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Division 1
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PROPOSED REVISION 1 TO REGULATORY GUIDE 1.131

QUALIFICATION TESTS OF ELECTRIC CABLES AND FIELD SPLICES FOR LIGHT-WATER-COOLED NUCLEAR POWER PLANTS

A. INTRODUCTION

Criterion III, "Design Control," of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires that, where a test program is used to verify the adequacy of a specific design feature, it include suitable qualification testing of a prototype unit under the most adverse design conditions. This regulatory guide describes a method acceptable to the NRC staff for complying with the Commission's regulations with regard to qualification testing of electric cables and field splices for service in light-water-cooled nuclear power plants to ensure that the cables and field splices can perform their safety-related functions.[1] The fire test provisions of this guide do not apply to qualification for an installed configuration.

B. DISCUSSION

IEEE Std 383-1974, "IEEE Standard for Type Test[2] of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations,"[3] was prepared

*Lines indicate substantive changes from previous issue.

[1]Regulatory Guide 1.29, "Seismic Design Classification," provides guidance with regard to identifying electric cables and field splices to which the design verification requirements of Appendix B to 10 CFR Part 50 apply.

[2]As used in this regulatory guide, the terms "qualification test" and "type test" are synonymous.

[3]Copies may be obtained from the Institute of Electrical and Electronics Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017.

by Working Group 12-32 of the Insulated Conductors Committee of the Power Engineering Society of the Institute of Electrical and Electronics Engineers, Inc. (IEEE), approved by the IEEE Nuclear Power Engineering Committee, and subsequently approved by the IEEE Standards Board on February 28, 1974. It was approved as an ANSI standard, ANSI N41.10-1975, on April 30, 1975. The standard delineates procedures for developing a program for qualification testing of cables and field splices. It supplements IEEE Std 323-1974, "IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations," which describes basic requirements for equipment qualification. IEEE Std 323-1974 is endorsed, with certain exceptions, by Regulatory Guide 1.89, "Qualification of Class 1E Equipment for Nuclear Power Plants."

Although IEEE Std 383-1974 has the word "Connections" in its title, its content does not address requirements peculiar to the qualification of connections. Therefore, the word "Connections" has been removed from the title of this regulatory guide. The IEEE Nuclear Power Engineering Committee is currently developing a separate standard that will address qualification of connections.

Shortly after IEEE Std 383-1974 was issued, several laboratories and cable-testing facilities experienced difficulty in producing a consistent flame source by using the burner and flame source procedures specified in the standard. An IEEE task force investigation into the problem was eventually expanded to include an evaluation of various flame sources to determine if the 70,000 Btu/hr flame source specified in the standard was correct for use in fire qualification testing. The investigation found that inconsistencies in the flame source were traceable to the inadvertent use of incorrectly sized burners during certain tests.

A series of tests was conducted to determine if the correct flame source had been selected, and the results, as evaluated by the IEEE task force and the NRC staff, indicated no basis for changing the 70,000 Btu/hr. Additional research was conducted to determine the sensitivity of variations in fire qualification test parameters and to establish specific values for those parameters that demonstrate a high degree of sensitivity. Such parameters as test cell size, ambient air and equipment temperature, cable tray construction, method of tying cables to the tray, and burner orientation were found to require specific definition in order to help ensure more consistent results among various test facilities.

The flame tests covered by Section 2.5 of the standard provide a test primarily of the flame-retarding tendency of the cable material. These tests are conducted with cables in a specific configuration and subjected to a defined fire source. However, the ability of the cable to retard fire may vary significantly under different environmental conditions, cable configurations, and fire sources. It should be recognized that the objective of the flame test is to provide guidance for the selection of fire-retardant cables rather than to establish the adequacy of the installation of cables in a nuclear power plant. Moreover, the adequacy of the cable system as installed depends on other factors in addition to the properties of the cables. For example, cable separation criteria are partially delineated in Regulatory Guide 1.75, "Physical Independence of Electric Systems," and more fully delineated in Regulatory Guide 1.120, "Fire Protection Guidelines for Nuclear Power Plants," which also gives the fire protection guidelines.

IEEE Std 383-1974 is concerned with some aspects of cables both inside and outside the containment and establishes procedures for simulating operating conditions so that type testing will be adequate for the intended service conditions. It covers normal operating and design basis event conditions, except that the fire test is only a reference configuration and flame rather than the design basis configuration and fire exposure.

C. REGULATORY POSITION

Conformance with the requirements of IEEE Std 383-1974, "IEEE Standard for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations," is acceptable for qualifying electric cables and field splices as components (fire test provisions do not apply to qualification for an installed configuration) for service in light-water-cooled nuclear power plants to ensure that the cables and field splices can perform their safety-related function subject to the following:

1. In lieu of Section 1.3.4.2.3, "Other Design Basis Events," the following should be used:

"The remainder of the complete spectrum of design basis events (e.g., events such as a steam line break) shall be considered in case they represent different types or more severe hazards to cable operation."

2. In lieu of Section 1.3.5.3, "Test Design Basis Event," the following should be used:

"Type tests for design basis event conditions shall consist of subjecting non-aged and aged cables and field splices to a sequence of environmental extremes that simulate the most severe postulated conditions of a design basis event and specified conditions of installation. Type tests shall demonstrate margin by application of multiple transients, increased level, or other justifiable means. Satisfactory performance of the cable will be evaluated by electrical and physical measurements appropriate to the type of cable during or following the environmental cycle, or both. The factors for margin given in Section 6.3.1.5 of IEEE Std 323-1974 shall be used where applicable.

"The values of pressure, temperature, radiation, chemical concentrations, humidity, and time in IEEE Std 323-1974 do not represent acceptable limits for all nuclear power stations. The user of this standard shall ensure that the values used in the required type tests represent acceptable limits for the service conditions in which the cable and field splices will be installed."

3. In lieu of Section 2.1, "Introduction," the following should be used:

"Type tests described in this document are methods that shall be used to qualify electrical cables and field splices for use in nuclear power generating stations. Tests of the cable or field splice, as applicable, shall then supplement the cable tests in order to qualify the field splices and other aspects unique to planned usage.

"The values of pressure, temperature, radiation, chemical concentrations, humidity, and time indicated in IEEE Std 323-1974 do not represent acceptable limits for all nuclear power generating stations.

"The user of this guide shall ensure that the values used in the required type tests represent acceptable limits for the service conditions in which the cable and field splices will be installed.

"Results of prior tests that are being used as the bases for the present tests shall be referenced in the documentation."

4. Section 2.3.1, "Temperature and Moisture Resistance," lists an industry standard of the Insulated Power Cable Engineers Association, IPCEA S-19-81, "Rubber Insulated Cable," for a moisture-resistance test. The exception allowed in the second paragraph of Section 6.9.1 of IPCEA S-19-81 should not be taken unless it can be certified that the insulation, in the absence of covering, can meet the requirements of IPCEA S-19-81.

5. In lieu of Section 2.3.2, "Long-Term Physical Aging Properties," the following should be used:

"Aging data shall be developed to establish long-term performance of the insulation. Synergistic effects[4] on aging due to simultaneous application of environmental conditions shall be considered in the accelerated aging program. Investigation shall be performed to determine if there are synergistic effects and, where identified, they shall be accounted for in the qualification program. The effects of temperature may be evaluated using the Arrhenius technique. A minimum of 3 data points, including one at 136°C or lower and two or more others at least 10°C apart in temperature, shall be used.

"If accelerated aging techniques cannot reliably produce end-of-life conditions, the following ongoing qualification procedure should be used:

"Ongoing Qualification Procedure--Some types of cables and field splices (hereafter referred to only as cables) may not respond in a representative manner to accelerated aging techniques to establish end-of-design-life conditions. Consequently, the qualified life would be less than the required design life. There are two suggested methods for achieving long-term (design

[4]See NUREG/CR-0276 (SAND78-0799), "Qualification Testing Evaluation Program," August 1978.

life) qualification: (a) After a planned period less than the qualified life of the cable has been reached, representative cables[5] should be replaced with new cables and the removed cables subjected to a qualification test similar to that performed prior to installation. This test should include additional accelerated aging. Successful completion of this test extends the qualified life of the installed cables. This procedure should be repeated until the qualified life equals or exceeds the required design life. (b) Additional identical cables should be installed in a nuclear power generating station location or other environmentally equivalent locations where power loading and service conditions equal or exceed those of the cable to be qualified. A cable should be removed after a planned period less than the previously qualified life and subjected to a qualification test similar to that performed prior to installation. This test should include accelerated aging. Successful completion of this test extends the qualified life of the installed cable. Sufficient additional identical cables should be initially installed in order that the above procedure can be repeated until the qualified life equals or exceeds the required design life.

"If the above methods demonstrate that the qualified life is less than the design life, a periodic replacement plan should be instituted."

6. The radiological source term and exposure rate simulating loss-of-coolant accident (LOCA) conditions referred to in Section 2.4.2, "Radiation Exposure--Total," should be obtained from Regulatory Guide 1.89 rather than from IEEE Std 323-1974.

7. In lieu of Section 2.5.1, "General," the following should be used: "This section describes the method for type testing of grouped cables via the vertical tray flame test to determine their relative flame-retardant properties. Additional testing shall be done to demonstrate that the fire-retardant properties of the cable are not adversely affected by aging; otherwise, the vertical tray flame test shall be conducted separately on aged as well as unaged cable."

[5] Representative cables should be selected from those cables that have received the most severe service conditions (including loading, mechanical stress and pressure, temperature, radiation, and chemical environment).

8. In lieu of Section 2.5.2.2, the following should be used:
"The fire test provisions of the standard are useful in screening out cable insulation and jacket materials according to relative flame-retardant properties, but they shall not be construed as qualification of any installed cable system configuration. If field splices are to be used in cable trays, fire tests shall be made to demonstrate that the fire-retardant properties of the cable are not altered unacceptably by the field splice."

9. In lieu of Section 2.5.4.1, the following should be used:
"Tests shall be conducted within a test enclosure. The test enclosure shall be a nominal 8 ft x 8 ft x 8 ft compartment as shown in Figure 1 of this guide. The interior surfaces of the enclosure shall be of mineral material such as marinite board or similar inorganic material. Several observation windows and an access door shall be provided. The interior surface shall be painted flat black. A nominal 12-inch-high opening shall be provided at floor level across the entire front and rear walls. The top of the enclosure shall be completely open. Ventilation of the building or room in which the test is conducted shall be sufficient to prevent oxygen depletion by recirculation of combustion products. Ambient air and cable tray temperature shall be 78° ± 5°F (25.6° ± 2.7°C) prior to each test."

10. In lieu of Section 2.5.4.2, the following should be used:
"A tray configuration perpendicular to the plane of the horizon shall be used. The tray shall be a steel, open-ladder-type cable tray nominally 8 feet long and 12 inches wide. The side channels shall be nominally 3-3/8 inches deep with 1-inch flanges and 0.060 inch thick. The rungs shall be nominally 1 inch x ½ inch U-shaped channels, 0.125 inch thick, and welded to the side rails at 9-inch intervals."

11. In lieu of Section 2.5.4.3, the following should be used:
"Multiple lengths of cable shall be used and arranged in a single layer filling the center 6-inch portion of the tray with a separation of approximately one-half the cable diameter between each cable. The cables shall be tied at 18-inch intervals along the cable tray (every other rung) using No. 16 AWG

steel-wire ties. The test shall be conducted three times to demonstrate reproducibility. All three tests must meet the requirements of Section 2.5.5, "Evaluation," for the cable to be considered as having passed the test."

12. In lieu of Section 2.5.4.4, the following should be used:
"Commercial-grade propane and air shall be premixed and supplied to the burner. The propane flow rate shall correspond to a heat input rate of approximately 70,000 Btu per hour based on the gross heating value of the propane, and the airflow rate shall be sufficient to provide an air-propane ratio of 5.8 to 1 in the burner. The procedure detailed below shall be followed:"

13. In lieu of the first sentence of Section 2.5.4.4.1, the following should be used:
"The ribbon burner[6] shall be mounted parallel to the plane of the horizon. The burner head shall be midway between the tray rungs with the center of the burner positioned 24 ± 1/8 inches from the bottom of the tray. The burner face shall be located 4 ± 1/8 inches from the cable, in front of the cable tray."

14. In lieu of Section 2.5.4.4.3, the following should be used:
"The proper flame source shall be achieved when the fuel input rate is 70,000 ± 1,600 Btu per hour and the supply airflow is 163 ± 10 standard cubic feet per hour. Flow rates are to be monitored by rotameters as shown in Figure 2 of this guide."

15. In lieu of Section 2.5.4.4.4, the following should be used:
"Test procedure - ignite the burner and allow it to burn for 20 minutes. Record the maximum flame height for each minute during the test, the length of time the flame continues to burn after the gas burner is shut off, and the

[6] An American Gas Furnace Co. 10-in, 11-55 drilling, ribbon-type, catalog no. 10X 11-55 with an air-gas Venturi mixer, catalog no. 14-18 (2 lb_f/in^2 max. gauge pressure) is the only presently available model that has been found satisfactory for purposes of these tests.

maximum jacket/insulation damage (which includes the length of cable material consumed, melted, blistered, or charred)."

16. Section 2.5.4.5 is not endorsed by this regulatory guide.

17. Section 2.6, "Documentation of Type Testing," should be supplemented with the following:

"Provide data necessary to document satisfactory compliance with the procedure outlined."

18. The recommendations indicated by "should" and the options indicated by "may" in the sections of IEEE Std 383-1974 indicated below have sufficient importance to be treated the same as requirements of the standard:

a. Section 1.3.1, "Cable Description"
b. Section 1.3.2, "Field Splices or Connection Description"
c. Section 1.3.4.1, "Meeting Service Conditions"; the first sentence.
d. Section 1.3.4.2.1, "Design Basis Event--LOCA"
e. Section 1.4.1, "General"
f. Section 1.4.3, "Test Results"
g. Section 1.4.4, "Test Evaluation"
h. Section 2.2, "Type Test Samples"
i. Section 2.3.3.3
j. Section 2.3.3.4
k. Section 2.4.3, "LOCA Simulation"
l. Section 2.4.3.1
m. Section 2.4.3.2
n. Section 2.4.4, "Post LOCA Simulation Test"
o. Section 2.5.5, "Evaluation"
p. Section 2.5.6, "Instrument Cable and Single Conductors from Multiconductor Assembly"; the recommendation that the tested cable pass a flame-resistance test in accordance with ASTM D2220-68.

19. Section 3, "References," of IEEE Std 383-1974 lists additional applicable IEEE standards. The specific applicability or acceptability of these referenced standards has been or will be covered separately in other regulatory guides, where appropriate.

D. IMPLEMENTATION

IEEE Std 383-1974, which is endorsed by this guide, reflects current regulatory practice. It was written as an ancillary standard to IEEE Std 323-1974 and has been used by industry in conjunction with IEEE Std 323-1974 in qualifying electric cable. IEEE Std 323-1974 is endorsed by Regulatory Guide 1.89 and has been effective since July 1, 1974. Therefore, except in those cases in which an applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods described in IEEE Std 383-1974 will be used in the evaluation of all construction permit applications and reference system preliminary design applications for which the issue date of the Safety Evaluation Report (SER) is after July 1, 1974.

This proposed guide, however, augments the reference standard by providing more specific guidance to enhance test result consistency and has been released to encourage public participation in its development. Therefore, except in those cases in which an applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods described in the active guide (reflecting public comments) will be used to evaluate all construction permit applications and reference system preliminary design applications for which the issue date of the SER is later than the implementation date to be specified in the active guide. The implementation date will not be earlier than December 1, 1979.

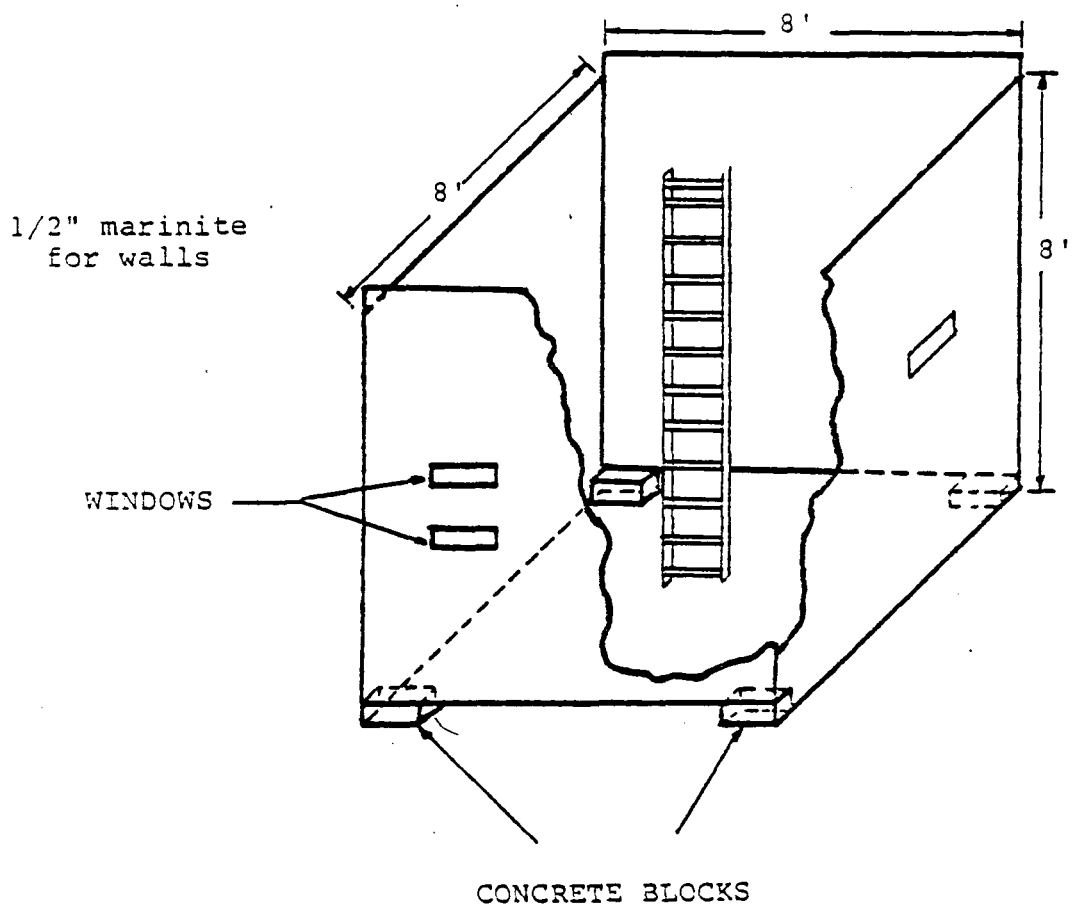

Figure 1. ENCLOSURE

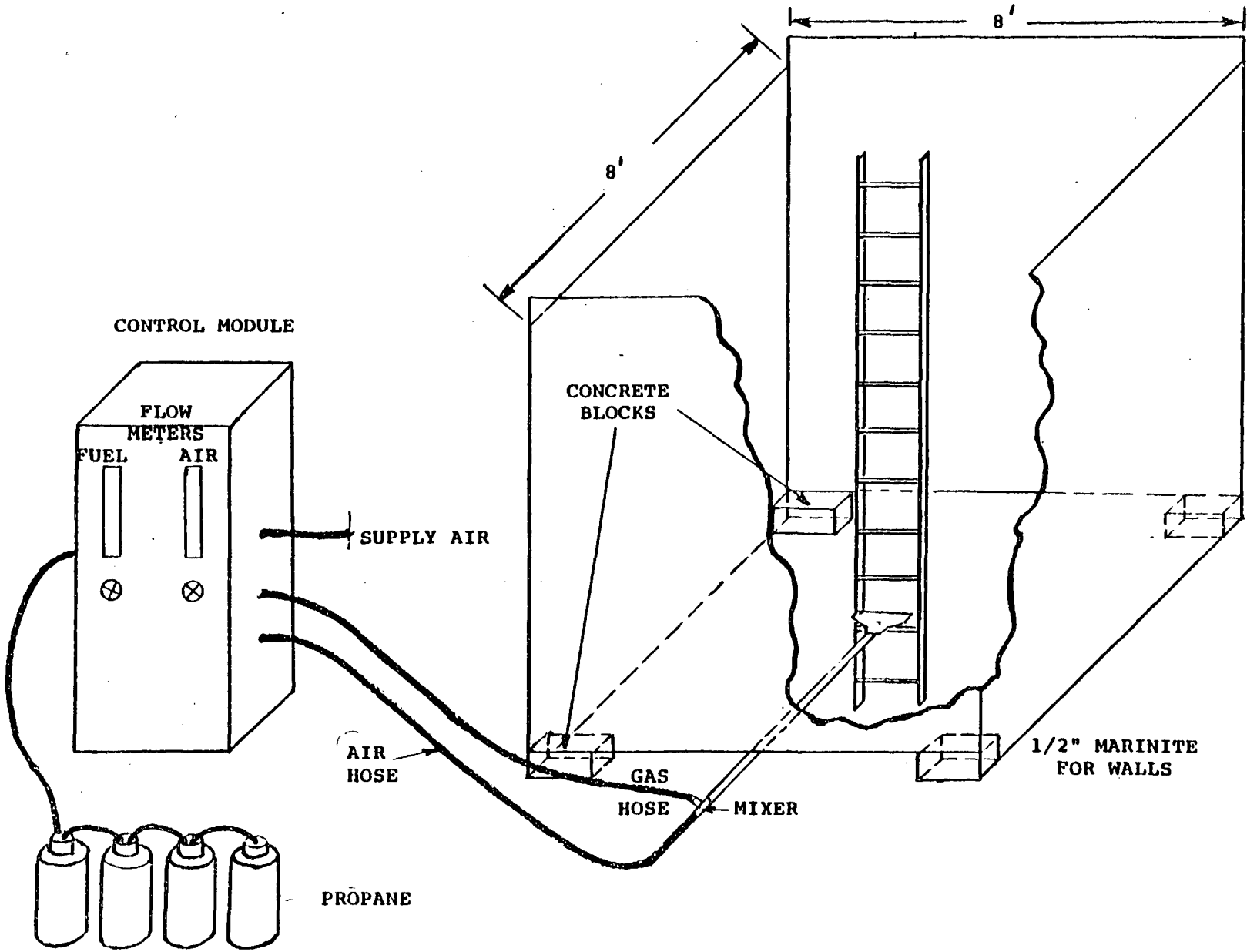

Figure 2. TEST SETUP

DRAFT VALUE/IMPACT STATEMENT

1. BACKGROUND

Regulatory Guide 1.131 is being revised to respond to comments received on the guide and to include more specific definition of fire-testing parameters based on the results of research conducted at Underwriters Laboratories. Also, the word "Connections" is being deleted from the guide title in order to coincide with the content of IEEE Std 383-1974, which is endorsed by the guide. Although IEEE Std 383-1974 has the word "Connections" in its title, its content does not address requirements peculiar to the qualification of connections. The IEEE Nuclear Power Engineering Committee is currently developing a separate standard that will address qualification of connections.

2. SUBSTANTIVE CHANGES AND THEIR VALUE/IMPACT

2.1 Regulatory Position 4

Regulatory position 4 was added to modify a provision of a referenced industry standard (in IEEE Std 383-1974) so that all cables used in nuclear power plants should meet the accelerated water absorption criterion without regard to separators, insulation thickness, and protective cover removability. The referenced industrial standard (Insulated Power Cable Engineers Association [IPCEA]) would exempt cables that have a nonconductive separator between the conductor and insulation, insulation less than 45 mils thick, and insulation having a covering that cannot be removed without damage to the insulation.

2.1.1 Value

The elimination of any exemptions permitting cable to not meet the water absorption criterion will help ensure that no cable intended for use in safety-related circuits will fail to perform its function because of short circuits caused by water absorption. This requirement is particularly significant since deluge systems are proposed as a means of preventing fire propagation.

2.1.2 Impact

There should be no impact since several cable vendors contacted currently do not take the exemption but certify, by other test data, that cables that physically cannot be tested as described will meet or exceed the water absorption criterion of IPCEA S-19-81.

2.2 Regulatory Position 5

Regulatory position 5 was modified to provide that synergistic effects on aging due to simultaneous application of environmental conditions be given consideration in the accelerated aging program.

2.2.1 Value

Research studies of an NRC-sponsored program at Sandia Laboratories have established that, while all materials may not, some materials do exhibit synergistic effects under simultaneous application of accelerated aging environmental conditions. Therefore, in order to ensure that during qualification testing a cable sample is put in true end-of-life conditions, synergistic effects must be given consideration. This is essential as part of the demonstration that equipment (cables) important to safety will function under all conditions in which they will be required to function.

2.2.2 Impact

This provision could have a significant impact on cable qualification. If synergistic effects are known to exist in a given cable material, the cost would be approximately $30,000 per test for simultaneous temperature and radiation aging, provided a facility can be found to apply a sufficiently high temperature and radiation dose rate to accomplish the desired age conditioning in a reasonably short period of time (3 days). If a facility cannot be found that can provide the environmental conditions for a short accelerated age-conditioning time, the costs will increase in direct proportion to the length of time required for lower temperature and radiation dose rate values.

2.3 Regulatory Position 5 (continued)

Regulatory position 5 was modified to provide that locations other than in-plant could be suitable for ongoing qualification test programs provided equivalent service and environmental conditions are met.

2.3.1 Value

A wider range of facilities will be available for conducting ongoing qualification testing, thus providing an alternative to removing cable from an operating plant for use in ongoing qualification.

2.3.2 Impact

There is no impact. The provision merely expands the numbers of places where ongoing qualification tests can be accomplished.

2.4 Regulatory Position 7

Regulatory position 7 was modified to provide for testing other than full-scale vertical tray flame testing to demonstrate that the fire-retarding properties of cable are not adversely affected by aging.

2.4.1 Value

The provision broadens the acceptable evidence that aging of cable does not adversely affect the fire-retarding properties, thus providing alternative ways for achieving the desired results without expensive full-scale tests.

2.4.2 Impact

There is no impact. The provision merely establishes other acceptable methods of meeting an existing requirement.

2.5 Regulatory Position 9

Regulatory position 9 was added to specify size, ventilation requirements, and ambient temperature of the test cell used in fire qualification tests.

2.5.1 Value

It has been demonstrated that test results for a given type of cable vary from facility to facility depending on test cell configuration and other test parameters. This provision standardizes cell size and other significant test parameters to help ensure that consistent results can be obtained in various test facilities.

2.5.2 Impact

The impact should be minimal. Any test room or bay, no matter how large, can be used by constructing an inexpensive test cell inside the room and by using inorganic board material clamped together to form the standard test cell. Other parameters, including ambient temperature and ventilation requirements, can be easily regulated with existing equipment to meet the requirements with little, if any, additional cost.

2.6 Regulatory Position 10

Regulatory position 10 was added to specify the cable tray construction to be used in the fire qualification test.

2.6.1 Value

Cable tray construction can have a pronounced effect on the way cables burn. Trays of different masses or rung spacing could alter heat absorption and burning pattern, thus affecting test results. Specifying a standard tray will contribute to obtaining consistent results.

2.6.2 Impact

There is no impact. The use of a cable tray is an existing requirement. The provision merely provides standardization.

2.7 Regulatory Position 11

Regulatory position 11 was added to clarify that the intent of the three fire tests is to demonstrate reproducibility and that all three tests must meet

the fire-retarding requirements in order for the cable to be considered as having passed the fire-retardancy test. Also, a provision was added that, during the fire test, the cable should be tied on every other rung using metal ties.

2.7.1 Value

The provision is to prevent a misunderstanding that a particular cable type, having passed one or two of the three fire tests, would be considered acceptable. Additionally, metal ties do not burn and hence will keep the cable in a relatively fixed position during the test, thus helping ensure reproducibility.

2.7.2 Impact

There is no impact. It was the original intent of the standard that all three tests meet the requirements in order to consider the cable as having passed the test. Also, tying the cable is not a new requirement. The provision merely standardizes the use of nonburnable ties.

2.8 Regulatory Positions 15 and 17

Regulatory positions 15 and 17 were added to supplement the record of test results by recording flame height at regular intervals during the test and by specifying that data recorded during qualification testing should be of sufficient detail to substantiate compliance with test requirements.

2.8.1 Value

Documentation requirements of IEEE Std 383-1974 fail to specify the necessity for recording the rate of cable burning during the fire test. Inclusion of the rate of burning will add another cable characteristic useful for the designer in cable application.

2.8.2 Impact

There should be very little impact since a record of the cable burning rate is a small addition to the documentation already required.

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