that are wrapped in either the Hemyc (with or without air gaps) or M.T. fire barrier material. The Hemyc wrap tests will be performed for a period of 60-minutes each, followed by a hose stream test and post-test visual inspection of the fire wrap. The M.T. test will be similar with the principal difference being that it will be conducted for a period of 3-hours. A description of these tests and of the overall approach are provided below.

2 Objective

The objective of this program is to assess the fire protection rating of Hemyc and M.T. fire protection wraps by subjecting various test specimens (conduit, cable trays, cable drops, condolets (access fittings), junction boxes, and raceway support structure analogues) that are enclosed within the wraps to standard temperature-time conditions as specified in NFPA 251 and ASTM E 119. The types and characteristics of the wraps enclosing the test specimens are intended to simulate as-installed configurations.

A secondary objective of these tests is to assess the ability of Rockbestos Surprenant Firezone R fire rated cables to withstand the ASTM E 119 time-temperature environment.

3 Approach

The following sections describe the test specimens and the test conditions to be employed for the performance assessments of the Hemyc and M.T. fire barrier systems.

3.1 Test specimens

The principal test specimens will include a variety of cable raceway types covered with either the Hemyc 1-hour fire wrap or M.T. 3-hour wrap. In one test, the test specimens will be wrapped with Hemyc fire barrier material directly (i.e., without air gaps). The test specimens in the second test will be enclosed in Hemyc wrap that is framed with structural supports to provide a 5-cm (2 in.) air gap between the wrap and the raceway. For the third test, the test specimens (conduits, condolets, a cable drop and junction box) will be covered with the M.T. fire barrier wrap and subjected to a 3-hour ASTM E 119 furnace exposure. A conduit and condolet LB (an "L" shaped conduit fitting with the access cover on the back, "B") assembly, direct wrapped in Hemyc fire barrier material and a number of support structure specimens directly wrapped with Hemyc material will also be included in the three-hour test, as will three Rockbestos Surprenant Firezone R cables that will be supported in an unwrapped cable tray.

The types of test specimens and the configurations of the fire barrier material wrapping selected for these tests are based principally on the application usage information provided to the NRC/NRR by industry (Letter: Emerson, NEI, to Frumkin, NRC/NRR, "Promatec Hemyc 1-Hour and MT 3-Hour Fire Barrier Systems," December 28, 2001 and via letter: Marion, NEI, to Hannon, NRC/NRR, "Comments on NRC Hemyc Test Plan," December 6, 2002). The testing of the Hemyc wrapped conduit/box assembly during the three-hour test run is being conducted in order to gain some additional data regarding the Hemyc material's performance beyond the one-hour time-temperature exposure conditions.

The testing of empty raceways is intended to provide bounding qualification of the protective material performance under standard test conditions. For example, items of larger thermal mass should be bounded by these tests. Also, this method is per NRC guidance and represents current staff positions on bounding test approaches. Additionally, it is also intended that the assembly and installation of the Hemyc and M.T. fire barriers will be done in accordance with the vendor's specifications and meet all required vendor quality standards.

The test specimens will include the following items:

- A 27-mm (1 in.) steel conduit arranged in a modified "U" configuration such that one vertical leg and one end of the horizontal span of the conduit intersect at a condolet LB access fitting, forming a right angle, while the other end of the horizontal span transitions to the second vertical leg via a conduit radius bend or elbow.
- A 63-mm (2½ in.) steel conduit arranged in a modified "U" configuration such that one vertical leg and one end of the horizontal span of the conduit intersect at a condolet LB access fitting, forming a right angle, while the other end of the horizontal span will transition to the second vertical leg by means of a conduit radius bend or elbow.
- A 103-mm (4 in.) steel conduit arranged in a modified "U" configuration such that one

vertical leg and one end of the horizontal span of the conduit intersect at a 30 cm x 61 cm x 25 cm (12" x 24" x 10") steel junction box, forming a right angle, while the other end of the horizontal span will transition to the second vertical leg through a conduit radius bend or elbow in one of the one-hour tests. For the three-hour test, the large diameter (103-mm) conduit will be coupled to the junction box at the mid-point of its horizontal span to allow a cable drop to intersect the top of the box from the furnace ceiling. In that test the sharp right angle transition will employ a large condolet LB fitting while the other horizontal-to-vertical transition will be made by means of a radius bend or elbow.

- A 305-mm (12 in.) wide steel ladder-back cable tray. The cable tray will be constructed in a modified "U" configuration such that one vertical leg and one end of the horizontal span of the conduit intersect at a right angle, while the other end of the horizontal span will transition to the second vertical leg by means of a tray vertical curve.
- A 610-mm (24 in.) wide steel ladder-back cable tray. The cable tray will be constructed in a modified "U" configuration such that one vertical leg and one end of the horizontal span of the conduit intersect at a right angle, while the other end of the horizontal span will transition to the second vertical leg by means of a tray vertical curve.
- A 914-mm (36 in.) wide steel ladder-back cable tray. The cable tray will be constructed in a modified "U" configuration such that one vertical leg and one end of the horizontal span of the conduit intersect at a right angle, while the other end of the horizontal span will transition to the second vertical leg by means of a tray vertical curve.
- Two short cable drops: one consisting of a single 8 AWG bare copper wire and the other being a 250 kcmil bare copper wire.
- Four separate support structure test elements consisting of four different cross sections (threaded rod, Unistrut®, angle iron and square tube) formed into a right angle ("L") configuration and partially covered by the Hemyc material. These structures are being included in the test program to evaluate the magnitude of heat transmission along their wrapped length and the possible thermal coupling effect on any supported assemblies.

In addition, three Rockbestos Surprenant Firezone R cables will be subjected to the furnace environment during the three-hour test in order to evaluate their ability to withstand the ASTM E 119 time-temperature profile. One each of a power (3 conductor), control (5 conductor) and instrument (2 conductor) type cables will be tested. These cables will be placed and secured in a separate, unwrapped 305-mm (12 in.) wide ladder-back cable tray during the three-hour test. During the test, the insulation resistance (IR) between the individual conductors to all of the other conductors in the Firezone R cables, and the IR between the individual conductors and electrical ground will be monitored continuously during the test using the Sandia Insulation Resistance Measurement System. The 305-mm steel cable tray supporting the three Firezone R cables will be electrically isolated from the other raceway test specimens.

Each of the fire protection wrapped cable raceway test specimens will be tested without any cables routed through them. A bare #8 copper conductor, instrumented with thermocouples along its length, will be routed through each of the raceway test specimens. The thermocouples will be attached to the bare copper conductor at 150-mm (6 in.) spacing intervals. Additional thermocouples will be attached to the outer surfaces of the conduit test specimens and along the length of both side rails of the cable tray test specimens at 150-mm intervals. The protective wrap at one end of each conduit test specimen will be flared and attached to the furnace ceiling interface. The opposite end of these conduit test specimens will be insulated with fiber filler inside and around the outside wall at the ceiling interface. Likewise, the protective wrap at the top of all cable drops will be flared around the furnace ceiling penetration while the cable drop interface with other test specimens (tray or junction box) will not be flared.

Table 1 presents the test conditions to be investigated in terms of fire wrap type and configuration of each of the test specimens during each test. Note that no conduits will be tested in the air gap framed configuration and that no trays will be tested with M.T. wrap. Also, the support structure specimens will be protected only with direct wrap Hemyc material in the tests using both 38-mm (1½ in.) and 50-mm (2 in.) thicknesses. In addition, a 27-mm (1 in.) conduit and condolet LB assembly, wrapped with Hemyc fire wrap will be included in the three-hour test.

Table 1. Test Matrix

	Test 1	Test 2	Test 3
	Hemyc (1-Hour Direct Wrap)	Hemyc (Framed for Air Gap)	M.T. (3-Hour Direct Wrap)
27-mm Conduit	X	(Not included)	X*
63-mm Conduit	X	(Not included)	X
103-mm Conduit	X	(Not included)	X
305- mm Tray	X	X	(Not included)
610-mm Tray	X	X	(Not included)
914-mm Tray	X	X	(Not included)
8 AWG Cable Drop	X	X	X
250 kcmil Cable Drop	X	X	(Not included)
Junction Box	X	X	X
Support Structures	X	(Hemyc direct wrap)	(Hemyc direct wrap)
Firezone R Cables	(Not included)	(Not included)	(No protective wrap)

* Test 3 will also include a separate 27-mm conduit test specimen direct wrapped in Hemyc material.

A detailed construction plan for each of the test specimens will be developed. The plan will define the specific details of the design and assembly of each test specimen and the installation of the designated fire wrap. Drawings and descriptions of the dimensions and setup configurations in the furnace and instrumentation details will also be provided. The fabrication and installation of the fire protective wraps will conducted be in accordance with vendor procedures and provisions will be made to verify that all material/installation quality requirements are met. The detailed construction plan is expected to be distributed as an appendix to the final test plan.

Following the completion of the detailed construction plan and final test plan the required materials and equipment will be procured. The type of material and equipment obtained will include cables, raceways (conduit, trays, condolets, and junction boxes), metal to fabricate the support structure specimens, Hemyc and M.T. fire barrier wrap assemblies, framing material for the fire barrier wraps, thermocouples and extension wire, miscellaneous hardware (nuts, bolts, screws, etc.) plus spare parts.

The test specimens will be assembled in accordance with the detailed construction plan as the material and equipment are obtained. The process will include the installation of the thermocouples to the outer surfaces of the test specimens and checkout for proper operation prior to the installation of the fire barrier wraps. It is possible that assembly checklists will be developed for each of the test specimens and included as part of the final test plan. The fire barrier wraps will be installed around the test specimens per the manufacturer's procedures.

Photographs of the test specimens, both during and after assembly, will be taken prior to testing and kept as part of the test documentation.

3.2 Test criteria

The test specimens will be subjected to the ASTM E 119 time-temperature profile in the test furnace. An assessment of the fire barrier wrap performance will be based on two principal factors:

1. *The time at which the average unexposed side temperature of the fire barrier system, as measured on the exterior surface of the raceway or component, exceeds 139 C (250 F) above its initial temperature. Or the time at which a single temperature reading of a test specimen exceeds 30% of the maximum allowable temperature rise (i.e., 181 C [325 F]) above its initial temperature.*

2. *The fire barrier system remains intact during the fire exposure and water hose stream test without developing any openings through which the cable raceway is visible.*

3.3 Test facilities

A Request for Proposal will be distributed soliciting bids on providing test services for the primary test series. Included in the RFP will be a discussion of the scope of the tests, specific tasks to be performed, and furnace requirements. Desirable facility support capabilities will include the availability of a test specimen assembly area, data acquisition interfaces for the test specimen thermocouples, providing photo/video records of the test specimens and tests, and a summary report/documentation of the conduct of each test.

Upon receipt of the proposals, they will be evaluated against the predetermined selection criteria until two finalists are left. It is expected that site visits will be made by SNL and/or NRC representatives to evaluate the specific capabilities and furnace dimensions to be incorporated into the detailed construction plan. Based on the results of these visits a finalist will be chosen and a contract will be negotiated and placed.

3.4 Primary tests

Three separate test runs will be conducted as part of the primary test series. Two of the tests will test the performance of 1-hour Hemyc fire barrier wrap systems and the third test will assess the performance of 3-hour M.T. fire barrier wrap. All of the primary tests will be conducted using the ASTM E 119 standard time-temperature furnace profile (Figure 1).

As indicated above, these tests will be governed by the conditions provided in a formal test plan. Initially, a draft test plan will be written for review and comment by NRC. Then the final test plan, incorporating the changes directed by NRC, will be issued.

The test specimens will consist of those items described in Section 3.1, Test Specimens, above. The specific setup and configuration for each test is discussed below. It should be noted, however, that the test conditions and configurations described below assume the availability and use of a floor furnace of specific dimensions; based on the outcome of the testing services solicitation and contracting process, certain details may require modification.

3.4.1 Test #1

The first test of the primary test series will be conducted on eleven test specimens directly wrapped with Hemyc fire barrier blankets (i.e., without framework to provide air gaps between the wrap and raceways). The nominal thickness of the protective blankets will be 38 mm (1½ in.) for the cable trays and 50 mm (2 in.) for the conduit and cable drops. One of the support structure specimens will be wrapped with a 38 mm thick Hemyc blanket and the other with a 50 mm thick blanket.

Figure 2 shows the planned configuration of the test specimens inside the furnace. Looking at the elevation and plan views in the figure, the arrangement of the test specimens is as follows (from left to right):

- The 27-mm (1 in.) conduit and condolet LB assembly,
- the 305-mm (12 in.) wide cable tray with the small (8 AWG) cable drop entering from above,
- two support structures (both formed out of threaded rod),
- the 610-mm (24 in.) wide cable tray with the large (250 kcmil) cable drop entering from above,

- the 103-mm (4 in.) conduit and 30 cm X 61 cm X 25 cm (12" x 24" x 10") junction box assembly,
- the 914-mm (36 in.) cable tray, and
- the 63-mm (2½ in.) conduit and condolet LB assembly.

This arrangement of the test specimens was selected in order to minimize the potential for one specimen to influence the response of another specimen to the thermal environment. Note that one end of each conduit test specimen has its protective wrap flared around the furnace ceiling penetration.

The conduit and cable trays will be supported from the furnace ceiling in a modified “U” configuration. Each tray and conduit will include one sharp 90-degree transition from the horizontal span to one of the vertical legs. At the other transition point a radius bend will be used. In the case of the conduit test specimens, a condolet fitting or junction box will be employed to provide the right angle transition from horizontal to vertical. The cable trays will be modified and assembled to accommodate the right angle turn. The two vertical runs of these test articles will be approximately 0.6 m (24 in.) along each leg and the horizontal span will be ~1.4 m (54 in.).

Other test specimens will include two cable drop bundles and support structure analogues. A direct wrap cable bundle (250 kcmil bare copper wire) will be dropped through the top of the furnace and join the 610-mm (24 in.) cable tray at its mid-point. Similarly, a smaller (8 AWG bare copper wire) direct wrapped cable bundle will be dropped through the top of the furnace and join the 305-mm (12 in.) cable tray at its mid-point. The two partially direct wrapped support structure test specimens will be hung from the top of the furnace. The temperature data collected from these articles will be used to evaluate the potential transmission of heat along the wrapped portion of the specimens.

The minimum distance from the furnace walls and the test specimens will be 30 cm (12 in.) and the minimum distance between adjacent test specimens will be ~33 cm (13 in.).

3.4.2 Test #2

The second primary test will be conducted on twelve test specimens, six of which will be wrapped with Hemyc fire barrier blankets and employing the necessary framework to provide a minimum of 50-mm (2 in.) air gaps between the wrap and item. The nominal thickness of the protective blankets will be 38 mm (1½ in.). This test will also include six support structure test specimens, directly wrapped in the Hemyc fire barrier material without employing the 50-mm air gap. Three of the support structure specimens–one of each cross section–will be covered with a 38-mm (1½ in.) thick Hemyc wrap and the remaining three will be covered with a 50-mm (2 in.) thick wrap.

The planned arrangement of the test specimens in the furnace during Test #2 is shown in Figure 3. Looking at the elevation and plan views in the figure, the arrangement of the test specimens is as follows (from left to right):

- The 305-mm (12 in.) wide cable tray with the small (8 AWG) cable drop bundle entering from above,

- two support structures made of tube steel with 75 mm x 75 mm square cross sections,
- the 610-mm (24 in.) wide cable tray with the large (250 kcmil) cable bundle entering from above,
- two support structures made of Unistrut®,
- the 30 cm x 61 cm x 25 cm (12" x 24" x 10") junction box,
- two support structures made of angle iron, and
- the 914-mm (36 in.) cable tray.

This arrangement of the test specimens was selected in order to minimize the potential for one specimen to influence the response of another specimen to the thermal environment.

As was the case for Test #1, the cable trays will be supported from the furnace ceiling in a modified "U" configuration. Each tray and conduit will include one sharp 90-degree transition from the horizontal span to one of the vertical legs. At the other transition a radius bend will be used. The cable trays will be modified and assembled to accommodate the right angle turn. The two vertical runs of these test articles will be approximately 0.6 m (24 in.) along each leg and the horizontal span will be ~1.3 m (50 in.).

The junction box will be supported from the furnace ceiling by two Unistrut® channels that are hung on four threaded rods. These junction box supports will be directly wrapped with Hemyc material separately from the box. (Note that the junction box supports are not considered as part of this test and will not be instrumented; however any failure in their performance during the test will be noted and investigated as deemed appropriate.) A wrapped (250 kcmil bare copper wire, with air gap) cable bundle will be dropped through the top of the furnace and join the 610-mm (24 in.) cable tray at its mid-point. Another wrapped cable bundle (8 AWG bare copper wire, with air gap) will be dropped through the top of the furnace and join the 305-mm (12 in.) cable tray at it mid-point. The partially direct wrapped support structure test specimens will be hung from the top of the furnace. The temperature data collected from these articles will be used to evaluate the potential transmission of heat along the wrapped portion of the specimens.

The minimum distance from the furnace walls and the test specimens will be 30 cm (12 in.) and the minimum distance between adjacent test specimens will be ~25 cm (10 in.).

3.4.3 Test #3

The final test of the primary test series will be conducted on eleven test specimens, five of which will be wrapped with M.T. 3-hour fire barrier blankets but without any framework to provide air gaps between the wrap and raceway. The nominal thickness of the M.T. protective covering will be ~76 mm (3 in.). In addition, four structural support specimens, partially wrapped in 38-mm (1½ in.) thick Hemyc wrap (direct wrapped), and one 27-mm (1 in.) conduit/pull box enclosed in Hemyc wrap, also direct wrapped, will be included in the third test.

Three Rockbestos Surprenant Firezone R cables will be supported in an unwrapped 305-mm (12 in.) wide steel ladder back cable tray inside the furnace for this test. These cables will be continuously monitored for changes in their insulation resistance (conductor-to-conductor and conductor-to-ground) during the three hour long test.

Figure 4 shows the configuration of the test specimens in the furnace during Test 3. Looking at the elevation and plan views in the figure, the arrangement of the test specimens is as follows (from left to right):

- The 27-mm (1 in.) conduit and condolet LB assembly, wrapped in M.T. material;
- two support structures (one 75 mm x 75 mm square cross section tube steel and one angle iron), directly wrapped in Hemyc material;
- the 103-mm (4 in.) conduit and 30 cm x 61 cm x 25 cm (12" x 24" x 10") junction box assembly, wrapped in M.T. material with a small cable bundle, also wrapped with M.T., entering at the top of the junction box;
- two support structures (one Unistrut® channel and one threaded rod), directly wrapped with Hemyc material;
- the 63-mm (2½ in.) conduit and pull box assembly, wrapped in M.T. material;
- one 27-mm (1 in.) conduit and pull box, directly wrapped in Hemyc material; and
- the unprotected 305-mm (12 in.) cable tray containing the three Firezone R test cables.

As in the other two tests, the conduit assemblies will be supported from the furnace ceiling in a modified “U” configuration. Each conduit will include one sharp 90-degree transition from the horizontal span to one of the vertical legs and a radius bend will be used for the other transition. A condolet fitting will be employed to provide the right angle turn. The two vertical runs of these test articles will be approximately 0.6 m (24 in.) along each leg and the horizontal run will be ~1.3 m (50 in.). One end of each conduit assembly will have its protective wrap flared at the furnace ceiling interface.

No cable trays are included as test specimens for this test. The four partially protected (direct Hemyc wrap only–no air gap) support structure test specimens will be hung from the top of the furnace in between the other test specimen groups.

The unwrapped 305-mm (12 in.) cable tray will be supported from the furnace ceiling in a “U” configuration. This tray is being employed only to support the fire resistant Rockbestos cables, thus the tray will not include any sharp horizontal-to-vertical transitions. The purpose for including these Firezone R cables in the test is to determine their ability to withstand the ASTM E 119 temperature conditions.

The minimum distance from the furnace walls and the test specimens will be 30 cm (12 in.) and the minimum distance between adjacent test specimens will be 45 cm (18 in.).

3.5 Conduct of tests

Each of the primary test runs will be conducted by exposing the test specimens to the time-temperature profile as specified in ASTM E 119, Standard Test Methods for Fire Tests of Building Construction and Materials. By this method, the temperature inside the furnace should reach 927 C (1700 F) at the end of the one-hour tests and 1052 C (1925 F) at the end of the 3-hour test. Figure 1 shows the desired temperature profile as a function of time.

The insulation resistance of the three Rockbestos Surprenant Firezone R cables will be monitored continuously during the three-hour test. The insulation resistance of each conductor in the test cable to the other conductors in the cables as well as the insulation resistance between each conductor in the test cables to ground will be recorded as a function of time using the Sandia Insulation Resistance Measurement System. A single-phase 120 VAC source will be applied to each conductor in turn while leakage currents generated in the other conductors is monitored and logged. Peak leakage currents will be limited to 1 A or less. The cable tray supporting the Firezone R cables will be connected to electrical ground.

Upon completion of each ASTM E 119 temperature run (one- and three-hours), the furnace will be opened (or the complete test assembly will be removed from the furnace) and a hose stream will be applied to all of the test articles. The hose stream test will consist of a water stream applied at random to all exposed surfaces of the test specimens through a 38-mm (1½ in.) fog nozzle set at a discharge angle of 15 degrees with a nozzle pressure of 517 kPa (75 psi) at a minimum discharge rate of 284 lpm (75 gpm) with the tip of the nozzle at a maximum distance of 3 m (10 ft) from the test specimen. The hose stream application will be continued for at least 5 minutes upon completion of the test.

A visual inspection of all test articles will be conducted following the hose stream test. The purpose of the inspection will be to ascertain whether the fire barrier wraps remained intact during the fire exposure and hose stream test without developing any openings or breaches. Visible indications of an opening will include obvious tears or displacement of a wrap section or a view of the covered raceway through the wrap.

Photographs of the test specimens, both prior to and after disassembly, will be taken during the post-test inspection and kept as part of the test documentation.

3.6 Instrumentation and data collection

The primary data to be generated in these tests will be component temperatures as indicated by Type-K thermocouples. Test #1 will require the use of ~340 thermocouples and Test #2 will require ~240 thermocouples. Approximately 270 thermocouples will be needed for Test #3. The outputs of the thermocouples will be sent to a computerized data collection unit for recording and storage. Each thermocouple's output will be recorded at least once per minute. It is expected that Teflon coated thermocouples will be used during the M.T. test (Test #3) to ensure that there will not be interference from any gases evolving from the protective wraps.

Figures 5-12 show the preferred attachment locations of the thermocouples on the conduit, trays, cable drops, junction box and support structure test specimens during the three tests. Routing the thermocouples for monitoring the tray temperatures will be by laying the bundles in the tray at the entry point and branching the thermocouples off for attachment to the tray rails and bare copper conductor at the appropriate locations. Similarly, for the cable drop thermocouples, the thermocouples will be bundled with the cable drop cables at the point of entrance on the ceiling of the furnace and branching off the thermocouples for attachment to the bare copper conductor wire at the appropriate points.

Each conduit will have thermocouples attached to the outer surface located along the outside perimeter of the “U” shape (see Figures 5, 7 , 9 and 12). The routing of thermocouples for monitoring the temperature of the conduit will require that a series of small thermocouple bundles be placed around the circumference of the conduit and run to their individual attachment locations between the conduit and fire wrap. In order to minimize the effect of these small bundles on the test results, the conduit thermocouples will be run in underneath the wrap from both ends of the test specimen. In addition, the bare copper wires routed through the interior of the conduit test specimens will also be instrumented with thermocouples. The junction boxes and condolet fittings will have at least one thermocouple attached to each side (6 in all) located at or as closely as possible to the geometric center of the side walls.

The reader should note that the thermocouple locations indicated in these figures are for information purposes only. The thermocouples will be installed at 150-mm (6 in.) intervals along the conduits, cable tray rails, condolets, junction boxes, and bare #8 copper wires in accordance with the guidance provided in Supplement 1 to Generic Letter (GL) 86-10 and Regulatory Guide (RG) 1.189.

The Sandia Insulation Resistance Measurement System will be used to monitor the changes in insulation resistance occurring within the Rockbestos Surprenant Firezone R cables during Test 3. The concept of the SNL IR measurement system is based on the assumption that if one were to impress a unique signature voltage on each conductor in a cable (or cable bundle), then by systematically allowing for and monitoring known current leakage paths, it should be possible to determine if leakage from one conductor to another, or to ground, is in fact occurring. That is, part or the entire voltage signature may be detected on any of the other conductors in the cable (or in an adjacent cable), or may leak to ground directly.

To illustrate, consider a three-conductor (3/C) cable, as illustrated in Figure 13. If 100 V are applied to Conductor 2, the degree of isolation of Conductors 1and 3 from Conductor 2 can be determined by systematically opening a potential conductor-to-conductor current leakage path and then reading the voltages of each conductor in turn while Conductor 2 is energized. Determining the IR between Conductors 1 and 2 at the time of voltage measurement on Conductor 2 is a simple calculation employing Ohm’s law.

The calculation of the three resistances for each conductor pair (one conductor-to-conductor path and each of the two conductor-to-ground paths) requires the measured voltages (V_i and V_j) for two complementary switching configurations. For example, the complement for the case illustrated in Figure 13 is shown in Figure 14. As illustrated in Figure 13, Conductor 2 is connected to the input side and conductor 3 is connected to the measurement side. The complementary case shows Conductor 3 on the input side and Conductor 2 on the measurement side, as shown in Figure 14. This complementary pair provides four separate voltage readings that can be used to determine the three resistance paths affecting these two conductors; namely, $R_{2\text{-}3}$, $R_{2\text{-}G}$, and $R_{3\text{-}G}$.

This concept is scalable for virtually any number of conductors in a cable or bundle of cables. Another advantage is that only the two voltage measurements for each switching configuration need to be recorded in real time; determining the resistances can be deferred until after the test is completed.

Employing this method to monitor the changes in insulation resistance of the individual conductors in the Firezone R cables during the furnace test will provide sufficient data to determine the degree, if any, of cable degradation. In addition, this method is able to identify the indications of insulation resistance recovery (e.g., healing) as the temperature of the furnace is decreased following the test period. Since the Sandia IR measurement system presently exists and has been demonstrated previously the cost impact to the program to include the Firezone R cables' IR measurements is expected to be small.

3.7 Follow-on tests

The decision to plan and conduct follow-on tests will be made on the basis of the primary test results.

4 Reporting and Documentation

The test data will be analyzed and the fire barrier performance will be evaluated based on the acceptance criteria. A test report will be submitted to NRC that will include recommendations, if any, for follow-on testing.

It should be recognized that the possibility exists that these test results may form the technical basis for broad acceptance of these fire protection systems by NRC, or provided the basis for enforcement action or backfit requirements, as deemed appropriate.

5 Recommendation for Research Enhancements

The appendix to this document proposes several modifications to this plan that would enhance the quality of these tests for research purposes. These suggestions are based in large measure on comments received from industry (letter: Marion, NEI, to Hannon, NRC/NRR, "Comments on NRC Hemyc Test Plan," December 6, 2002) on the previous draft of this program plan.

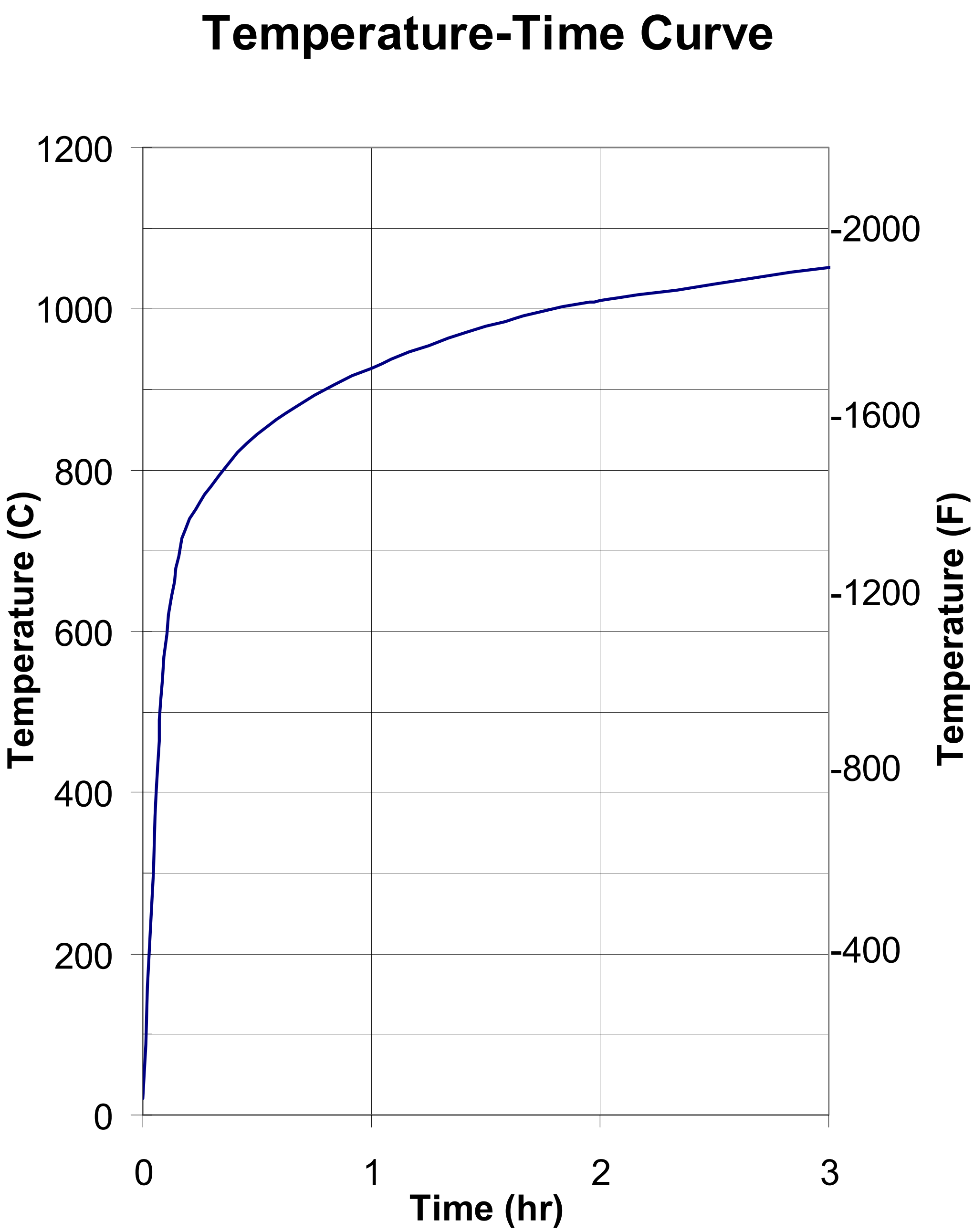

Figure 1: Excerpt of the Standard Time-Temperature Curve (based on data provided in ASTM E 119).

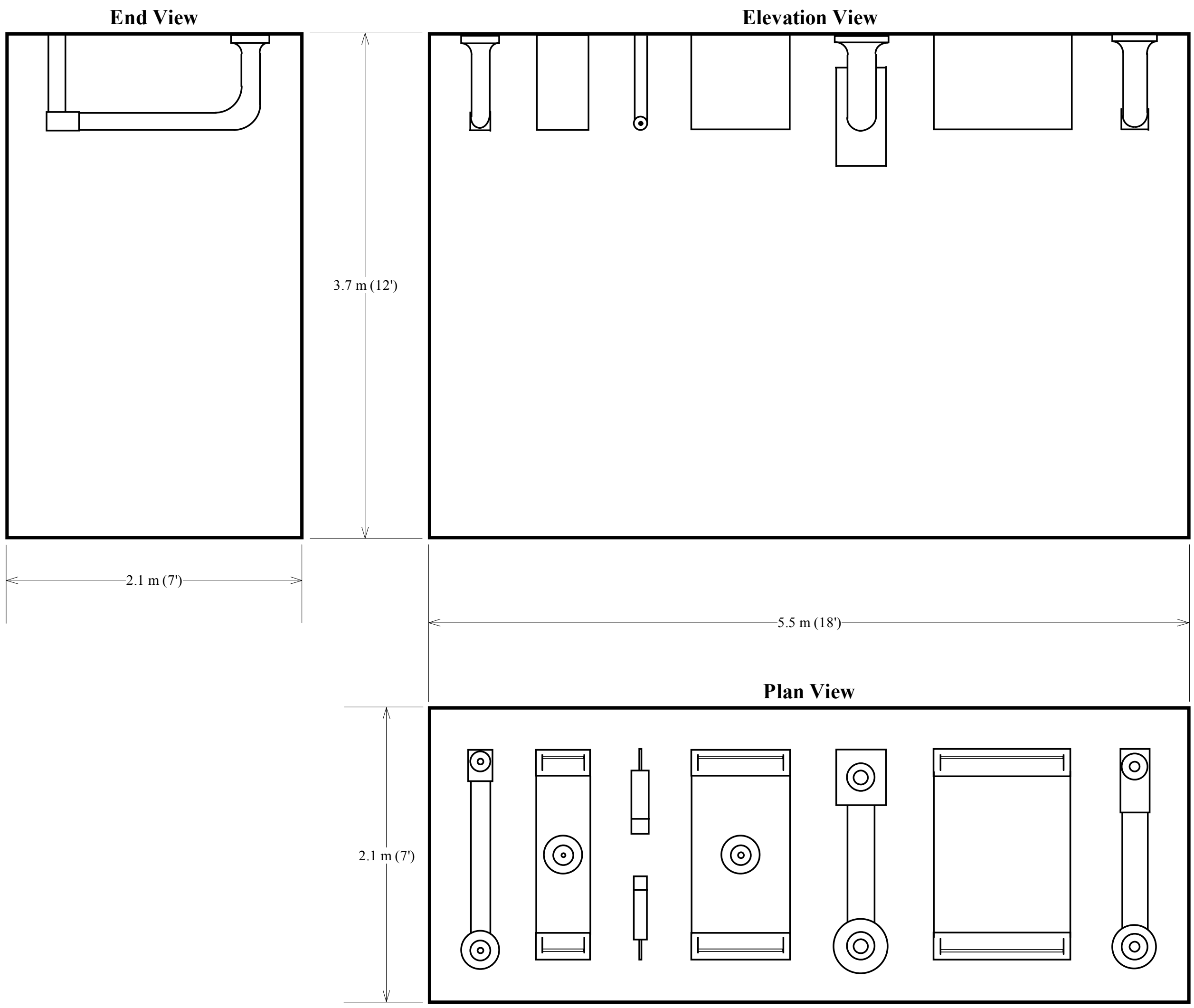

Figure 2: Test Specimen Layout for Test 1.

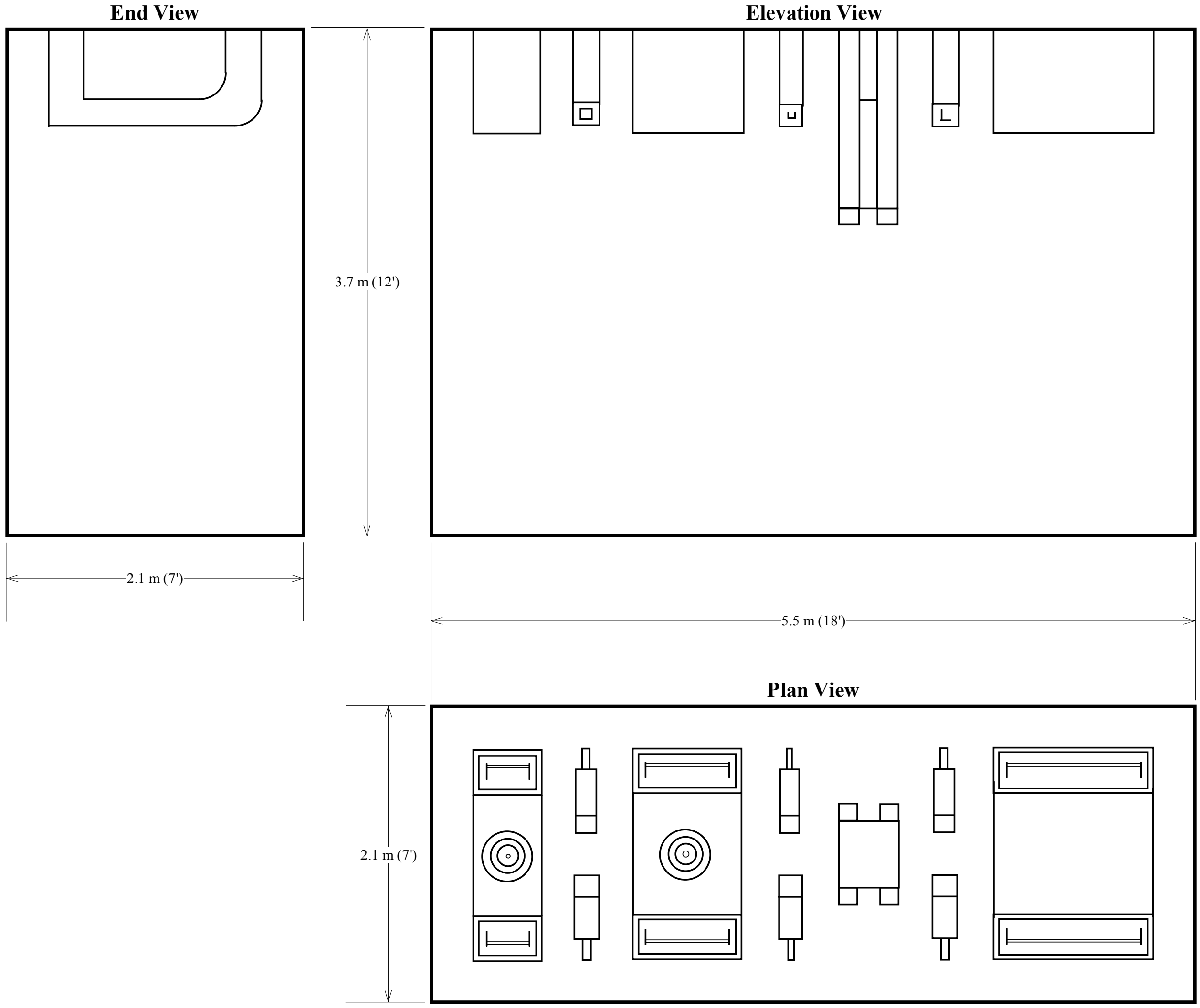

Figure 3: Test Specimen Layout for Test 2.

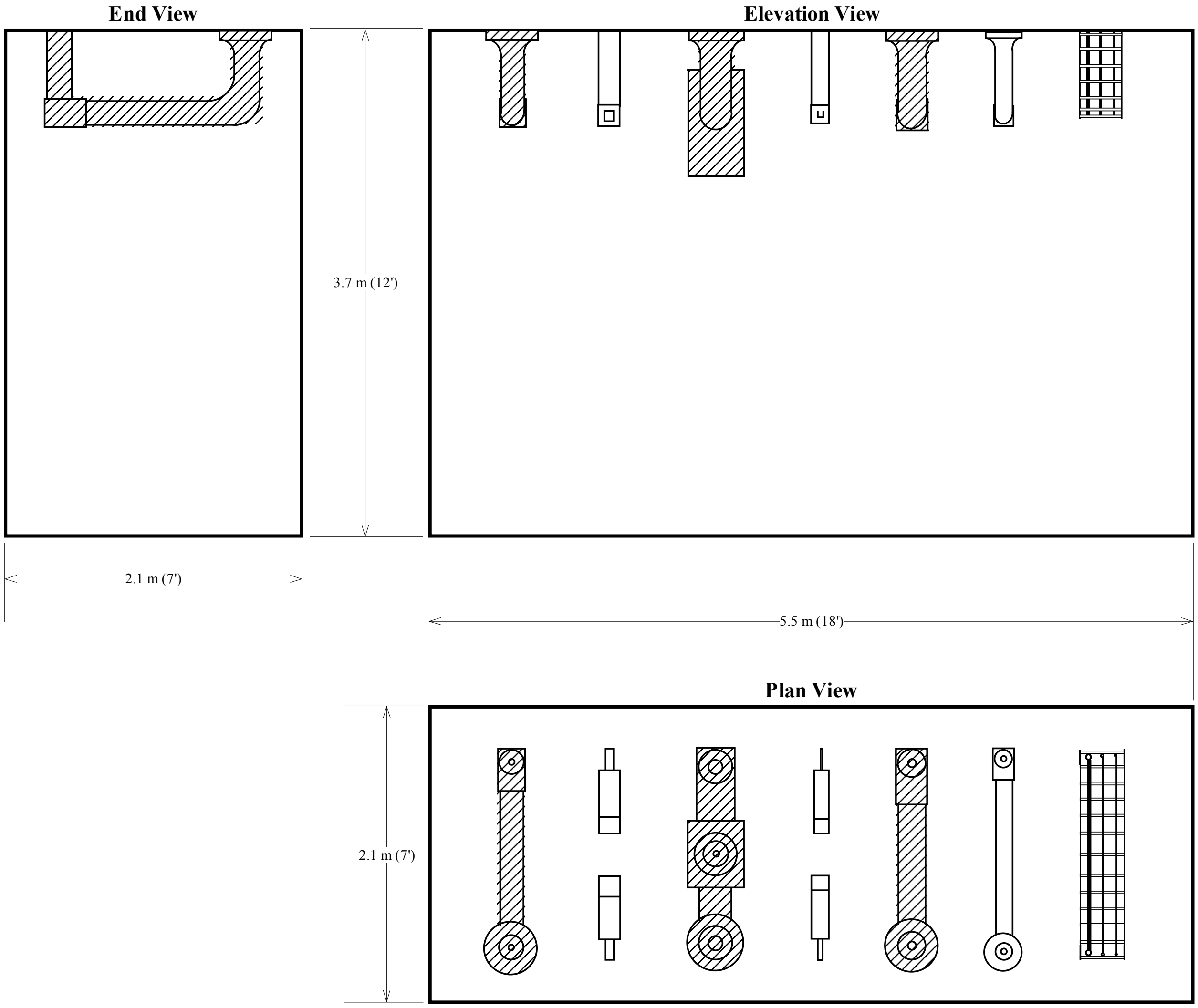

Figure 4: Test Specimen Layout for Test 3. Note that the shaded elements represent the test specimens protected with the M.T. fire wrap. Unshaded elements are enclosed in Hemyc fire wrap. The Firezone R fire rated cables will be installed in an unprotected, open cable tray.

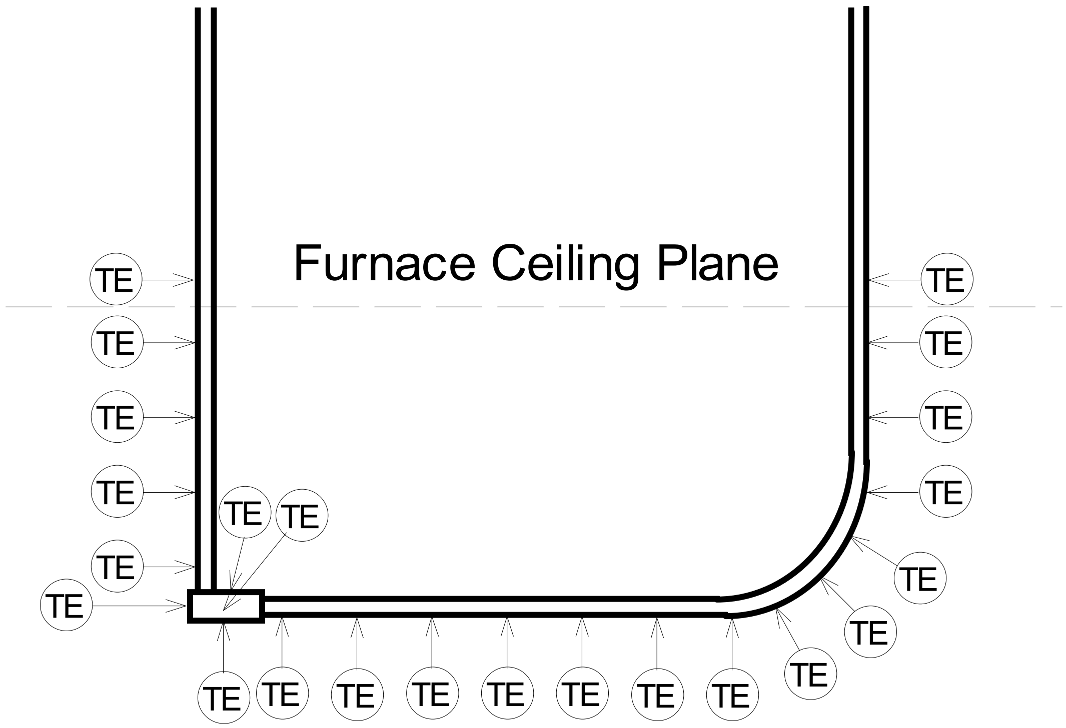

Figure 5: Planned Thermocouple Locations on 27-mm (1 in.) Conduit/Condolet LB Test Specimens. Note that at least one thermocouple will be attached to each face of the condolet fitting. A single bare copper wire (8 AWG) will be instrumented with thermocouples and routed inside the test specimen.

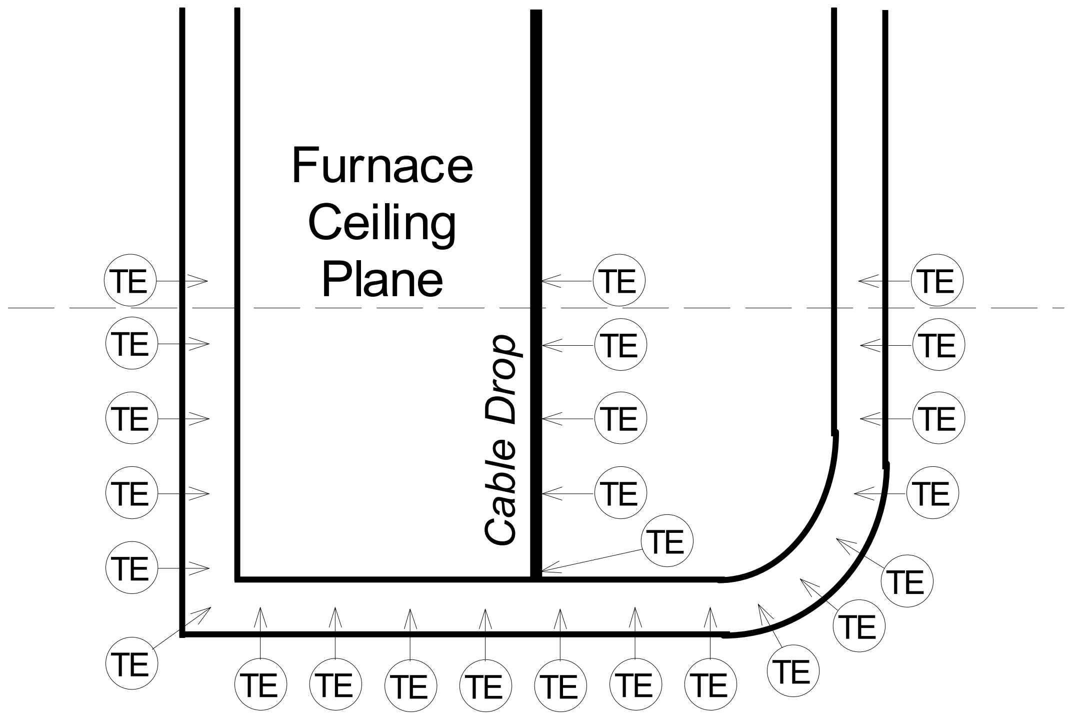

Figure 6: Planned Thermocouple Locations on the 305-mm (12 in.) and 610-mm (24 in.) Cable Tray Test Specimens during Tests #1 and #2. Note that the locations indicated reflect relative positions on each tray side rail and on the bare 8 AWG copper wire attached to the tray rungs. Also, note that the cable drop will consist of a bare 250 kcmil (610-mm tray) or a 8 AWG (305-mm tray) copper wire to which the thermocouples are attached.

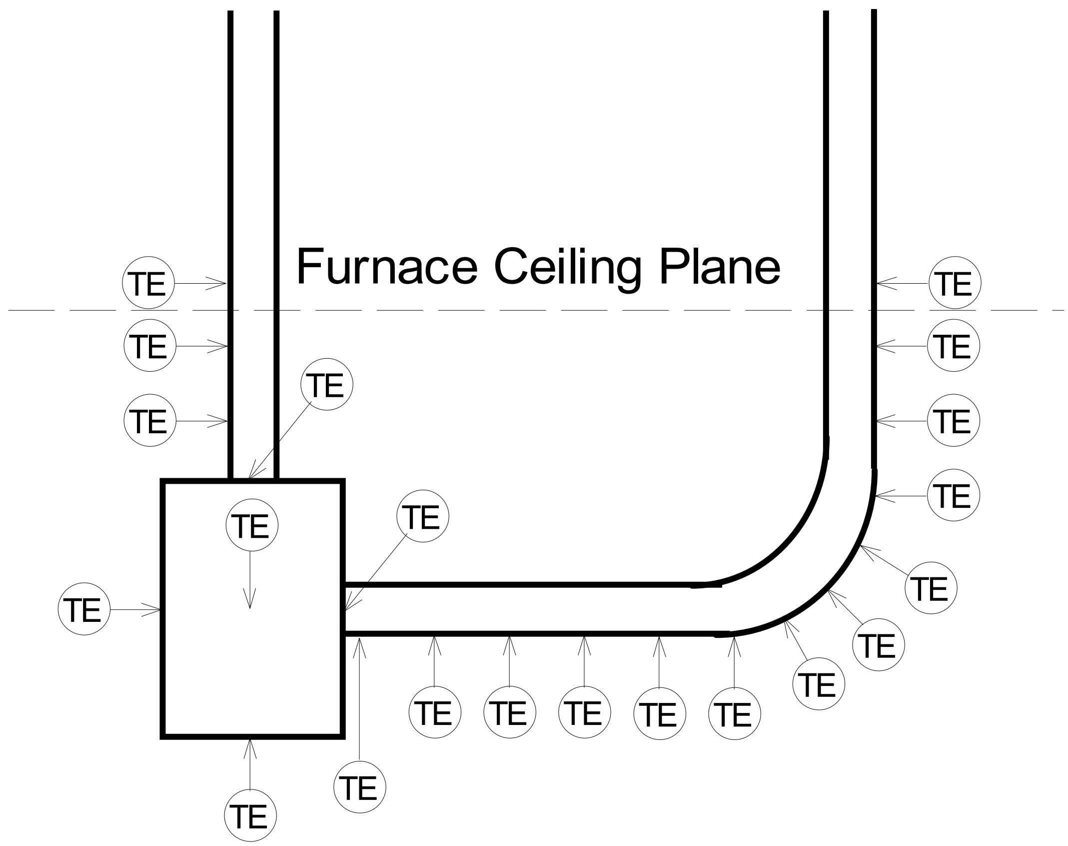

Figure 7: Planned Thermocouple Locations on the 103-mm (4 in.) Conduit and Junction Box Assemblies during Test #1. Note that a thermocouple will be attached to each face of the junction box (6 total). A single bare copper wire (8 AWG) will be instrumented with thermocouples and routed inside the test specimen.

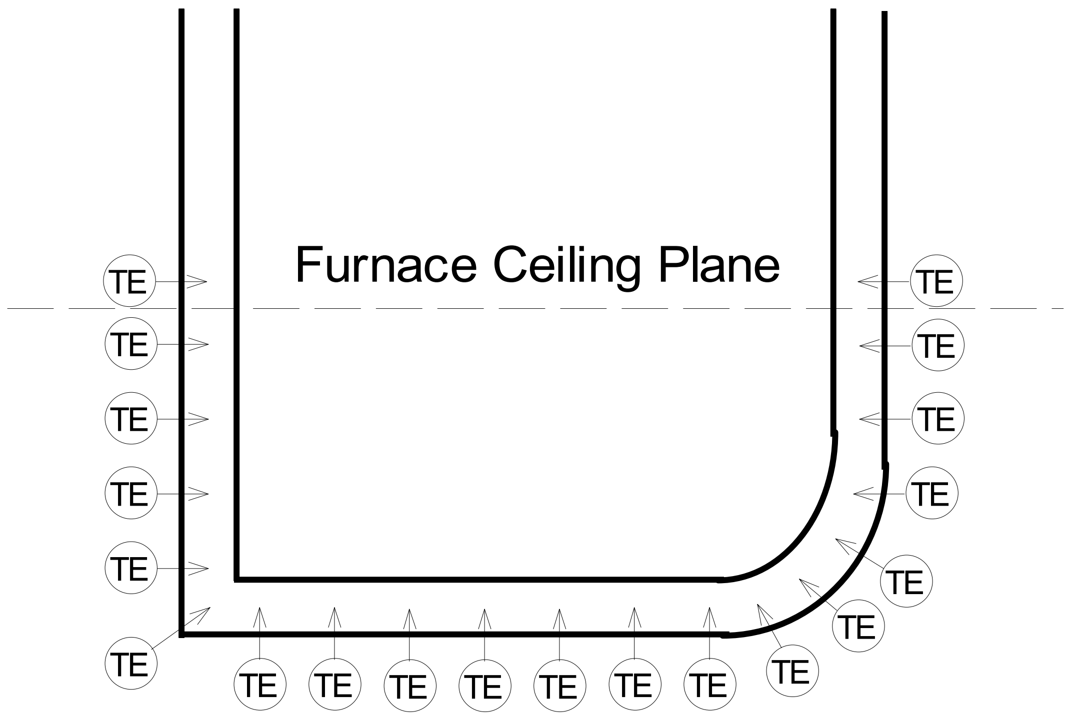

Figure 8: Planned Thermocouple Locations on the 914-mm (36 in.) Cable Tray Test Specimens. Note that the locations indicated reflect relative positions on each tray side rail and on the bare 8 AWG copper wire attached to the tray rungs.

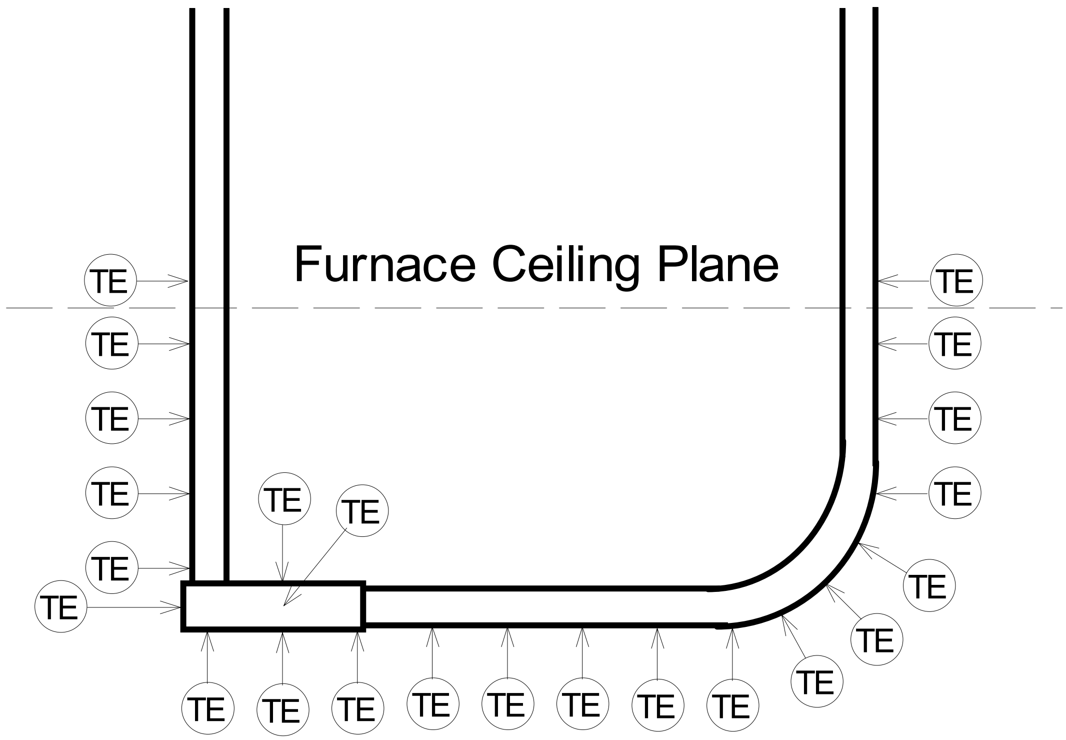

Figure 9: Planned Thermocouple Locations on the 63-mm (2½ in.) Conduit/Condolet LB Test Specimens. Note that at least one thermocouple will be attached to each face of the condolet LB fitting. A single bare copper wire (8 AWG) will be instrumented with thermocouples and routed inside the test specimen.

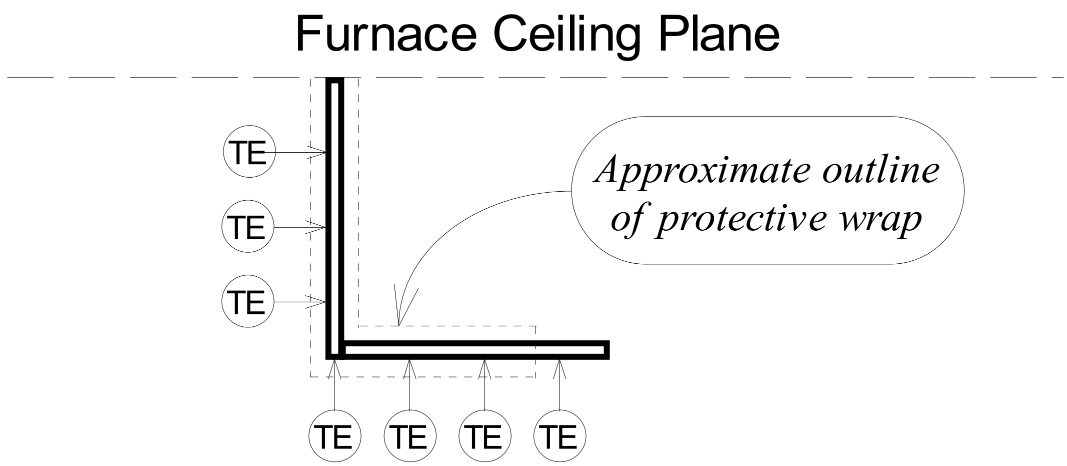

Figure 10: Planned Thermocouple Locations on the Partially Wrapped Support Structure Test Specimens.

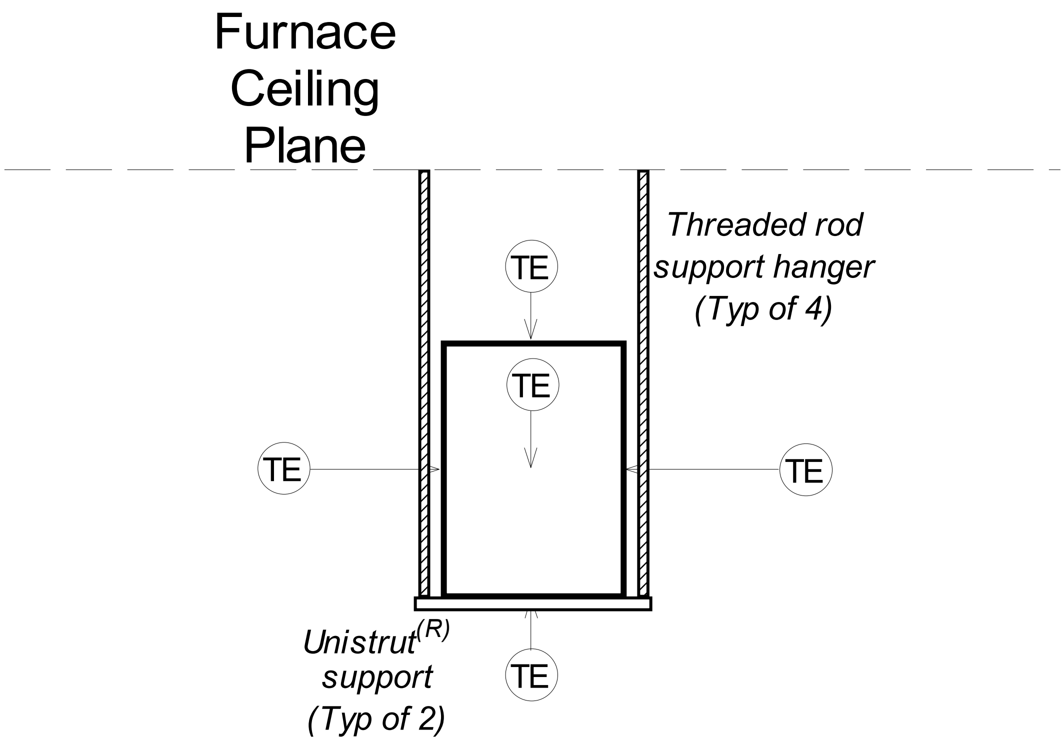

Figure 11: Planned Thermocouple Locations on the 30 cm x 61 cm x 25 cm (12 in. x 24 in. x 10 in.) Junction Box during Test #2. A thermocouple will be attached to each face of the junction box (6 total).

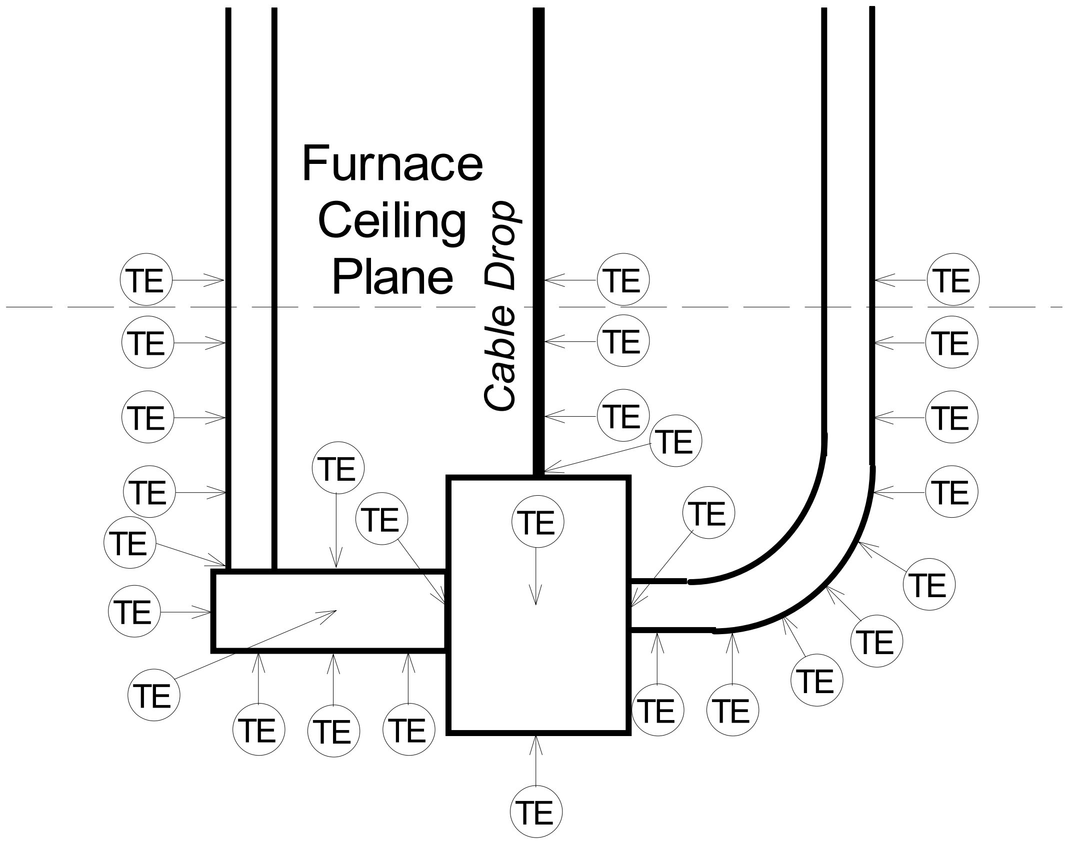

Figure 12: Planned Thermocouple Locations on the 103-mm (4 in.) Conduit and Junction Box/Cable Drop assemblies during Test #3. The cable drop will consist of a single bare copper wire (8 AWG) to which the thermocouples are attached. A thermocouple will also be attached to each of the six sides of the junction box.

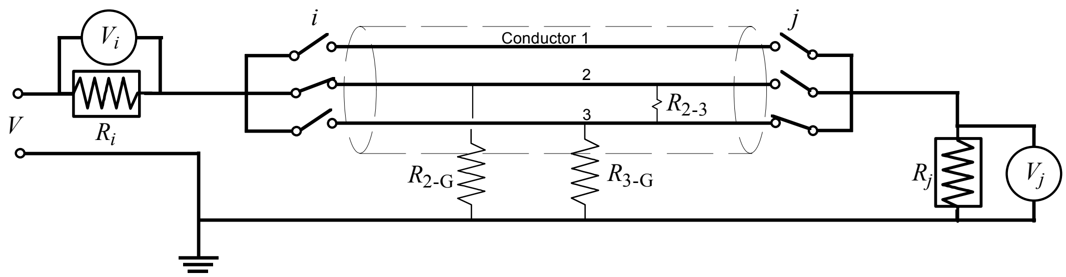

Figure 13: Schematic of the Insulation Measuring Circuit Showing Potential Leakage Current Paths.

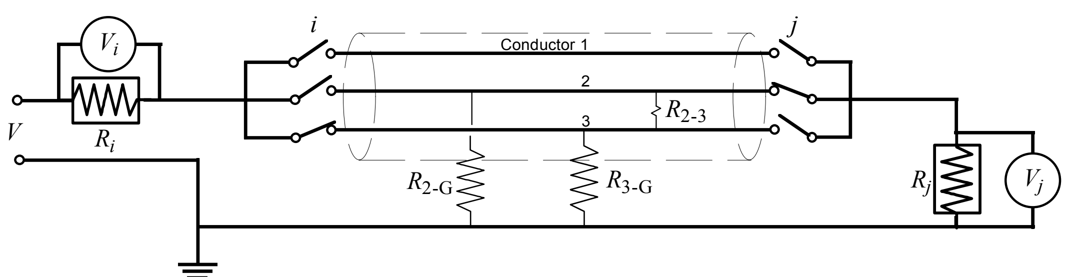

Figure 14: Complementary Insulation Measuring Circuit with Respect to the Circuit Shown in Figure 11.

APPENDIX
Research Program Considerations

The following items should be considered for inclusion in the test program to provide a research basis for the planned tests. Many of these recommendations were provided by industry comments received via letter.[1] The following list of considerations were not included in the revised fire barrier performance testing program plan because they did not fit in well with the very limited objectives of the NRR program. However, they should be given consideration in broadening the scope and objectives of a RES program.

Fire Barrier Performance Model Development – It would be beneficial to tailor the test program such that one principal outcome is the development of a mathematical model, based on the test data, that could estimate the expected performance of fire barriers that might differ from the tested configurations. The development of such a model would require a significant effort to include a variety of protected raceways so that the data and resulting model(s) would be applicable to a wide range of applications.

ANI Test Protocols and Multiple versus Single Raceways – The ANI Test Protocals test using a 'one layer' cable fill and circuit continuity. The current test protocal only tests single raceways not multiple raceways. The variety of cables, circuit voltages and raceway configurations used in actual plant configurations is diverse, and it would be difficult to consider a representative sample of cables, circuit voltages and multiple raceways within the same wrap in this test's scope. Such tests (using cable loading, energized circuits and multiple raceways) would likely be useful in developing a model to estimate expected fire barrier performance (see above).

Multiple Wrap Thicknesses – This test would test similar raceways in a variety of protective fire wrap thicknesses (e.g., 25-mm, 38-mm, 50-mm and 76-mm [1 in., 1½ in. 2 in. and 3 in.]). This test would provide a basis for assessing the effectiveness of a particular fire wrap based on applied thickness.

Industry Review and Observation – Consideration should be given to the industry's request that they be allowed to review and comment on the final test plan and detailed test specimen construction plans. They have also requested to be invited to be present to observe the construction of the test specimens, installation of the fire barriers and the conduct of the tests. Such involvement by industry representatives would be useful in that any potentially controversial issues concerning the fire barrier performance tests will be identified early and can be resolved in a timely manner.

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[1]Letter: Marion, NEI, to Hannon, NRC/NRR, "Comments on NRC Hemyc Test Plan," December 6 2002.