FIRE PROOF CABLE
DEVELOPMENT AND TEST PROGRAM

(To comply with the requirements of Appendix R to 10CFR50)

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11-2-83

11-2-83

DRAFT

Table of Contents

11-2-83

DRAFT

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INTRODUCTION

Where redundant safe shutdown circuits are not separated by a minimum of 20 feet with no interveninng combustibles within a given fire area, 10CFR50 Appendix R requires that one of the redundant circuits must be protected against an exposure fire. One or three hour rated fire barriers qualified in accordance with ASTM E119 may be used to envelope one train to obtain the required protection.

Fire barriers provide a rated seal around a given tray or conduit. As such, the fire barrier design and installation are specific to each different tray/conduit configuration and thus the appplication of the fire barriers is very complex, labor-intensive and costly.

We are proposing that the fire barriers will not be required if one of the mutually redundant circuits is run via cable which is fire rated in accordance with ASTM-E119. Such an approach would require a technical exemption from Appendix R. The Rockbestos Company is presently developing such a cable which would have advantages listed below.

We envision the following advantages:

1. Minimizes the need to provide fire barrier envelope around tray and conduit.

2. Installed in fewer manhours than fire barriers thereby reducing man rem exposures in radiation area. Helps to expedite the implementation of Appendix R modifications.

3. Minimizes maintenance thereby reducing man hours labor and man rem exposure (fire barrier integrity must be checked periodically).

4. Little or no impact on tray and conduit loadings for seismic purposes.

5. Other cables in tray not derated since no envelope provided around them.

6. Alterations to tray configurations do not compromise basic fire barrier characteristics of cable e.g., running new cable will not compromise cable integrity.

7. Cable breakouts from tray are automatically provided with the same protection as cable within the tray.

8. If using metal sheathed cable, need for conduit in dropouts is minimized due to armor like nature of stainless steel sheath. Steel sheath also provides mechanical protection and an added environmental barrier.

A cable development and test program for the Rockbestos cable is outlined in this document.

I. SCOPE

The cable, which was discussed earlier, is specifically designed to perform its intended function i.e., operation of equipment under the conditions of a fire and its aftermath as defined by ASTM-E119. The cable is designed for continuing performance to satisfy the 1 hour ASTM-E119 fire test oven requirement, which calls for the temperatures to peak at 1700°F at the end of the 1 hour time-temperature curve followed by the ASTM defined hosestream test. In addition, the cable is also designed to be operable* for at least 72 hours after fire exposure.

II. CABLE DESCRIPTION

FWR-1 & FWRS-1** cables are designed for use in nuclear power plants where assured operation of critical circuits is required under normal, LOCA, and fire conditions.

FWR-1 & FWRS-1 cables are of composite constructions. The materials composing the cables have been proven individually to meet each of the above conditions. By combining these materials in a sequential manner, all of the required properties are incorporated in a single construction.

IEEE 383 qualification - LOCA

This data is covered in Rockbestos QR 7801, covering identical material referred to in the QR document as Firewall SR. Qualification shall be done by analysis based upon test of cable using similar materials (see Rockbestos Qualification Report).

IEEE 383 Qualification - Flame

Vertical tray flame test with 70,000 BTU/hr burner. Note that this will be performed at the Rockbestos Research and Development Facility.

A. Conductors - H T Alloys.

B. Insulation

(i) Insulation - normal & LOCA conditions - Firewall SR** based polymer which had demonstrated 40 year capability at continuous 125°C, radiation resistance to 2 x 10^8 rads, and ability to survive a postulated LOCA as defined by IEEE 383 and Appendix A of IEEE 323. Furthermore, Firewall SR** in fire situations is converted to a non conductive ash.

*Term "operable" as defined in IE Information Notice 83-56.
**Rockbestos Identification Numbers.

DRAFT

(ii) Insulation - fire conditions - Proprietary combinations of inorganic materials which have been demonstrated to survive at least 1 hour under the temperature conditions as described by ASTM-E119. These materials because of the inorganic nature are not affected by aging or radiation and would have a life expectancy of at least equal to Firewall SR.

All insulation materials are qualified for Class 1E.

C. Jacket or Metallic Sheath - Outer protection is provided by a high temperature jacket for cables to be installed in steel conduit or by a continuously welded water tight corrugated stainless steel sheath for cables to be installed in trays.

D. Sizes - The cable will be available in multiple conductor 14 AWG and larger.

E. Flexibility - the cable will meet the NEC Standard. For metal sheathed cable, the minimum bending radius will be 12 times the external diameter of the stainless steel sheath.

F. Performance - The construction of the cable is such that each of the material's properties is enhanced by the other materials i.e., although Firewall SR is converted to a non conductive ash during fire, it supplements the fire protection provided by the inorganic layer.

Similarly, during normal operation, the Firewall SR layer provides sufficient insulation of itself, the inorganic layer provides additional insulation capability.

Cable failure, therefore, would require both layers to fail at the same point. Since the materials are different, different failure mechanisms would be involved and it is highly improbable that both layers would fail simultaneously.

The design is such that the cable will be capable of 40 year operation at a continuous conductor temperature of 125°C. Because of the higher resistivity of conductor material, conductor sizing will be adjusted for the required circuit performance.

III. PREVIOUS TESTING AND DEVELOPMENT OF CURRENT DESIGN

The present cable design evolved out of a critical cable Rockbestos had designed to meet a circuit integrity flame resistance test according to specification MIL-W-25038E (modified) at the Rockbestos Research Development Facility in Connecticut.

A. The Specification MIL-W-25038E

The specification MIL-W-25038E was modified:

(i) to extend the test duration from 5 minutes to 60 minutes, and

(ii) to increase insulation resistance.

During the test. the Rockbestos cable has been subjected to a 2000°F gas flame source and vibration with a displacement of 1.5 mm at 30 Hz for a 60 minute period using the specified test fixture and procedure while retaining insulation integrity with no insulation flaking or falling off the conductor.

B. The ASTM-E119 Oven and Water Spray Test.

The critical cable passing the specification MIL-W-25038E was then modified using materials suited to the nuclear utility industry. The modified cable designs were then subjected to a Rockbestos oven test, which reproduced the time-temperature curve referred to in the ASTM-E119, while monitored for circuit integrity, and later subjected to a 50 PSI water spray for 5 minutes while monitored for insulation resistance.

C. Testing Equipment

1. The oven is of fire brick construction and permits introduction of one cable monitored for circuit integrity. It is a Blue M Model 9652 electric pyrogenic oven.

2. The continuous temperature recorder is an Omega 3-channel using Type K thermocouples.

3. During the oven test, circuit integrity is monitored by 2 60-watt bulbs normally off during test. Should circuit fail, affected bulb lights. Power is 220 V/110 AC single phase.

4. Water spray source is a laboratory faucet using city water at 50 PSI.

5. Insulation resistance during the water spray test is measured on a Megohm meter (General Radio 1864).

6. Kelvin or Wheatstone bridge measured resistance of conductor.

7. Simpson digital multimeter monitored thermocouple potential (millivolt) change during time-temperature profile.

Successful results obtained from this test has led GPUN/Rockbestos to consider full scale ASTM-E119 acceptance testing.

IV. PLANNED TESTING

The ASTM-E119-82 standard outlines a standard method of "Fire Tests of Building Construction and Materials". This test is utilized to demonstrate a relative measure of fire performance expressed in hourly ratings of assemblies of masonry units and composite assemblies of structural materials for buildings ncluding bearing and other walls, partitions, columns, girders, beams, slabs, and composite slab and beam assemblies for floors and roofs. The test is also "applicable to other assemblies and structural units that constitute permanent integral parts of a finished building". The E-119 test may not be representative of all fire conditions which can vary with changes in the amount, nature and distribution of fire loading, ventilation, compartment size and configuration and heat sink characteristics of the compartment. However, as stated above, it does provide a relative measure of fire performance under specified fire exposure conditions. For this reason, the E-119 test has been adopted by the nuclear industry as the means for determining fire resistance ratings for:

A. Assemblies used to seal penetrations through structural units which have a proven fire resistance rating such that these assemblies can be considered an integral part of the structural unit in which they are installed and provide a fire resistance rating equivalent to the structural unit.

B. Assemblies used to envelop cable systems in cable tray or conduit to protect those cable systems from a fire originating outside the cable tray or conduit in order to assure circuit integrity and continued operability of that circuit both during and after the fire. This will, in effect, place the cable system within a separate fire area, thus achieving the goal as defined in Appendix R of minimizing the effect of fires on the ability to safely shutdown the plant and maintain the plant in a safe shutdown condition.

As stated previously, the E-119 test may not be representative of all fire conditions, but it does provide a relative measure of fire performance under specified fire conditions in a controlled laboratory. The conduct of the fire test is controlled by the standard time temperature curve. The time temperature curve is an approximation of the severity and duration of a fire. The E-119 test demonstrates the conduct of the specific test specimen under the time-temperature curve and assigns hourly fire endurance ratings to that in the following two manners:

A. By measuring the transmission of heat through the test specimen during the test. The hourly rating is assigned based upon the test specimen's ability to limit temperature on the side not exposed to the fire to not more than 250°F above its initial temperature.

B. By measuring the load carrying ability of the test specimen or the assembly the test specimen is protecting under the test exposure.

It should be noted that hourly fire endurance ratings as determined by the E-119 test during the period of fire exposure do not determine the suitability for use of the test specimen after the fire exposure.

It is apparent, from the above, that the testing of a cable's ability to withstand the effects of a fire is a departure from the objective of the E-119 test which is to measure the fire performance of building construction and materials. The cable cannot be placed within this classification. However, since the goal of Appendix R is to minimize the effect of fires on the ability of the plant to shutdown, a cable which can withstand the effects of such fires, retain circuit integrity and continue operability both during and after the fire will achieve the ultimate goal of Appendix R though this is an alternate means. If the ultimate goal of Appendix R can be achieved with the use of such a cable, a method of demonstrating the cable's ability to withstand the effects of the fire must be established. Since the E-119 test is the accepted means of demonstrating fire endurance characteristics, subjecting this cable to test conditions specified in E-119 is the most prudent choice. However, due to the uniqueness of the application, it becomes necessary to tailor the E-119 test both in the test set up and in the acceptance criteria, as close as reasonably possible to the application for which the cable will be utilized in the plant.

The primary reason for using test conditions, as specified in the E-119 test, is to assure that the cable's measure of performance when exposed to fire, is comparable to that of other cables with fire barriers. By subjecting the cable to time temperature curve conditions, an accepted means used to approximate the severity and duration of a fire is achieved. The test configuration will parallel the E119 test for load carrying ability in that the temperature of the unexposed side of the insulation, that being the conductor, will not be measured. Rather, the operability of the cable will be demonstrated under the test exposure. The test on the cable, however, will go beyond the objective of the E119 test. The proposed test will additionally determine the operability for use of the cable for a specified period of time after the fire endurance test in order to demonstrate its ability for continued operation until repairs can be made.

A point by point comparison of the GPUN/Rockbestos Cable Fire Test Program with applicable sections of the ASTME-119-82 "Standard Methods of Fire Tests of Building Construction and Materials" is contained in Appendix A.

V. DETAILS OF TEST SET-UP

A. Test Method

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1. ASTM-E119 Fire Endurance Test

   The raceway/cable configurations will be exposed to the standard time-temperature curve specified in ASTM-E119-82 for a minimum of one hour. The standard time temperature curve is illustrated in Figure 1.

   The required accuracy of the temperature control requirements under this test program is that the area under the test time-temperature curve obtained by averaging the results from thermocouple reading shall be within 10% of the corresponding area under the standard time-temperature curve.

2. Water Hose Stream Tests

   The raceway/cable configurations shall be exposed to a water hose stream test as specified below within three minutes after completion of the fire endurance test. The hose stream test shall be conducted for a period not less than 1 minute and not more than 1-1/2 minutes.

   The hose stream shall be delivered through a 50 ft., 1-1/2 inch hose discharging through a 1-1/2 inch electrically safe fog nozzle having a 30° fog pattern. The nozzle will be adjusted during the hose stream test to provide the maximum water pressure at the outlet of the nozzle. Water pressure at the hose inlet shall be 100 psig + 5 psig. The tip of the nozzle shall be held no closer than 10 feet and no greater than 20 feet from all surfaces of the test assembly.

3. Cable Electrical Tests

   The Rockbestos test cables will be energized in a manner which is representative of their most severe operating requirements during and after a fire.

B. Test Facilities

1. Location/arrangement - Underwriters Laboratories, Northbrook, Ill. or other qualified test laboratories to perform ASTM E119 Test. They will conduct and independently certify the test.

2. Test Witnesses - The following organizations will be invited to witness the test.

   a. ANI (American Nuclear Insurers)
   b. NML (Nuclear Mutual Limited)
   c. NRC (Nuclear Regulatory Commission)
   d. GPUNC (GPU Nuclear Corp.)
   e. EEI (Edison Electric Institute)
   f. Rockbestos

C. Test Cables

Three sizes of Rockbestos fireproof cable will be tested:

1. 3C - AWG #6
2. 3C - AWG #14
3. 2C - AWG #14 twisted pair shielded.

The 3 conductor AWG #6 and the AWG #14 cables will be considered power and control cables. The 2C AWG #14 shielded cable will be used for instrumentation.

The above cables will be tested in the following two constructions:

1. Stainless steel sheathed - this construction of cable will be run in cable trays and used for cable drops.

2. Non metal sheathed - this cable will be run in conduit.

Justification for cable sizes tested as Worst Case Conditions.

1. The smaller the conductor used in the ASTM-E119 oven bake test, the physically weaker it will be and the more subject to stresses of thermal excursion.

2. The smaller conductor will have less thermal lag because of its smaller mass and therefore overheat because of current considerations faster.

3. The rate of change of resistance with time for a constant rate of oxidation is inversely proportional to the cube of the radius of the conductor. The smaller conductor would suffer a proportionately larger reduction in crossectional area because of potential surface oxidation and hence would be subjected to greater stresses (see 1 and 2) leading to faster potential failure.

4. The maximum voltage stress for a given wall is maximized for the smaller conductor. The stress increases with decreasing diameter size (maximum stress formula.

Other types of cables to be mixed in tray with the fireproof cables for test:

1. G.E. Vulkene
2. XLP/PVC
3. EP/CSPE
4. EP/EP

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D. Test Configuration

Each of the two cable constructions will be tested in an installed configuration as described below, representative of its field application as typical of field installation as reasonably possible.

1. Cable tray configuration - for stainless steel sheathed cables.

   A proposed tray test system is shown in Figure 2. The three sizes of the Rockbestos cable will be run to include the following cable configurations:

   a. horizontal run
   b. vertical run
   c. drop out from tray to tray
   d. sharp bend - but not sharper than the allowed minimum cable bending radius.

   The test tray will be a 24" wide, ladder type containing one layer of cables of different insulating constructions to simulate actual field conditions. The Rockbestos test cables will be placed on top of the other cables. Figure 3 shows a typical cross section of the test tray cable arrangement.

2. Conduit configuration - for non metal sheathed cables.

   Figure 2 also shows a proposed conduit test arrangement depicting 3 conduits each having a vertical and horizontal run. A 1-1/2 inch rigid steel conduit will be used to contain the 3C AWG #6 test cable. A 3/4 inch rigid steel conduit will contain the 3C AWG #14 cable and another 3/4 inch rigid steel conduit will contain the 2C AWG #14 shielded cable. No other types of cable will be mixed with the Rockbestos fireproof cable inside the conduit.

3. Cable in tray to cable in conduit transition - the stainless steel sheathed cable will be used for this cable run, but the sheathing will be removed for that section of cable which runs in the conduit.

   Figure 2 shows the test arangement of the 3 test cables as each makes the transition from the tray to a conduit via the use of a suitable fitting. The same diameter conduits will be used as for the cable in conduit.

E. Cable Electrical Integrity Test

1. The 3C AWG #6 and the 3C AWG #14 test cables will be energized with test currents equal to the maximum steady state currents that these cables will experience in actual field applications. They will remain energized during the one hour oven test and afterwards for a total of at least 72 hours and up to 80 hours. Inrush current tests will be performed on these cables which will involve de-energizing

the cables from their steady state test input followed immediately by energizing them for 15 seconds with their inrush currents. The inrush current test will be performed at 5 equally spaced intervals during the 80 hour energization period with the first inrush current test being performed sometime during the last 15 minutes of the 1 hour oven test.

2. The 2C AWG #14 shielded cables will be energized with about 1 amp for the test period commencing at the start of the oven test. The conductor to shield to ground insulation resistance will be measured before the start and after the completion of the ASTM E119 test and also after the 80 hour energization period.

F. Test Instrumentation

Thermocouples used in this test program shall conform to the ASTME119, Standards for T/C arrangements.

All instrumentation used in the test program shall be calibrated traceable to the National Bureau of Standards.

VI. PERFORMANCE CRITERIA

The purpose of the test is to demonstrate circuit integrity and operability for 72 hours. The test will be extended an additional 8 hours to demonstrate margin.

The following performance conditions must be demonstrated in order for the cable to be considered acceptable for use in its intended function.

A. The control and power test cables shall feed steady state test currents of 3.4 amps and 21 amps for the #14 AWG cable and #6 AWG cable, respectively, without unforced interruption during the 80 hour energization period and voltage drop will be measured and application made accordingly.

B. The power and control test cables shall feed inrush currents of 19.8 amps and 120 amps for the #14 AWG cable and #6 AWG cable, respectively, for 15 seconds at 5 intervals during the 80 hour energization period. These inrush currents correspond to the locked rotor currents for a 2HP and a 15 HP motor, respectively, which are the maximum motor sizes which will be connected to the corresponding cables. The locked rotor currents stated above shall be switched in for 15 seconds, and current and voltage drop across the conductor shall be recorded during load.

C. Shield continuity shall be demonstrated through the duration of the 80 hour test. The conductor to shield to ground insulation resistance will be above 50 k ohms when measured.

That cable which meets all the applicable conditions above shall be considered acceptable for use in its intended function while withstanding a one hour fire.

APPENDIX A

ASTM E-119-82 FIRE TEST	GPJN ROCKBESTOS CABLE FIRE TEST
I. SCOPE	
1.1 These methods are applicable to assemblies of masonry units and to composite assemblies of structural materials for buildings, including bearing and other walls and partitions, columns, girders, beams, slabs and composite slabs and beam assemblies for floors and roofs. They are also applicable to other assemblies and structural units that constitute permanent integral parts of a finished building.	1.1 The E-119 test is being utilized and tailored to test the performance of Rockbestos cable under the same fire conditions that building structural materials performance under fire conditions is determined. While not constituting an integral part of the building structure in which the cable will be installed, use of the E-119 test to demonstrate performance of the cable under the fire exposure conditions specified by the E-119 test provides a common reference point between the cable and test which have been conducted on cable raceway protective envelope systems.
1.2 It is the intent that classifications shall register performance during the period of exposure and shall not be construed as having determined suitability for use after fire exposure.	1.2 The intent of the test is not to qualify the cable as a fire barrier but to demonstrate performance of the cable both during the period of exposure and for a period of 80 hours (72 hours being the criteria for acceptance) from the beginning of the test. In this sense, the test will demonstrate suitability of the cable for use after the fire exposure; however, it does not mean that the cable will not be replaced once repairs are made to permit replacements of the exposed cable.

DRAFT

11-2-83

1.3 This standard should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazards or fire risk of materials, products or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment, which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.

NOTE 1 A method of fire hazard classification based on rate of flame spread is covered in ASTM Method E-84 Test for Surface Burning Characteristics of Building Materials.

1.4 The results of these tests are one factor in assessing fire performance of building construction and assemblies. These methods prescribe a standard fire exposure for comparing the performance of building construction assemblies. Application of these test results to predict the performance of actual building construction requires careful evaluation of test conditions.

2. SIGNIFICANCE

2.1 This standard is intended to evaluate the duration for which the types of assemblies noted in 1.1 will contain a fire or retain their structural integrity or exhibit both properties dependent upon the type of assembly involved during a predetermined test exposure.

1.3 The purpose of this test is to demonstrate performance of the cable under fire exposure conditions, not to determine its flame spread or smoke contribution rating. It is important to note that the Nuclear Regulatory Commission has unofficially stated that the cable being tested does not constitute an "intervening combustible". The term "intervening combustible" is utilized for determining non-compliances with Sections III.G.2.b and d of Appendix R to 10CFR50 with respect to "separation of cables and equipment associated non safety circuits of redundant trains" systems required to safely shutdown the reactor.

1.4 As stated previously, the E-119 test is being tailored to demonstrate cable fire performance under identical exposure conditions utilized for testing cable raceway envelope systems. Attention will be paid to the cable configurations tested under the fire exposure conditions specified by the E-119 test in order to assure their performance under actual plant fire exposure conditions.

2.1 This test is not intended to demonstrate the ability of the cable to contain a fire. It will, however, demonstrate the ability of the cable to retain its operating integrity for the duration of the fire exposure and for at least 72 hours from the start of the fire exposure test. By retaining its operating integrity, its structural integrity will also be demonstrated.

DRAFT

11-2-83

2.2 The test exposes a specimen to a standard fire exposure controlled to achieve specified temperatures throughout a specified time period. In some instances, the fire exposure may be followed by the application of a specified standard fire hose stream. The exposure, however, may not be representative of all fire conditions which may vary with changes in the amount, nature and distribution of fire loading, ventilation, compartment size and configuration, and heat sink characteristics of the compartment. It does, however, provide a relative measure of fire performance of comparable assemblies under these specified fire exposure conditions. Any variation from the construction or conditions (ie, size, method of assemblies and materials) that are tested may substantially change the performance characteristics of the assembly.	2.2 The cable to be tested will be exposed to the standard fire exposure controlled to achieve specified temperature for a one(1) hour duration. The fire exposure will be followed by a fire hose stream test. While the test is not representative of all fire conditions, it will, by use of the standard fire exposure conditions, provide a relative measure of cable performance under fire conditions. The configurations which will be tested will be representative of conditions of cable routing which can be expected in any plant so that the cable can be routed in the plant in any manner while not changing its performance characteristics as demonstrated in the test.
2.3 The test standard provides for the following:	2.3 The test performed parallels the E119 test as follows:
2.3.1 In walls, partitions and floor or roof assemblies.	2.3.1.1 The test is not intended to demonstrate the ability of the cables to contain a fire but to demonstrate cable performance both during and after the fire exposure.
2.3.1.1 Measurement of the transmission of heat.	
2.3.1.2 Measurement of the transmission of hot gases through the assembly sufficient to ignite cotton waste.	2.3.1.2 Same as 2.3.1.1.
2.3.1.3 For load bearing elements, measurement of the load carrying ability of the test specimen during the test exposure.	2.3.1.3 The intent of the test parallels this provision of the E-119 test in that cable performance will be demonstrated during the test exposure with the added feature of demonstrating cable performance for at least 72 hours from the beginning of the test.
2.3.2 For individual load bearing assemblies such as beams and columns: Measurement of the	2.3.2 This test does not evaluate the capability of unprotected steel supports to remain intact during the fire exposure test.

DRAFT

11-2-83

load carrying ability under the test exposure with some consideration for the end support conditions (that is, restrained or not restrained.

2.4 The test standard does not provide the following:

2.4.1	Full information as to performance of assemblies, constructed with components or lengths other than those tested.	2.4.1	This test does not demonstrate the performance of all assemblies or configurations which can be expected in the plant, but the configurations tested will represent worst case conditions. Any other configuration which may exist in the plant which may differ from that which is tested can be expected to perform as well or better than that which is tested.
2.4.2	Evaluatior of the degree by which the assembly contributes to the fire hazard by generation of smoke, toxic gases, or other products of combustion.	2.4.2	See response to paragraph 1.3.
2.4.3	Measurement of the degree of control or limitation of the passage of smoke or products of combustion through the assembly.	2.4.3	See response to paragraph 2.3.1.1.
2.4.4	Simulation of the fire behavior of joints between building elements such as floor-wall or wall-wall, etc., connections.	2.4.4	This test does not have any parallel with this paragraph in the E-119 test.
2.4.5	Measurement of flame spread over surface of tested element.	2.4.5	See response to paragraph 1.3.
2.4.6	The effect of fire endurance of conventional openings in the assembly, that is, electrical receptacle outlets, plumbing pipe, etc., unless specifically provided for in the construction tested.	2.4.6	While not specifically part of the test, penetrations of cable through the wall/ ceiling of the test oven will be sealed with an appropriate fire seal.

DRAFT

11-2-83

CONTROL OF FIRE TESTS

3. TIME-TEMPERATURE CURVE

3.1 The conduct of fire tests of materials and construction shall be controlled by the standard time temperature curve as shown in Fig. 1. The points on the curve that determine its character are:
1000°F(538°C) at 5 min. 1850°F(1010°C) at 2 hr.
1300°F(704°C) at 10 min. 2000°F(1093°C) at 4 hr.
1550°F(843°C) at 30 min. 2300°F(1260°C) at 8 hr.
1700°F(927°C) at 1 hr. or more

3.2 For a closer definition of the time temperature curve, see Appendix A-1. (See attached Appendix A-1).

Note 2 Recommendations for Recording Fuel Flow to Furance Burners.

The following provides guidance on the desired characteristics of instrumentation for recording the flow of fuel to the furnace burners. Fuel flow data may be useful for a furnace heat balance analysis for measuring the effect of furnace or control changes and for comparing the performance of assemblies of different properties in the fire endurance test.

Record the integrated (cumulative) flow of gas (or other fuel) to the furnace burners at 10 min, 20 min, 30 min, and every 30 min. thereafter or more frequently. Total gas consumed during the total test period is also to be determined. A recording flow meter has advantages over periodic readings on an instantaneous or totalizing flow meter. Select a measuring and

3.1 The conduct of this test shall be controlled by the standard time temperature curve for a period of 1 hour from the beginning of the test.

3.2 See response to paragraph 3.1.

NOTE 2 This test will incorporate the recommendations of Note 2 for recording fuel flow to the furnace burners.

DRAFT

11-2-93

recording system to provide flow rate readings accurate to within ± 5%.

Report the type of fuel, its higher (gross) heating value and the fuel flow (corrected to standard conditions of 60°F (16°C) and 30.0 in Hg) as in function of time.

4. Furnace Temperatures

The temperatures fixed by the curve shall be deemed to be the average temperature obtained from the readings of not less than nine thermocouples for a floor, roof wall or partition and not less than eight thermocouples for a structural column symmetrically disposed and distributed to show the temperature near all parts of the sample, the thermocouples being enclosed in protection tubes of such materials and dimensions that the time constant of the protected thermocouple assembly lies within the range from 5.0 to 7.2 min (Note 3). The exposed length of the pyrometer tube and thermocouple in the furnace chamber shall not be less than 12 inches (305 mm). Other types of protecting tubes or pyrometers may be used that, under test conditions, give the same indication as the above standard within the limit of accuracy that applies for furnace-temperature measurements. For floors and columns, the junction of the thermocouples shall be placed 12 in. away from the exposed face of the sample at the beginning of the test and, during the test, shall not touch the sample as a result of its deflection. In the case of walls and partitions, the thermocouples shall be placed 6 in (152 mm) away from the exposed face of the sample at the beginning of the test, and shall not touch the sample during the test, in the event of deflection.

4. The temperature fixed by the curve for this test shall be deemed the average temperature obtained from the readings of a suitable number of thermocouples distributed within the test furnace. The specific configuration will be determined by the test facility selected for the test.

DRAFT

11-2-83

Note 3 A typical thermocouple assembly meeting these time-constant requirements may be fabricated by fusion welding the twisted ends of No. 18 gage chromel-alumel wires, mounting the leads in porcelain insulators and inserting the assembly so that the thermocouple bead is 1/2 inch from the sealed end of a standard weight nominal 1/2 inch iron steel or Inconel pipe. The time constraint for this and for several other thermocouple assemblies was measured in 1976. The time constant may also be calculated from knowledge if its physical and thermal properties. See Research Report RR E-5-1001 available from ASTM headquarters.

4.2 The temperatures shall be read at intervals not exceeding 5 min during the first 2 hours and thereafter may be increased to not more than 10 min.

4.3 The accuracy of the furnace control shall be such that the area under the time temperature curve, obtained by averaging the results from the pyrometer readings, is within 10 percent of the corresponding area under the standard time-temperature curve shown in Fig. 1 for fire tests of 1 hour or less duration, within 7.5% for those over 1 hour and not more than 2 hours, and within 5% for tests exceeding 2 hour in duration.

5. TEMPERATURES OF UNEXPOSED SURFACES OF FLOORS, ROOFS, WALLS AND PARTITIONS

4.2 The temperatures shall be read at intervals not exceeding 5 min. for the duration of the hour fire exposure.

4.3 The accuracy of the furnace control shall be such that the area under the time temperature curve, obtained by averaging the results of all pyrometer readings, is within 10% of the corresponding area under the Standard time-temperature curve as shown in Figure 1 for the 1 hour duration of the test.

5. Since the intent of this test is to demonstrate the ability of the cable to function both during and after the fire exposure and not to contain a fire, measurement of the temperature of the unexposed surface or cable conductor is not germane to this test. See response to paragraphs 2.1, 2.3.1.1 and 2.3.1.2.

DRAFT

11-2-83

6.1 Results shall be reported in accordance with the performance in the tests prescribed in these methods. They shall be expressed in time periods of resistance, to the nearest integral minute.	6.1 Since it is not the intent of this test to assign a fire barrier rating to the cable, its performance shall be classified as having been qualified to function both during the fire exposure conditions specified by the standard time temperature curve for a duration of one hour followed by a hose stream test and for a period of at least 72 hours from the start of the fire exposure test.
Reports shall include observations of significant details of behavior of the material or construction during the test and after the furnace fires is cut off, including information on deformation, spalling, cracking, burning of the specimen or its component parts, continuance of flaming, and production of smoke.	The report shall include observations of significant details of behavior of the material being tested during the test, after the furnace fire is cut-off and after the hosestream test. Information such as deformation, spalling, cracking, burning of the specimen or specimens surrounding the cables, continuance of flaming and production of smoke shall be noted.
6.2 Reports of tests involving wall, floor, beam or ceiling constructions in which restraint is provided against expansion, contraction, or rotation of the construction shall describe the method used to provide this restraint.	6.2 This test is not applicable to this feature.
6.3 Reports of tests which other than maximum load conditions are imposed shall fully define the conditions of loading used in the test and shall be designated in the title of the report of the test as a restricted load condition.	6.3 Due to the nature of this test, verification of circuit integrity as detailed in the test program can be termed as a parallel to testing under maximum load conditions. Cables will be energized with test current equal to the maximum steady state conditions that these cable will experience in actual field applications. Cables will remain energized during the one hour fire exposure and continue for at least 72 hours from initiation of the fire exposure. In addition, inrush current tests which involve de-energizing cables from their steady state followed immediately by energizing them at approximately 6 times their steady state test current will be performed. Results of these tests will be included in the report.

DRAFT

11-2-83

6.4 When the indicated resistance period is 1/2 hour or over, determined by the average or maximum temperature rise on the unexposed surface or within the test sample, or by failure under load, a correction shall be applied for variation of the furnace exposure from that prescribed, where it will affect the classification, by multiplying the indicated period by two thirds of the difference in area between the curve of average furnace temperature and the standard curve for the first three fourths of the period and dividing the product by the area between the standard curve and a baseline of 68°F (20°C) for the same part of the indicated period, the latter increased by 54°F·h or 30°C·h (3240°F min or 1800°C min) to compensate for thermal lag of the furnace thermocouples during the first part of the test. For fire exposure in the test higher than standard, the indicated resistance period shall be increased by the amount of the correction and be similarly decreased for fire exposure below standard.

6.5 Unsymmetrical wall assemblies may be tested with either side exposed to the fire, and the report shall indicate the side so exposed. Both sides may be tested, and the report shall so indicate the fire endurance classification applicable to each side.

6.4 The technique for correcting the time frame for which the cable is under a fire exposure will be utilized if necessary. Although it is not the intent of this test to attach a fire classification to the cable, deviations from the standard curve exceeding the requirements of paragraph 4.3 will be corrected in the manner prescribed by paragraph 6.4 in order to increase or decrease the resistance period, whichever may be the case. Note that if this technique is employed, it is expected that the resistance period would increase where the test cable is located in the cable tray test configurations since the effect of mixing the test cable with cables which may ignite would most likely create a condition where the standard curve is exceeded. The test report will reflect this if necessary.

6.5 This test does not have any parallel with this paragraph in the E-119 test.

DRAFT

11-2-83

TEST SPECIMENS

7. Test Specimen

7.1 The test specimen shall be truly representative of the construction for which the classification is desired, as to materials, workmanship, and details such as dimensions of parts, and shall be built under conditions representative of those obtaining as practically applied in building construction and operation. The physical properties of the materials and ingredients used shall be determined and recorded.

7.1 Cables tested will be identical in construction, materials, workmanship and dimensions of parts to that which will be utilized in field applications and will therefore be truly representative. Note that for simplicity and with justification, not all cable sizes will be tested. Those sizes selected for the test are representative of the worst case. Any other cable sizes not included in the test can be expected to perform as well or better than those which are tested.

Test configurations also encompass any configuration which will be utilized in field applications. Again, while not including every single configuration, the configurations being tested are representative of worst case conditions. Any other configuration which may exist in the field can be expected to perform as well or better than those which are tested.

7.2 The size and dimensions of the test specimens specified herein are intended to apply for rating constructions of dimensions within the usual general range employed in buildings. If the conditions of use limit the construction to smaller dimensions, a proportionate reduction may be made in the dimensions of the specimens for a test qualifying them for such restricted use.

7.2 The intent of this test is to qualify all sizes of cable for use in field applications as discussed in paragraph 7.1.

7.3 When it is desired to include a built-up roof covering, the test specimen shall have a roof covering of 3-ply, 15lb (6.8 kgm) type felt not in excess of 120lb (54kgm) per square (100 ft^2 ($9m^2$)) of hot mopping asphalt without gravel surfacing. Tests of assemblies with this covering do not preclude the field use of other built-up roof coverings.

7.3 This test does not have any parallel with this paragraph in the E-119 test.

DRAFT

E-152-83

CONDUCT OF FIRE TESTS

8. FIRE ENDURANCE TEST

8.1 Continue the fire endurance test on the specimen with its applied loads, if any until failure occurs, or until a specimen has withstood the test conditions for a period equal to that herein specified in the conditions of acceptance for the given type of construction.

8.1 The intent of this test is to demonstrate as a condition of acceptance, performance during the specified period of fire exposure (1 h) with appropriate corrections for the time frame made per the requirements of paragraph 6.4, if necessary. The fire exposure portion of the test will not be continued, with applied loads, until failure occurs.

8.2 For the purpose of obtaining additional performance data, the test may be continued beyond the time the fire endurance classification is determined.

8.2 The fire exposure portion of this test will be discontinued after 1 hour (with appropriate corrections applied per para. 6.4). However, circuit integrity as defined in paragraph 6.3 will be demonstrated for a least 72 hours from the start of the fire exposure test as a condition of acceptance. Note that a safety margin of 8 hours for demonstrating circuit integrity will be added to 72 hours; however, the conditions for acceptance will be 72 hours from the start of the fire exposure portion of the test.

9. HOSE STREAM TEST

9.1 Where required by the conditions of acceptance, subject a duplicate specimen to a fire exposure test for a period equal to one half of that indicated as the resistance period in the fire endurance test, but not for more than 1 hour, immediately after which subject the specimen to the impact, erosion and cooling effects of a hose stream directed first at the middle and then at all parts of the exposed face, changes in direction being made slowly.

9.1 The conditions of acceptance of this test, require the hose stream. However, since the purpose of the test is to demonstrate circuit integrity following the fire exposure and hose stream, a duplicate specimen will not be tested. The cable tray configuration and conduit configurations being tested will be removed from the furnace and subjected to a hose stream after the 1 hr. fire exposure.

DRAFT

11-2-83

9.2 Exemption - The hose stream test shall not be required in the case of constructions having a resistance period, indicated in the fire endurance test, of less than 1 hour.

9.2 Since this test requires a fire exposure for 1 hour, the exemption from E-119 hose stream requirements is not applicable.

9.3 Operational Program - The submitter may elect, with the advice and consent of the testing body, to have the hose stream test made on the specimen subjected to the fire endurance test and immediately following the expiration of the fire endurance test.

9.3 The hose stream test, as stated in para. 9.1, will be performed on the specimens subjected to the fire endurance test and immediately following the expiration of the fire endurance test.

9.4 Stream Equipment and Details - The stream shall be delivered through a 2-1/2 inch (64 mm) hose discharging through a National Standard Playpipe of corresponding size equipped with a 1-1/8 inch (29 mm) discharge tip of the standard taper smooth-bore pattern without shoulder at the orifice. The water pressure and duration of application shall be as prescribed in Table 1.

9.4 National Standard Playpipes which utilize a straight stream are not recommended for use on electrically live circuits. A more representative test will be utilized. An electrically safe 1-1/2 inch fog nozzle connected to a 1-1/2 inch hose (50 ft length) having a 30° fog pattern will more accurately demonstrate extinguishment under actual field conditions. The nozzle will be adjusted during the hose stream test to provide the maximum water pressure at the outlet of the electrically safe fog nozzle. Water pressure at the hose inlet shall be 100 psig.

This is more typical of fire fighting techniques which are employed in extinguishing cable fires.

9.5 Nozzle Distance - The nozzle orifice shall be 20 feet (6 m) from the center of exposed surface of the test specimen if the nozzle is so located that when directed at the center, its axis is normal to the surface of the test specimen. If otherwise located, its distance from the center shall be less than 20 feet by an amount equal to 1 ft (305 mm) for each 10 degrees of deviation from the normal.

9.5 The nozzle shall be no closer than 10 feet and no further than 20 feet from all surfaces of the test assembly . The hose stream test shall be conducted for a period not less than 1 minute and not more than 1-1/2 minutes for the test assemblies being sprayed.

DRAFT

11-2-83

Sections 10 through 46 are addressed towards specific testing of structural assemblies. Addressing sections 1 through 9 of the E-119 standard adequately describes the nature of this test and draws parallels with the E-119 test where appropriate. As a result, comparisons with sections 10 through 46 do not prove useful for cable fire testing. Specific details of the test set up and acceptance criteria are provided in "Planned Testing".

DRAFT

11-2-83

11-2-83

DRAFT

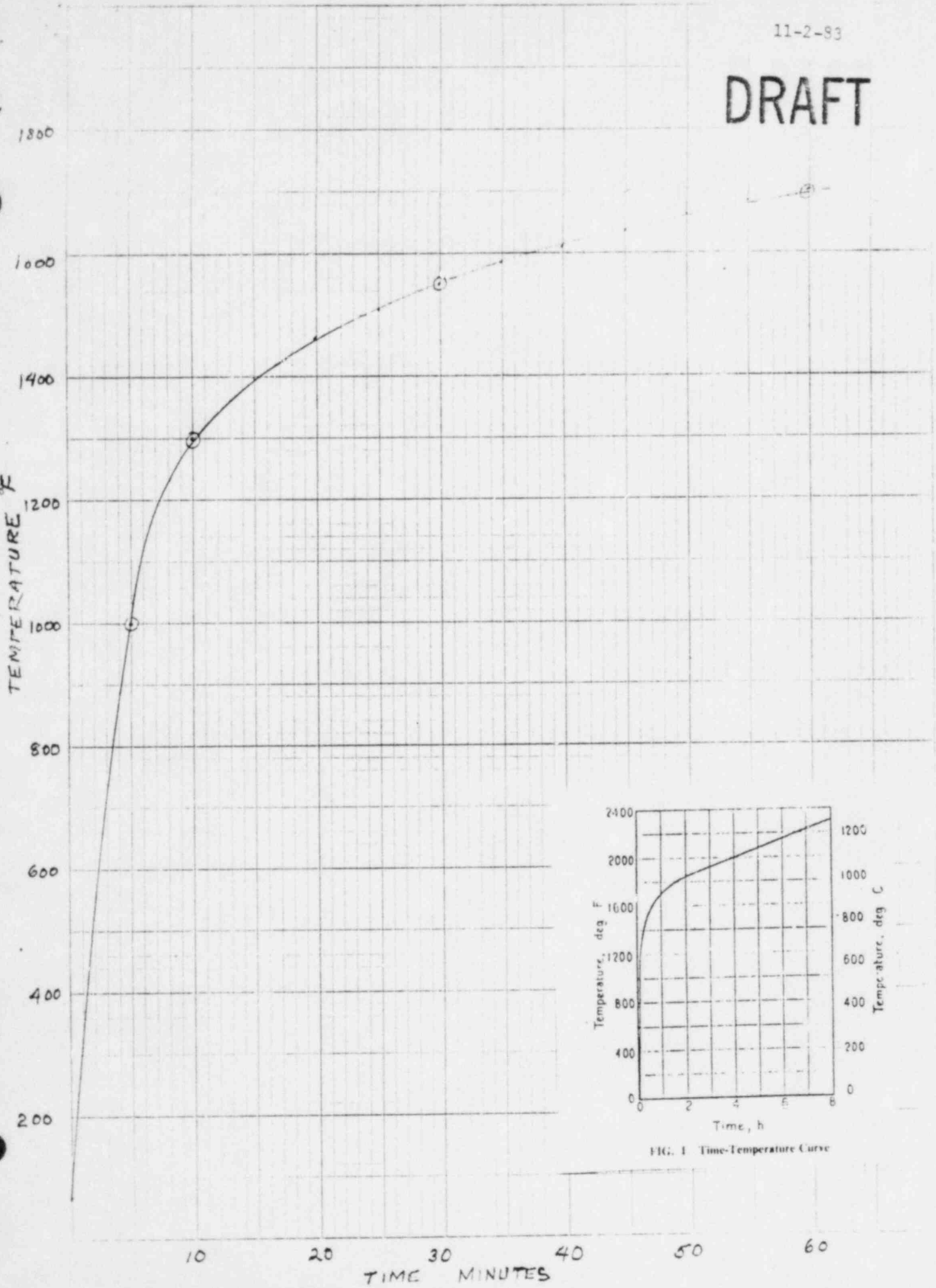
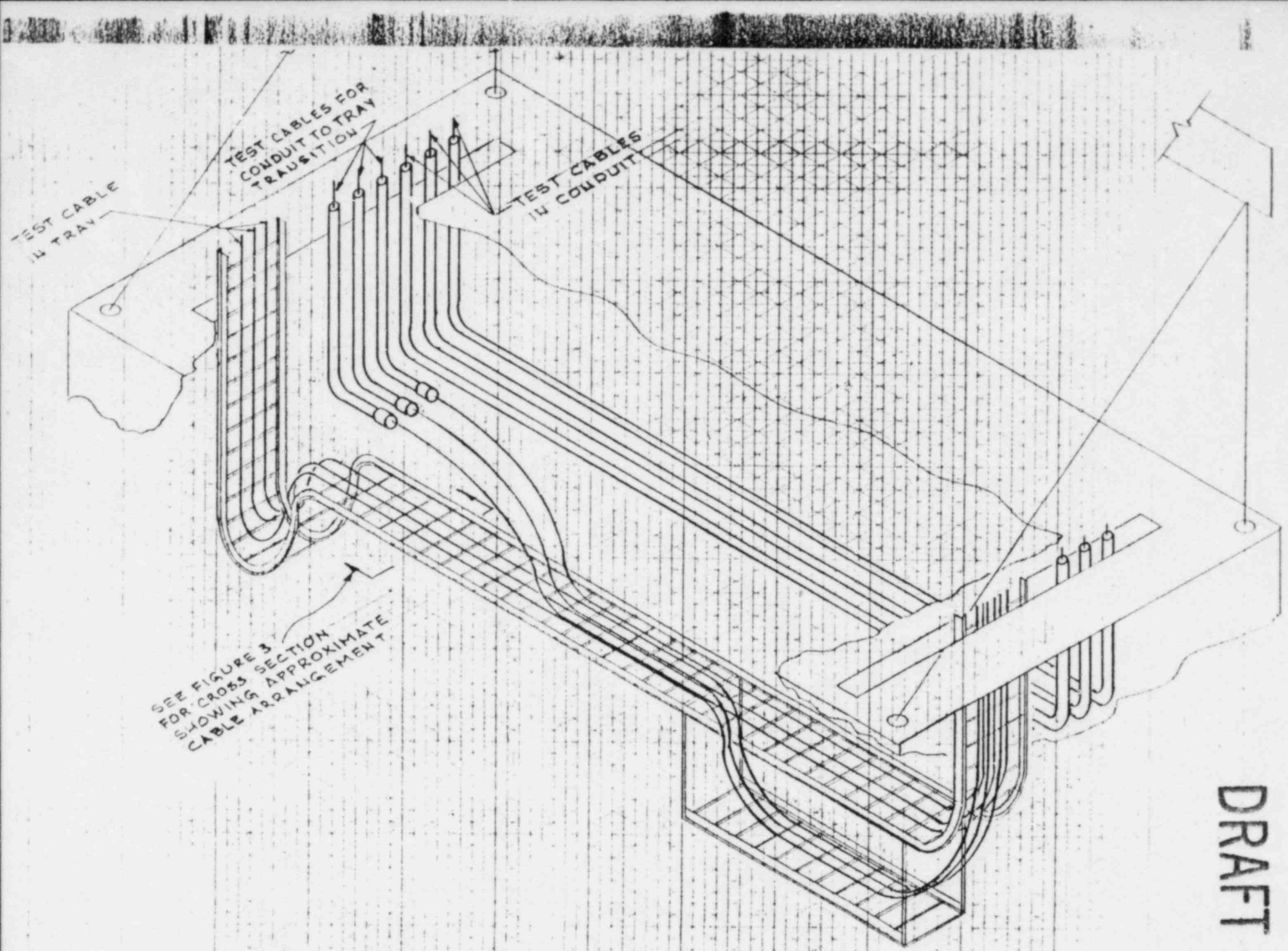


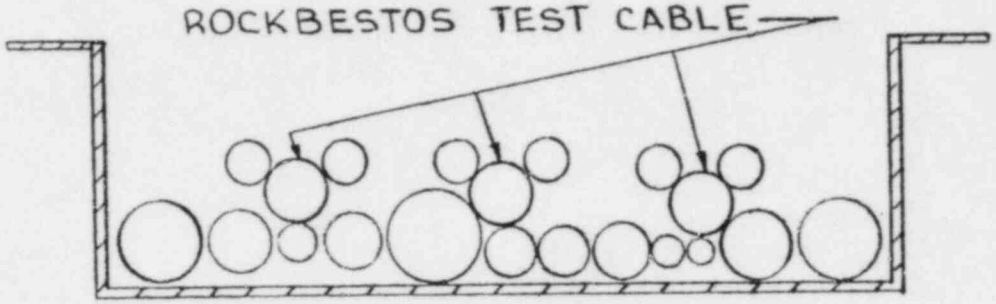
FIG. 1 Time-Temperature Curve



DRAFT

11-2-83

FIGURE 2 PROPOSED CABLE TEST CONFIGURATION



TEST CABLE TRAY WHICH INCLUDES CABLES REPRESENTING A VARIETY OF INSULATING MATERIALS. THE STANDARD TRAY CABLES WILL OVERLAP THE ROCKBESTOS TEST CABLE IN A CRISS CROSSING MANNER.

FIGURE 3

DRAFT

11-2-83