IEEE Std 384-1992
(Revision of IEEE Std 384-1981)

IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits

Sponsor
**Nuclear Power Engineering Committee
of the
IEEE Power Engineering Society**

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IEEE Standard Board

Abstract: The independence requirements of the circuits and equipment comprising or associated with Class 1E systems are described. Criteria for the independence that can be achieved by physical separation and electrical isolation of circuits and equipment that are redundant are set forth. The determination of what is to be considered redundant is not addressed.
Keywords: associated circuit, barrier, Class 1E, independence, isolation, isolation device, raceway, separation

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Foreword

(This foreword is not a part of IEEE Std 384-1992, IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits.)

This standard provides criteria and requirements for establishing and maintaining the independence of Class 1E equipment and circuits and auxiliary supporting features by physical separation and electrical isolation.

This 1992 revision of IEEE Std 384-1981, IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits, reflects the results of separation testing completed by the nuclear industry on internally generated electrical faults. The working group has performed the following activities:

1) Assessed completed industry test reports to determine their applicability in support of changes in separation distances and reported these results to the Nuclear Power Engineering Committee (NPEC).
2) Conducted a panel discussion on the test results at the 1988 Institute of Electrical and Electronics Engineers (IEEE) Winter Power Meeting.
3) Presented a technical paper on the test results at the 1989 IEEE Winter Power Meeting (IEEE Paper No. 90 WM 254-3EC).

The working group's review has resulted in changes to Section 6. of the standard as follows:

1) Separation distance criteria for configurations identified in IEEE Std 384-1981 have been reduced in some cases. In other cases, insufficient testing data were available to support reducing the distances in IEEE Std 384-1981.
2) Separation distance criteria for configurations not addressed in IEEE Std 384-1981 have been added to the standard based on test results. These configurations include cable trays and conduits, cable trays and cable in free air, and conduits and cable in free air.

Other sections of this standard have been reviewed, and many editorial improvements have been made. As part of this work, the working group assessed Nuclear Regulatory Commission (NRC) Regulatory Guide 1.75, Revision 2, which endorses IEEE Std 384-1974.

A Request for Interpretation of IEEE 384-1977, Paragraph 6.1.2 (now 7.1.2), was received by the working group regarding the phrase "maximum credible voltage or current transient." A definition of this phrase has been added to the standard.

A request for proposed revision from the DC Auxiliary Power Working Group (Nuclear Power Subcommittee of the Power Generation Committee) was received regarding the use of fuses as isolation devices in power circuits. The standard has been revised to permit the use of fuses as isolation devices in power circuits.

Section 8 of IEEE Std 384-1981 was previously included to provide *interim* criteria for implementation of independence requirements for safe shutdown systems required for exposure fires. 10 CFR 50, Appendix R has since been issued to provide the requirements for safe shutdown; consequently, Section 8 has been eliminated from the present issue of this standard.

The Working Group has received suggestions and recommendations regarding the application of fiber optic cabling to Class 1E circuits. However, to date, there have been no analyses or test programs submitted to the Working Group to support special criteria for separating these cables in a manner different than already provided by considering them equivalent to typical instrumentation cable. If sufficient information becomes available to justify special separation criteria, the Working Group will consider adding this criteria to the standard in a future revision.

The IEEE has developed these criteria to provide guidance in the determination of the independence requirements related to the class 1E systems of the nuclear facility. Adherence to these criteria may not suffice for assuring the public health and safety, because it is the integrated performance of the structures, the fluid systems, and the instrumentation and electric systems of the station that establish the consequences of accidents. Failure to meet these requirements may be an indication of system inadequacy. Each applicant has the responsibility to assure himself and others that this integrated performance is adequate.

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The Working Group feels that the criteria herein represent an industry and government consensus for ascertaining the adequacy of the independence of Class 1E systems.

The revision to this standard was prepared by Working Group SC 6.5 of Subcommittee 6 under the NPEC. At the time this standard was approved, the members of Working Group SC 6.5 were as follows:

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The Working Group acknowledges the contribution of T. S. Killen, former Working Group Chair, to the preparation of this revision.

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IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits

1. Scope

This standard describes the independence requirements of the circuits and equipment comprising or associated with Class 1E systems. It sets forth criteria for the independence that can be achieved by physical separation and electrical isolation of circuits and equipment that are redundant, but does not address the determination of what is to be considered redundant.

2. Purpose

This standard establishes the criteria for implementation of the independence requirements of IEEE Std 603-1991 [12][1] and IEEE Std 308-1991 [8].

3. References

The following publications shall be used in conjunction with this standard. When they are superseded by an approved revision, the revision shall apply:

[1] ANSI/ANS-58.2-1988, Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture.[2]

[2] ANSI/NFPA 80A-1987, Protection of Buildings From Exterior Fire Exposures.[3]

[3] ANSI/NFPA 321-1987, Basic Classification of Flammable and Combustible Liquids.

[4] ANSI/NFPA 803-1988, Fire Protection for Light Water Nuclear Power Plants.

[5] ASTM E84-91a, Test Methods for Surface Burning Characteristics of Building Materials.[4]

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[1] The numbers in brackets correspond to the references listed in Section 3. of this standard.
[2] ANS publications are available from the American Nuclear Society, 555 N. Kensington, La Grange Park, IL 60525.
[3] NFPA publications are available from Publication Sales, National Fire Protection Association, 1 Batterymarch Park, P. O. Box 9101, Quincy, MA 02269-9101, USA.
[4] ASTM publications are available from the Customer Service Department, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA.

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[6] ASTM E119-88, Method for Fire Tests of Building Construction and Materials.

[7] ASTM E136-92, Test for Behavior of Materials in a Vertical Tube Furnace at 750 °C.

[8] IEEE Std 308-1991, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations (ANSI).

[9] IEEE Std 383-1974 (Reaff 1992), IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations (ANSI).[5]

[10] IEEE Std 420-1982, IEEE Standard for the Design and Qualification of Class 1E Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations (ANSI).

[11] IEEE Std 494-1974 (Reaff 1990), IEEE Standard Method for Identification of Documents Related to Class 1E Equipment and Systems for Nuclear Power Generating Stations (ANSI).

[12] IEEE Std 603-1991, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations.

[13] IEEE Std 628-1987, IEEE Standard Criteria for the Design, Installation, and Qualification of Raceway Systems for Class 1E Circuits for Nuclear Power Generating Stations (ANSI).

[14] IEEE Std 690-1984, IEEE Standard for the Design and Installation of Cable Systems for Class 1E Circuits in Nuclear Power Generating Stations.

[15] NEMA VE 1-1991, Metallic Cable Tray Systems.[6]

4. Definitions

acceptable: Demonstrated to be adequate by the safety analysis of the station.

associated circuits: Non-Class 1E circuits that are not physically separated or are not electrically isolated from Class 1E circuits by acceptable separation distance, safety class structures, barriers, or isolation devices.

NOTE — Circuits include the interconnecting cabling and the connected loads.

auxiliary supporting features: Systems or components that provide services (such as cooling, lubrication, and energy supply) that are required for the safety system to accomplish its safety functions.

barrier: A device or structure interposed between redundant Class 1E equipment or circuits, or between Class 1E equipment or circuits and a potential source of damage to limit damage to Class 1E systems to an acceptable level.

cable in free air: That portion of a cable not routed in either a raceway or an enclosure.

Class 1E: The safety classification of the electric equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or are otherwise essential in preventing a significant release of radioactive material to the environment.

design basis events: Postulated abnormal events used in the design to establish the acceptable performance requirements of the structures, systems, and components.

division: The designation applied to a given system or set of components that enables the establishment and maintenance of physical, electrical, and functional independence from other redundant sets of components.

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[5] IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.
[6] NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street, NW, Washington, DC 20037, USA.

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NOTE — The terms division, train, channel, separation group, safety group, or load group, when used in this context, are interchangeable.

enclosure: An identifiable housing, such as a cubicle, compartment, terminal box, panel, or enclosed raceway, used for electrical equipment or cables.

flame retardant: Capable of limiting the propagation of a fire beyond the area of influence of the energy source that initiated the fire.

independence: The state in which there is no mechanism by which any single design basis event, such as a flood, can cause redundant equipment to be inoperable.

isolation device: A device in a circuit that prevents malfunctions in one section of a circuit from causing unacceptable influences in other sections of the circuit or other circuits.

maximum credible voltage or current transient: That voltage or current transient that may exist in circuits, as determined by test or analysis, taking into consideration the circuit location, routing, and interconnections combined with failures that the circuits may credibly experience.

raceway: Any channel that is designed and used expressly for supporting or enclosing wires, cable, or busbars. Raceways consist primarily of, but are not restricted to, cable trays and conduits.

redundant equipment or system: Equipment or system that duplicates the essential function of another piece of equipment or system to the extent that either may perform the required function regardless of the state of operation or failure of the other.

safety class structures: Structures designed to protect Class 1E equipment against the effects of the design basis events.

NOTE — For the purposes of this standard, separate safety class structures can be separate rooms in the same building. The rooms may share a common wall.

separation distance: Space that has no interposing structures, equipment, or materials that could aid in the propagation of fire or that could otherwise disable Class 1E systems or equipment.

5. General Independence Criteria

5.1 Required Independence

Physical separation and electrical isolation shall be provided to maintain the independence of Class 1E circuits and equipment so that the safety functions required during and following any design basis event can be accomplished.

5.2 Methods of Achieving Independence

The physical separation of circuits and equipment shall be achieved by the use of safety class structures, separation distance, or barriers or any combination thereof. Electrical isolation shall be achieved by the use of separation distance, isolation devices, shielding and wiring techniques, or combinations thereof.

5.3 Equipment and Circuits Requiring Independence

Equipment and circuits requiring independence shall be determined and delineated during the plant design and shall be identified on documents and drawings in a distinctive manner. (See IEEE Std 494-1974 [11] for guidance in identification.)

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5.4 Compatibility With Auxiliary Supporting Features

The independence of Class 1E circuits and equipment shall not be compromised by the functional failure of auxiliary supporting features. For example, an auxiliary supporting feature (such as Class 1E switchgear room ventilation) shall be assigned to the same division as the Class 1E system it is supporting in order to prevent the loss of mechanical function in one division from causing loss of electrical function in another division.

5.5 Associated Circuits

5.5.1 General

Non-Class 1E power, control, and instrumentation circuits become associated in one or more of the following ways:

1) Electrical connection to a Class 1E power supply without the use of an isolation device. (See Fig 1.)
2) Electrical connection to an associated power supply without the use of an isolation device. (See Fig 1.)
3) Proximity to Class 1E circuits and equipment without the required physical separation or barriers. (See Fig 2.)
4) Proximity to associated circuits and equipment without the required physical separation or barriers. (See Fig 2.)
5) Sharing a Class 1E or associated signal source without the use of an isolation device. (See Figs 3 and 8.)

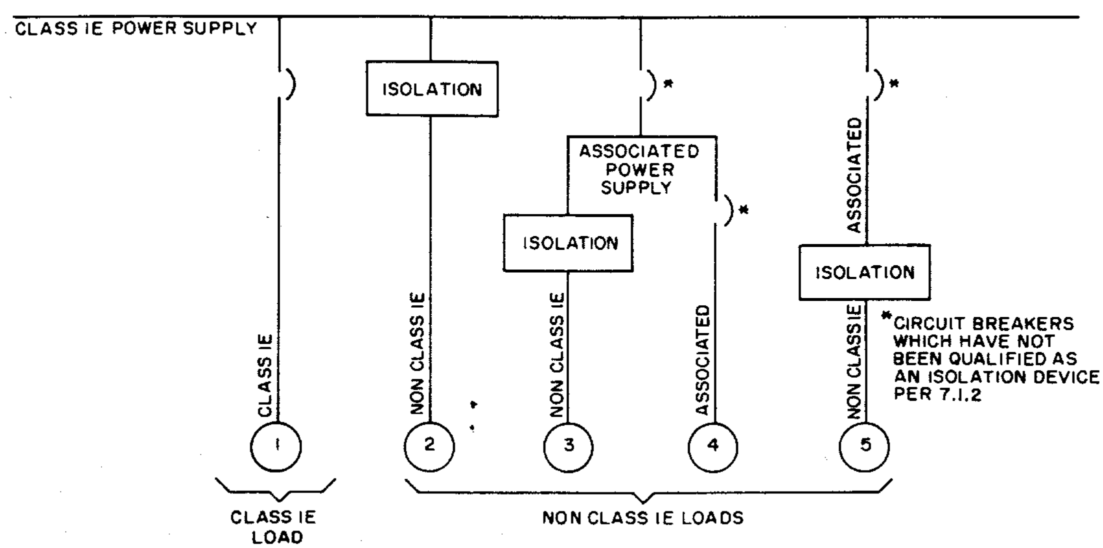

Figure 1—Examples of Association by Connection and Application of Isolation Devices

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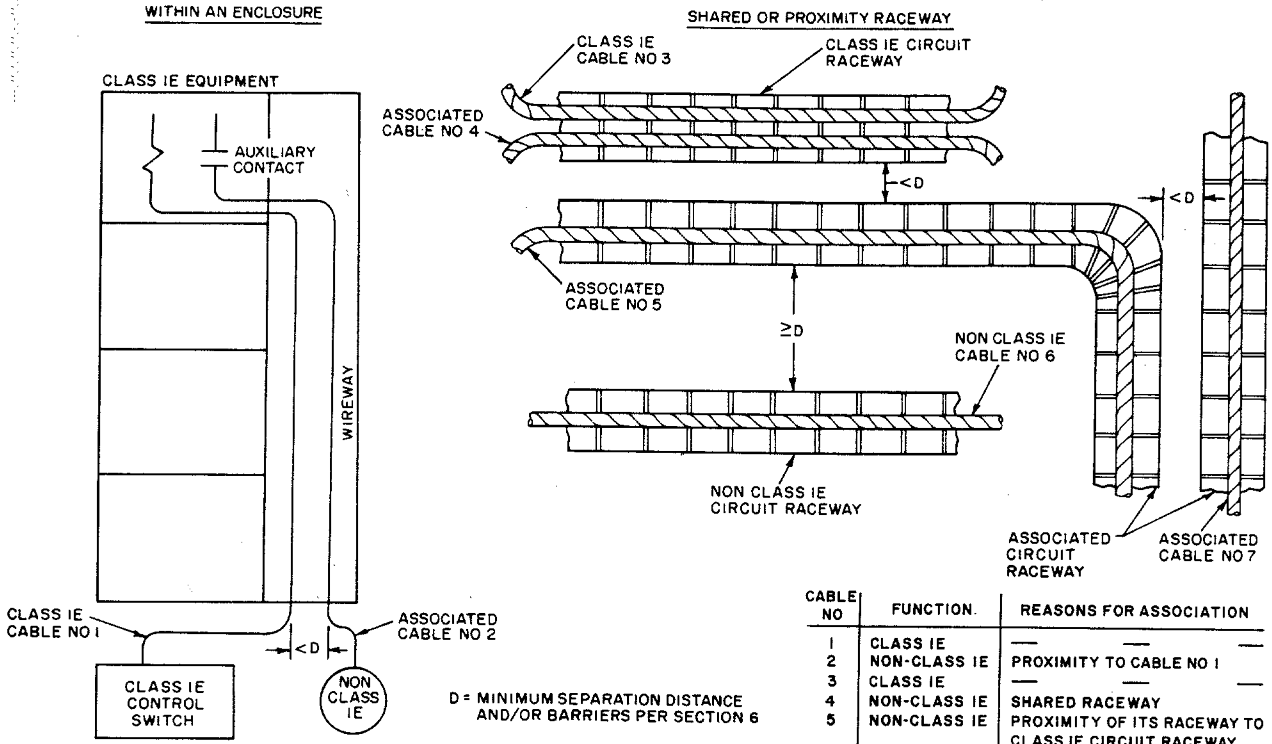

CABLE NO	FUNCTION.	REASONS FOR ASSOCIATION
1	CLASS IE	— — —
2	NON-CLASS IE	PROXIMITY TO CABLE NO 1
3	CLASS IE	— — —
4	NON-CLASS IE	SHARED RACEWAY
5	NON-CLASS IE	PROXIMITY OF ITS RACEWAY TO CLASS IE CIRCUIT RACEWAY
6	NON-CLASS IE	— — —
7	NON CLASS IE	PROXIMITY OF ITS RACEWAY TO ASSOCIATED CIRCUIT RACEWAY CONTAINING CABLE NO 5

Figure 2—Examples of Association by Proximity

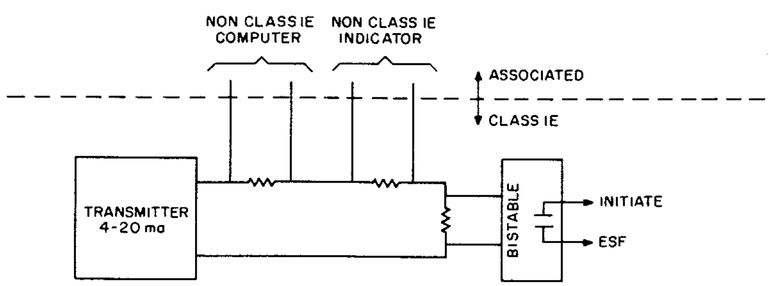

Figure 3—Association by Shared Signal Source

5.5.2 Criteria

Associated circuits shall comply with one of the following requirements:

1) They shall be uniquely identified as such or as Class 1E and shall remain with (traceable to the associated Class 1E division), or be physically separated the same as, those Class 1E circuits with which they are associated. They shall be subject to the requirements placed on Class 1E circuits, unless it can be demonstrated by analysis or testing that the absence of such requirements cannot degrade the Class 1E circuits below an acceptable level.

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2) They shall be in accordance with (1) above from the Class 1E equipment to and including an isolation device. Beyond the isolation device, such a circuit is non-Class 1E provided that it does not again become associated with a Class 1E system.
3) They shall be analyzed or tested to demonstrate that Class 1E circuits are not degraded below an acceptable level.

NOTE — Preferred power supply circuits from the transmission network and those similar power supply circuits from the unit generator that become associated circuits solely by their connection to the Class 1E distribution system input terminals are exempt from the requirements for associated circuits.

5.5.3 Qualification Requirements

Associated circuits, including their isolation devices or the connected loads without the isolation devices, shall be subject to the qualification requirements placed on Class 1E circuits to assure that the Class 1E circuits are not degraded below an acceptable level. Associated circuits need not be qualified for performance of function, since the function is non-Class 1E.

5.6 Non-Class 1E Circuits; General Criteria

The independence of non-Class 1E circuits from Class 1E circuits or associated circuits shall be achieved by complying with the following requirements:

1) Non-Class 1E circuits shall be physically separated from Class 1E circuits and associated circuits by the minimum separation requirements specified in 6.1.3, 6.1.4, 6.1.5, or 6.6, except as permitted in 5.6 (4), or the non-Class 1E circuits shall be associated circuits. (See Fig 2.)
2) Non-Class 1E circuits shall be electrically isolated from Class 1E circuits and associated circuits by the use of isolation devices, shielding, and wiring techniques or separation distance, except as permitted in 5.6 (4), or the non-Class 1E circuits shall be associated circuits. (See Fig 1.)
3) The effects of less than minimum separation or the absence of electrical isolation between the non-Class 1E circuits and the Class 1E circuits or associated circuits shall be analyzed to demonstrate that Class 1E circuits are not degraded below an acceptable level or the non-Class 1E circuits shall be associated circuits.
4) Non-Class 1E instrumentation signal and control circuits (see IEEE Std 690-1984 [14]) are not required to be physically separated or electrically isolated from associated circuits provided that (a) the non-Class 1E circuits are not routed with associated cables of a redundant division and (b) the non-Class 1E circuits are analyzed to demonstrate that Class 1E circuits are not degraded below an acceptable level. As part of the analysis, consideration shall be given to potential energy and identification of the circuits involved.

5.7 Mechanical Systems

Class 1E circuits shall be routed or protected so that failure of the mechanical equipment of one division cannot disable Class 1E circuits or equipment essential to the performance of the safety function by the systems of the redundant division(s). The effects of failure or misoperation of a mechanical system on its own division shall be considered when the Class 1E circuits or equipment are required to mitigate the consequences of such failure or misoperation. The effects of pipe whip, jet impingement, water spray, flooding, radiation, pressurization, elevated temperature, or humidity on redundant electrical systems caused by failure, misoperation, or operation of mechanical systems shall be considered. The potential hazard of missiles resulting from failure of rotating equipment or high energy systems shall be considered.

5.8 Structures and Equipment

Independence and redundance of required Class 1E systems shall be maintained during and subsequent to failure of structures and equipment not qualified for design basis events.

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5.9 Fire Protection Systems

In areas where redundant division equipment and circuits must be placed within the area of influence of a fixed fire protection system, the design of the equipment and circuits and the fire protection system shall be coordinated so that the independence of the Class 1E system will not be compromised.

5.10 Fire

5.10.1

An electrically generated fire in one Class 1E division shall not cause a loss of functions in its redundant Class 1E division.

5.10.2

The independence of redundant Class 1E circuits and equipment shall be such that a fire in a fire hazard area shall not prevent the capability to perform safety functions.

6. Specific Separation Criteria

6.1 Cables and Raceways

6.1.1 General

6.1.1.1 Classification of Areas

The areas through which Class 1E and associated circuits cables are routed and in which equipment is located shall be reviewed for the existence of potential hazards such as high energy piping, missiles, combustible material, ignition sources, and flooding. These areas shall be classified as follows:

1) Nonhazard areas (see 6.1.3).
2) Limited-hazard areas (see 6.1.4).
3) Hazard areas (see 6.1.5).

Separation commensurate with the damage potential of the hazard shall be provided for early in the design through the use of features such as separate rooms. Opposite sides of rooms or areas may be used provided that there is an adequate heat removal capability.

6.1.1.2 Minimum Separation Distances

The minimum separation distances specified in 6.1.3, 6.1.4, and 6.1.5 may be used to provide adequate physical separation if the following criteria are met:

1) All cables involved shall meet the fire propagation requirements of IEEE Std 383-1974 [9].
2) Exposed raceways other than conduit shall be noncombustible per ASTM E136-92 [7]. Exposed conduit shall meet the requirements of metallic conduit per IEEE Std 628-1987 [13].
3) Raceway fire stops through fire barriers shall have a fire-resistance rating commensurate with the fire hazards being protected against.
4) Open trays shall be as defined in NEMA VE 1-1991 [15] for ladder or trough-type.
5) Enclosed trays shall be solid-bottom-type as defined in NEMA VE 1-1991 [15] with a solid cover or open trays with solid top and bottom covers.

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These distances reflect the minimum acceptable for physical separation to maintain independence. Other considerations such as maintenance, cable pulling, and termination may require greater distances.

In 6.1.3, 6.1.4, and 6.1.5, separation distances are grouped into the following three categories:

1) Open to open: Includes open tray to open tray, open tray to free-air cable, and free-air cable to free-air cable configurations.
2) Enclosed to enclosed: Includes enclosed tray to enclosed tray, enclosed tray to conduit, and conduit to conduit configurations.
3) Enclosed to open: Includes enclosed tray to open tray, enclosed tray to free-air cable, conduit to open tray, and conduit to free-air cable configurations.

NOTE — For the purposes of this standard, conduit encompasses the following: rigid steel, rigid aluminum, electrical metallic tubing, flexible metal with or without coating, and intermediate metal.

If lesser separation distances are necessary they shall be established as in 6.1.1.3 to meet practical plant constraints.

6.1.1.3 Lesser Separation Distances

Lesser separation distances than those specified in 6.1.3, 6.1.4, and 6.1.5 can be established by analysis of the proposed cable installation. For lesser separation distances than those specified in 6.1.3 and 6.1.4, this analysis shall be based on tests performed to determine the flame retardant characteristics of the proposed cable installation considering features such as insulation and jacket materials, raceway fill, raceway types, and arrangements. For lesser separation distances than those specified in 6.1.5, the degree of hazards (such as size of the fire or pipe break) and mitigative measures (such as sprinklers) shall be considered.

6.1.2 Identification

Exposed Class 1E and associated circuit cable raceways shall be permanently marked in a distinct manner at intervals not to exceed 15 ft (4.5 m) and at points of entry to and exit from enclosed areas. Class 1E and associated circuit cable raceways shall be marked prior to the installation of their cables. Cables installed in these raceways shall be marked in a manner of sufficient durability and at intervals of approximately 5 ft (1.5 m) to facilitate initial verification that the installation is in conformance with the separation criteria. These cable markings shall be applied prior to or during installation.

Class 1E and associated circuit cables shall be identified by a permanent marker at each end in accordance with the design drawings or cable schedule.

The method of identification used to meet the above requirements shall readily distinguish between redundant Class 1E systems, between Class 1E and non-Class 1E systems, and between associated cables of different redundant Class 1E systems.

6.1.3 Nonhazard Area

The minimum separation distances used for these areas are based on hazards being limited to failures or faults internal to the electrical equipment or cables.

6.1.3.1 Area Designation

An area meeting the following requirements may be designated as a nonhazard area (previously called the cable spreading room).

1) The area shall not contain high energy equipment such as switchgear, transformers, rotating equipment, or potential sources of missiles or pipe failure hazards, or fire hazards.

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2) Circuits in the area shall be limited to control and instrument functions and those power supply circuit cables and equipment serving the equipment located within the area.
3) Power circuit cables in this area shall be installed in enclosed raceways.
4) Administrative control of operations and maintenance activities shall control and limit introduction of potential hazards into the area.

NOTE — Refer to IEEE Std 690-1984 [14] for definitions of power, control, and instrumentation cables.

6.1.3.2 Area Boundaries

1) The area shall be bounded by and separated from any other adjacent area by a fire barrier having a fire resistance rating commensurate with the fire hazard that can exist. In lieu of this, a 3-hour fire barrier shall be used. (See ANSI/NFPA 803-1988 [4] for fire barrier requirements and definitions.)
2) The area shall be bounded by and separated from any adjacent pipe hazard area or missile hazard area by a barrier capable of withstanding the design basis hazard at that location.

6.1.3.3 Routing Requirements

The minimum separation distances for circuits requiring separation per Section 5. are identified in Table 1.

Table 1—Minimum Separation Distances for Nonhazard Areas

Open to open configurations	1 in (2.5 cm) horizontal, 3 in (7.5 cm) vert.
Enclosed to enclosed configurations	1 in (2.5 cm) horizontal, 1 in (2.5 cm) vert.
Enclosed to open configurations	1 in (2.5 cm) horizontal, 3 in (7.5 cm) vert.*

*Vertical separation may be reduced to 1 in (2.5 cm) if the enclosed is below the open.

Examples of applications of these separation distances are shown in Fig 4.

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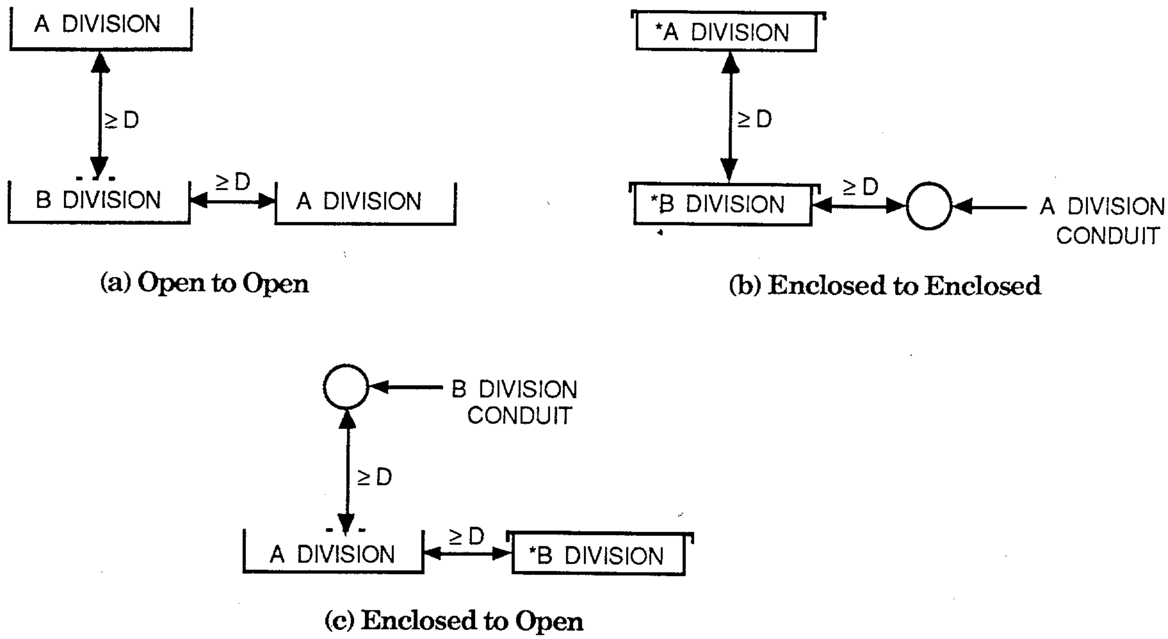

* = Solid bottom tray with cover.

D = Minimum separation distance (horizontal or vertical) (see 6.1.3 or 6.1.4).

NOTE: Horizontal separation is measured from the side rail of one tray to the side rail of the adjacent tray. Vertical separation is measured from the bottom of the top tray to the top of the side rail of the bottom tray. However, if the cables extend past the side rail, separation is measured to the closest cable.

Figure 4—Examples of Separation Distances

Where the above minimum separation distances cannot be maintained, barriers shall be provided between those circuits requiring separation. Figures 5, 6, and 7 illustrate examples of acceptable arrangements of barriers in which the minimum separation distance cannot be maintained.

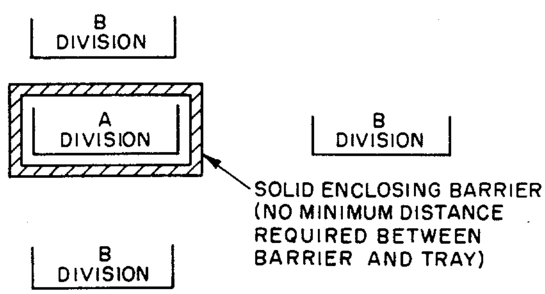

Figure 5—Example of Enclosing Barrier

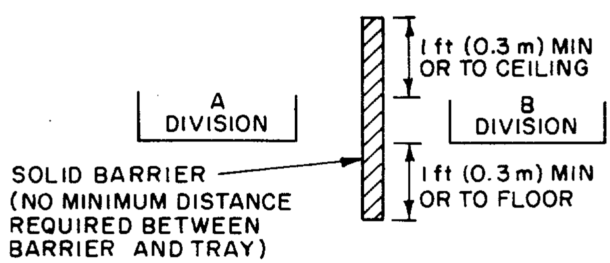

Figure 6—Example of Vertical Barrier

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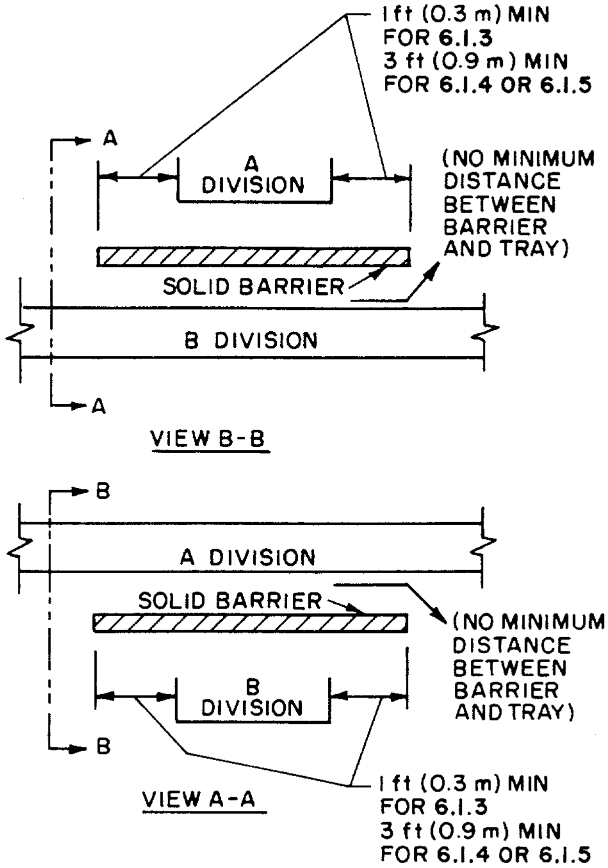

Figure 7—Example of Horizontal Barrier

6.1.4 Limited Hazard Areas

The minimum separation distances used for these areas are based on hazards being limited to failures or faults internal to the electrical equipment or cables. Limited hazard areas (previously called general plant areas) are those plant areas from which potential hazards such as missiles, non-electrically induced fires, and pipe failure are excluded.

NOTE — In both a limited hazard area and a nonhazard area, the only energy available to damage electrical circuits is that energy associated with failure or faults internal to electrical equipment or cables within the area. The primary difference between a limited hazard area and a nonhazard area is that power circuits and equipment are restricted in the nonhazard areas.

The minimum separation distances for circuits requiring separation per Section 5. are identified in Table 2. This table includes three columns that provide minimum distance requirements based on the types and sizes of the cables involved in each interaction.

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Table 2—Minimum Separation Distances for Limited Hazard Areas

	For interactions involving control and instrumentation cables only (same requirements as for nonhazard areas)	For interactions involving low-voltage power circuits with cables sizes ≤2/0 AWG	For interactions involving low-voltage power circuits with cable sizes > 2/0 AWG and all medium-voltage power circuits
Open to open configurations	1 in (2.5 cm) horizontal, 3 in (7.5 cm) vertical	6 in (15 cm) horizontal, 12 in (0.3 m) vertical	3 ft (0.9 m) horizontal, 5 ft (1.5 m) vertical
Enclosed to enclosed configurations	1 in (2.5 cm) horizontal, 1 in (2.5 cm) vertical	1 in (2.5 cm) horizontal, 1 in (2.5 cm) vertical	1 in (2.5 cm) horizontal, 1 in (2.5 cm) vertical
Enclosed to open configurations	1 in (2.5 cm) horizontal, 3 in (7.5 cm) vertical*	6 in (15 cm) horizontal, 12 in (0.3 m) vertical†	3 ft (0.9 m) horizontal, 5 ft (1.5 m) vertical

*Vertical separation may be reduced to 1 in (2.5 cm) if the enclosed is below the open.
†The minimum separation may be reduced to 1 in (2.5 cm) horizontal and 3 in (7.5 cm) vertical if the circuits in the open configuration are limited to control and instrumentation circuits.

Examples of applications of these separation distances are shown in Fig 4.

Where the minimum separation distances in Table 2 cannot be maintained, barriers shall be provided between those circuits requiring separation. Figures 5, 6, and 7 illustrate examples of acceptable arrangements of barriers in which the minimum separation distance cannot be maintained.

6.1.5 Hazard Areas

Independence of redundant Class 1E systems must be maintained at an acceptable level in hazard areas by cable routing restrictions or by a combination of special physical separation, as required by 6.1.6, 6.1.7, and 6.1.8.

The minimum distance between non-Class 1E circuits and Class 1E or associated circuits shall be as provided in 6.1.4.

6.1.6 Pipe Failure Hazard Areas

6.1.6.1 Area Designation

An area shall be designated a pipe failure hazard area if it contains piping normally operating at high or moderate energies. See ANSI/ANS 58.2-1988 [1].

For moderate energy piping, pipewhip and jet impingement need not be considered; however, the wetting and environmental effects must be considered.

6.1.6.2 Area Boundaries

Protection of nonhazard and limited hazard areas from pipe failure hazard areas shall be accomplished by the use of barriers, restraints, separation distance, or appropriate combination thereof.

6.1.6.3 Routing Requirements

The routing of Class 1E or associated circuit cables or raceways in pipe failure hazard areas shall conform to the following requirements, unless it can be demonstrated that pipe failure cannot prevent the Class 1E circuits and equipment from performing their safety function:

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1) Where the piping involved is qualified for design basis events, is not assignable to a single division, and the pipe failure requires no protective action; Class 1E or associated circuit cables or raceways routed through the area shall be limited to a single division.
2) Where the pipe failure requires protective action, Class 1E or associated circuit cables or raceways shall not be routed through the area except those cables (see NOTE) that must terminate at devices or loads within the area.

   NOTE — Special provisions (such as additional system redundancy or diversity) may be required for these cables to meet the single failure criteria.
3) Where the piping involved is qualified for design basis events, is assignable to a single division, and the pipe failure requires no protective action, Class 1E or associated circuit cables or raceways routed through the area shall be limited to the same division as the piping.
4) Where the piping involved is not qualified for design basis events, Class 1E or associated circuit cables or raceways shall not be located in the area, except for those cables that must terminate at devices or loads within the area.

   NOTE — Where Class 1E or associated circuit cables and raceways are routed in areas that have been classified as hazard areas due to nonqualified piping, they must be protected from the area by the methods specified in 6.1.6.2, or the piping involved must be qualified for design basis events.

6.1.7 Missile Hazard Areas

6.1.7.1 Area Designation

An area shall be designated a missile hazard area if it contains any missile source having sufficient kinetic energy under design basis event conditions to damage redundant Class 1E circuits routed through the area and separated as stated in 6.1.4.

6.1.7.2 Area Boundaries

Protection of nonhazard and limited hazard areas from missile hazard areas shall be accomplished by the use of barriers, orientation, separation distance, or appropriate combination thereof.

6.1.7.3 Routing Requirements

The routing of Class 1E or associated circuit cables or raceways through the area shall conform to the following requirements:

1) Where the missile source involved is qualified for design basis events, is not assignable to a single division, and the effect of the missile does not require protective action; Class 1E or associated cables or raceways routed through the area shall be limited to a single division.
2) Where the effect of the missile source involved requires protective action, Class 1E or associated circuit cables or raceways shall not be routed through the area, except those cables (see NOTE) that must terminate at devices or loads within the area.

   NOTE — Special provisions (such as additional redundancy or diversity) may be required for these cables to meet the single failure criteria.
3) Where the missile source involved is qualified for design basis events, is assignable to a single division, and the effect of the missile involved requires no protective action; Class 1E or associated circuit cables or raceways routed through the area shall be limited to the same division as the missile source.
4) Where the missile source involved is not qualified for design basis events, Class 1E or associated circuit cables or raceways shall not be routed in the area, except for those cables that must terminate at devices within the area.

   NOTE — Where Class 1E or associated circuit cables and raceways are routed in areas that have been classified as hazard areas due to nonqualified missile sources, they must be removed from that area by the methods in 6.1.7.2 or the missile source must be qualified for design basis events.

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6.1.8 Fire Hazard Areas

6.1.8.1 Area Designation

An area shall be designated a fire hazard area if it contains any of the following potential hazards:

1) Liquids which are classified as flammable or combustible per ANSI/NFPA 321-1987 [3].
2) Solids[7] exhibiting a flame spreading classification of 26 or higher per ASTM E84-91a [5].
3) Coatings exhibiting a flame spread classification of 50 or higher per ASTM E84-91a [5].

An area need not be designated a fire hazard area if administrative control provides suppression measures for temporary ignition source use or the introduction of the above hazards is temporary or limited to an acceptable quantity.

6.1.8.2 Area Boundaries

Protection of a nonhazard or limited hazard area from a fire hazard area shall be accomplished by the use of fire barriers or separation distance, or both, as follows: $SD + 17B \geq 50$ where SD is the separation distance from hazard to nonhazard and limited hazard areas in feet, and B is the fire barrier fire resistance rating per ASTM E119-88 [6] in hours (derived from ANSI/NFPA 80A-1987 [2]).

Lesser separation may be utilized if a test or analysis, taking into account the potential duration and intensity of the fire source, demonstrates that the effects of lesser separation do not degrade Class 1E circuits below an acceptable level.

6.1.8.3 Routing Requirements

The routing of Class 1E or associated circuit cables or raceways in fire hazard areas shall conform to the following requirements:

1) Where the fire hazard source involved is qualified for design basis events, is not assignable to a single division, and the fire requires no protective action; Class 1E or associated circuit cables or raceways routed through the area shall be limited to a single division.
2) Where the effect of the fire hazard requires protective action, Class 1E or associated circuit cables or raceways shall not be routed through the area, except those cables that must terminate at devices or loads within the area.

   NOTE — Special provisions (such as additional system redundancy or diversity) may be required for these cables to meet the single failure criteria.
3) Where the fire hazard source involved is qualified for design basis events, is assignable to a single division, and protective action is not required; Class 1E or associated circuit cables or raceways routed through the area shall be limited to the same division as the fire hazard.
4) Where the fire hazard source involved is not qualified for design basis events, Class 1E or associated circuit cables or raceways shall not be routed in the area except for those cables that must terminate at devices within the area.

   NOTE — Where Class 1E or associated circuit cables and raceways are routed in the areas that have been classified as hazard areas due to nonnuclear safety-related fire hazard sources, they must be protected from that area by the methods in 6.1.8.2.

6.2 Standby Power Supply

6.2.1 Standby Generating Units

Redundant Class 1E standby generating units shall be placed in separate safety class structures.

[7]Excluding cables.

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6.2.2 Auxiliaries and Local Controls

The auxiliaries and local controls for redundant standby generating units shall be located in the same safety class structure as the unit they serve or be physically separated in accordance with the requirements of Section 5..

6.3 DC System

6.3.1 Batteries

Redundant Class 1E batteries shall be placed in separate safety class structures.

6.3.2 Battery Chargers

Battery chargers for redundant Class 1E batteries shall be physically separated in accordance with the requirements of Section 5.

6.4 Distribution System

6.4.1 Switchgear

Redundant Class 1E distribution switchgear groups shall be physically separated in accordance with the requirements of Section 5..

6.4.2 Motor Control Centers

Redundant Class 1E motor control centers shall be physically separated in accordance with the requirements of Section 5.

6.4.3 Distribution Panels

Redundant Class 1E distribution panels shall be physically separated in accordance with the requirements of Section 5.

6.5 Containment Electrical Penetrations

Redundant Class 1E containment electrical penetrations shall be physically separated in accordance with the requirements of Section 5.. Compliance with Section 5. will generally require that redundant penetrations be widely dispersed around the circumference of the containment. The minimum physical separation for redundant penetrations shall meet the requirements for cables and raceways given in 6.1.4 and 6.1.5.

Non-Class 1E circuits routed in penetrations containing Class 1E circuits shall be treated as associated circuits in accordance with the requirements of 5.5.

6.6 Control Switchboards

6.6.1 Location and Arrangement

Main control switchboards shall be located in a non-hazard area within a safety class structure. Local control switchboards shall be located in accordance with 6.1.

Separation of redundant Class 1E equipment and circuits may be achieved by locating them on separate control switchboards physically separated in accordance with the requirements of 6.1. Where operational considerations

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dictate that redundant Class 1E or Class 1E and non-Class 1E equipment be located on a single control switchboard or cabinet, the requirements of 6.6.2, 6.6.3, 6.6.4, 6.6.5, and 6.6.6 shall apply.

6.6.2 Internal Separation

The minimum separation distance between circuits requiring separation per Section 5. that are internal to the control switchboards can be established by analysis of the proposed installation. This analysis shall be based on tests performed to determine the flame retardant characteristics of the wiring, wiring materials, equipment, and other materials internal to the control switchboard. Where the control switchboard materials are flame-retardant and analysis is not performed, the minimum horizontal separation distance shall be 1 in (2.5 cm) and the minimum vertical separation distance shall be 6 in (15 cm). The minimum vertical separation distance may be reduced to 1 in (2.5 cm) if the wiring is supported to ensure that under worst-case transient conditions:

1) Heating of non-Class 1E wires will not result in the wires sagging and touching Class 1E wires or components and
2) Heating of Class 1E wires will not result in the wires sagging and touching Class 1E wires or components in a redundant division.

An acceptable support method includes stainless steel ties and other metallic supports spaced every 6 in (15 cm) along the length of the wires.

In the event the above separation distances are not maintained, barriers shall be installed between circuits requiring separation.

6.6.3 Internal Wiring Identification

Class 1E wire bundles or cables internal to the control switchboards shall be identified in a distinct permanent manner at a sufficient number of points to readily distinguish between redundant Class 1E wiring and between Class 1E and non-Class 1E wiring.

For a control switchboard or compartment therein containing only Class 1E wiring of a single division, no distinctive identification is required.

6.6.4 Common Terminations

Where circuits requiring separation per Section 5. are terminated on a common device, the provisions of 6.6.2 shall be met.

6.6.5 Non-Class 1E Wiring

Non-Class 1E wiring, not separated from Class 1E or associated wiring by the minimum separation distance (determined in 6.6.2) or by a barrier, shall become associated circuits and shall be subject to the applicable requirements of 5.5.

NOTE — Refer to IEEE Std 420-1982 [10] for additional criteria regarding control switchboards.

6.6.6 Cable Entrance

Cables requiring separation per Section 5. entering the control switchboard enclosure shall meet the requirements of 6.1.

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6.7 Instrumentation Cabinets

Instruments requiring separation per Section 5. shall be located in separate cabinets or compartments of a cabinet complying with the requirements of 6.6.

Where the instruments requiring separation are located in separate compartments of a single cabinet, attention must be given to routing of external cables to the instruments to assure that cable separation is retained.

In locating Class 1E instrument cabinets, attention shall be given to the effects of all pertinent design basis events.

6.8 Sensors

Sensors requiring separation per Section 5. shall be independent and sufficiently separated that capability of the protection system will be maintained despite any single design basis event or result therefrom.

6.9 Actuated Equipment

Locations of Class 1E actuated equipment, such as pump drive motors and valve operating motors, are normally dictated by the location of the driven equipment. The resultant locations of this equipment must be reviewed to ensure that separation of actuated equipment is acceptable.

7. Specific Electrical Isolation Criteria

7.1 Power Circuits

7.1.1 General

Electrical isolation of power circuits shall be achieved by Class 1E isolation devices applied to interconnections of the following kinds of circuits (see Fig 1):

1) Non-Class 1E and Class 1E circuits
2) Associated circuits and non-Class 1E circuits

NOTE — Refer to IEEE Std 690-1984 [14] for a definition of power cables.

7.1.2 Isolation Devices

A device is considered to be a power circuit isolation device if it is applied such that the maximum credible voltage or current transient applied to the non-Class 1E side of the device will not degrade below an acceptable level the operation of the circuit on the other side of that device.

7.1.2.1 Circuit Breaker Tripped by Fault Currents

A circuit breaker automatically tripped by fault current is considered an isolation device, provided the following coordination criteria are met:

1) The breaker time-overcurrent trip characteristic for all circuit faults will cause the breaker to interrupt the fault current prior to initiation of a trip of any upstream breaker. Periodic testing shall demonstrate that the overall coordination scheme remains within the limits specified in the design criteria. This testing may be performed as a series of overlapping tests.

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2) The power source shall supply the necessary fault current for sufficient time to ensure the proper coordination without loss of function of Class 1E loads.

NOTE — For example, diesel generator excitation systems should be capable of providing the required transient current during faults.

7.1.2.2 Circuit Breaker Tripped by Accident Signals

A circuit breaker is considered an isolation device if it is automatically tripped by an accident signal generated within the same division as that to which the isolation device is applied provided that the time delay involved in generating the accident signal and tripping the breaker does not cause unacceptable degradation of the Class 1E power system.

7.1.2.3 Input Current Limiters

Devices that will limit the input current to an acceptable value under faulted conditions of the output are considered isolation devices. Periodic testing shall verify that the current-limiting characteristic has not been compromised or lost.

NOTE — Devices in this category may include inverters, regulating transformers, and battery chargers with current limiting characteristics.

7.1.2.4 Fuses

A fuse may be used as a power isolation device if the following criteria are met:

1) Fuses shall provide the design overcurrent protection capability for the life of the fuse.
2) The fuse time-overcurrent trip characteristic for all circuit faults shall cause the fuse to open prior to the initiation of an opening of any upstream interrupting device.
3) The power source shall supply the necessary fault current to ensure the proper coordination without loss of function of Class 1E loads.

NOTE — The effects of single-phasing shall be considered for three-phase ac circuits.

7.2 Instrumentation and Control Circuits

7.2.1 General

Electrical isolation methods shall be used as required in instrumentation and control circuits to maintain the independence of redundant circuits and equipment such that safety functions required during and following any design basis event can be accomplished. This electrical isolation of instrumentation and control circuits shall be achieved through the use of Class 1E isolation devices applied to interconnections of (a) Class 1E and non-Class 1E circuits, (b) associated circuits and non-Class 1E circuits, or (c) Class 1E logic circuits of redundant divisions as shown in Fig 8. Shielding and wiring techniques may also be necessary to achieve and maintain the independence of redundant circuits and equipment.

NOTE — Refer to IEEE Std 690-1984 [14] for definitions of control and instrumentation cables.

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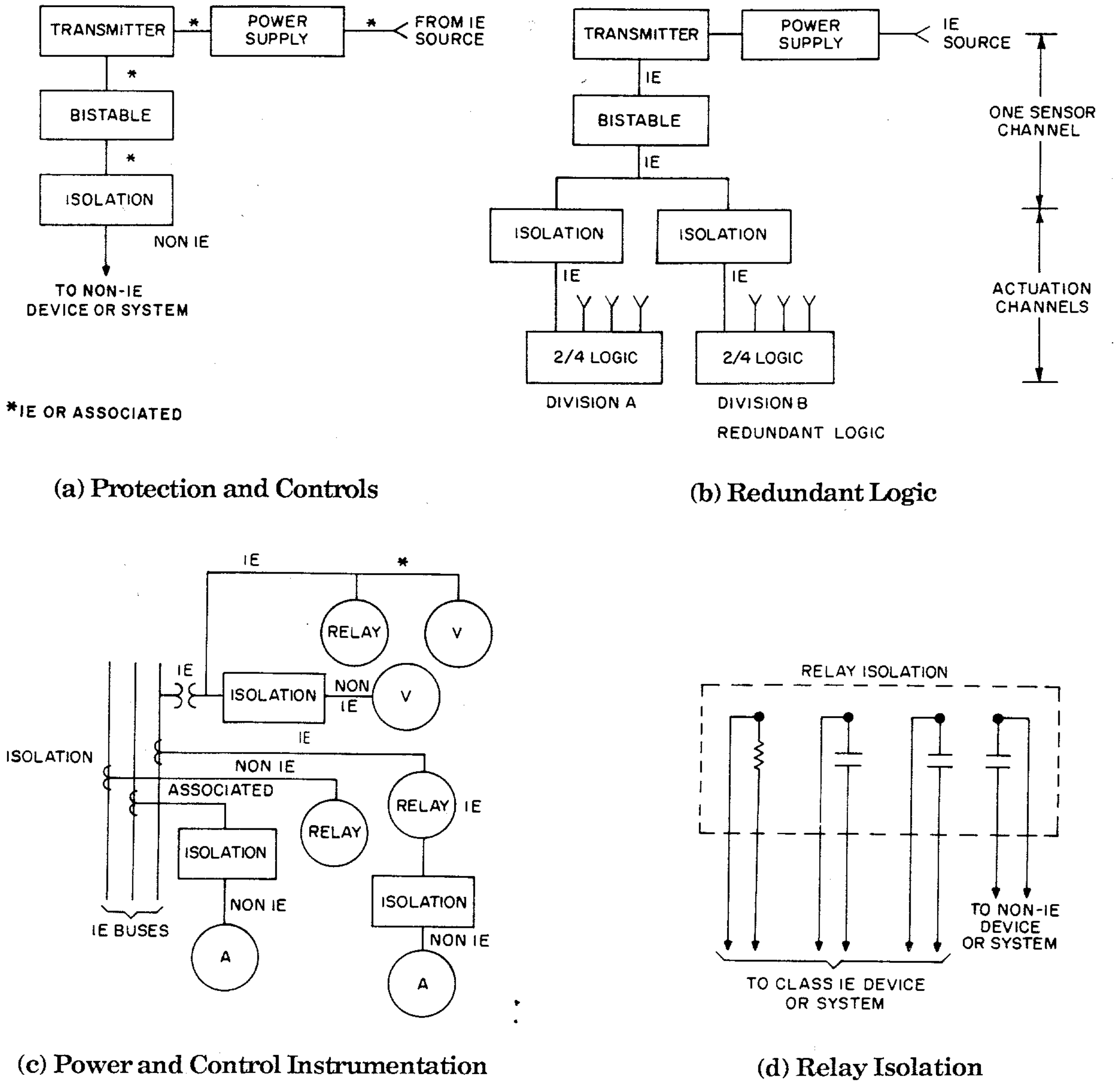

Figure 8—Examples of Isolation Device Application in Control and Instrumentation Circuits

7.2.2 Isolation Devices

7.2.2.1 General

A device is considered an electrical isolation device for instrumentation and control circuits if it is applied so that (a) the maximum credible voltage or current transient applied to the device's non-Class 1E side will not degrade the operation of the circuit connected to the device Class 1E or associated side below an acceptable level; and (b) shorts, grounds, or open circuits occurring in the non-Class 1E side will not degrade the circuit connected to the device Class 1E or associated side below an acceptable level.

The highest voltage to which the isolation device non-Class 1E side is exposed shall determine the minimum voltage level that the device shall withstand across the non-Class 1E side terminals, and between the non-Class 1E side terminals and ground. Transient voltages that may appear in the non-Class 1E side must also be considered.

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The separation of the wiring at the input and output terminals of the isolation device may be less than 1 in (2.5 cm) as required in 6.6.2 provided that it is not less than the distance between input and output terminals.

Minimum separation requirements do not apply for wiring and components within the isolation device; however, separation shall be provided wherever practicable.

The capability of the device to perform its isolation function shall be demonstrated by qualification test. The qualification shall consider the levels and duration of the fault current on the non-Class 1E side.

7.2.2.2 Acceptable Isolation Devices

When the requirements of 7.2.2.1 are met, the following devices may be used as acceptable isolation devices for instrumentation and control circuits:

1) Amplifiers
2) Control switches
3) Current transformers
4) Fiber optic couplers
5) Photo-optical couplers
6) Relays
7) Transducers
8) Power packs
9) Circuit breakers

NOTE — In using contact-to.contact isolation, consideration shall be given to the effect on independence that may occur from welding of contacts.

7.2.2.3 Fuses

When the requirements of 7.2.2.1 are met, a fuse may be used as an isolation device (except between redundant divisions) if the following additional criteria are met:

1) Fuses shall provide the design overcurrent protection capability for the life of the fuse.
2) The fuse time-overcurrent trip characteristic for all circuit faults shall cause the fuse to open prior to the initiation of an opening of any upstream interrupting device.
3) The power source shall supply the necessary fault current to ensure the proper coordination without loss of function of Class 1E loads.

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Annex A Relationship of Cable Testing Programs to IEEE Std 384-1992 (Informative)

(This appendix is not a part of IEEE Std 384-1992, IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits, but is included for information only.)

The separation criteria presented in this standard were developed by the IEEE Nuclear Power Engineering Committee Working Group Subcommittee (SC) 6.5 through the review of test programs conducted by various public utilities. These tests were conducted to address the issue of NRC Regulatory Guide 1.75 compliance during the construction of commercial nuclear power generating stations. These utility sponsored test programs used actual plant construction materials, simulated plant installations, and were conducted with actual plant fault current situations.

The typical test sequence was a four-step procedure. The first step was the measurement of electrical properties on the test cables to establish a baseline condition. The second step involved the heating of the cables with current until nominal plant operating temperatures were achieved on the conductors of the test specimens. The third step was the application of a long-term fault current to the fault cable that was intentionally placed in the worst possible physical location relative to the other cables. This current was allowed to flow until either the cable conductor fused open or indications of phase-to-phase short circuits occurred. In the latter case, the fault current was increased to short-circuit current level amperage, after which the fault cable open-circuited rapidly. The last step consisted of repeating the electrical parameter measurements and comparing the results to the baseline values. The test data included video tapes of the results, temperature data from multiple thermocouples mounted on the test setup, test currents, times of application of currents, still photographs, and electrical parameter test results. All test programs were documented in formal test reports which were used as the basis for licensing the affected plants.

Working Group SC 6.5 obtained permission from ten of the utilities to review the test data and to determine if a revision to the standard was warranted. The test data were separated into the categories in Section 6. of the standard and the results evaluated by the committee members. Additional test programs have been conducted beyond the ten reviewed by the Working Group. Although not released to the Working Group, the members are familiar with these test programs and feel that the additional data would further support the separation criteria in this standard.

The results of the data review effort were presented in a panel discussion at the IEEE Power Engineering Society (PES) Winter Meeting in 1988, and a technical paper was written and presented at the 1989 Winter PES Meeting. This technical paper ("Cable Separation—What Do Industry Testing Programs Show?" IEEE Reference Number 90 WM 254- 3EC) was published detailing the committee's data analysis and recommended separation distances.

This standard does not incorporate all of the recommendations in the technical paper. Specifically, cable wrapping systems and raceway crossing criteria are not used. Although test data exists on the use of cable wrapping materials to lessen the recommended separation distances, no specified recommendation on the use of these materials is included in this standard. The reason for this omission is that the test results vary widely with the type of material and application of the wrapping system to the cables. The use of cable wrapping is an acceptable method to reduce the separation distances but each wrapping system should be analyzed or tested on a case-by-case basis. Working Group SC 6.5 also did not incorporate the recommendations in the technical paper regarding raceway crossing configurations. The reason for this omission was to simplify the separation criteria. In addition, in some cases, Working Group SC 6.5 modified the separation criteria recommendations provided in the technical paper to be consistent with other areas of the standard and to add margin in areas where it was felt to be prudent.

Users of this standard should be aware that the testing program did not utilize medium voltage cables, and thus, the separation distances for these circuits were not revised.

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