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Std 384-1977)

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 Standards Board

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Foreword

(This Foreword is not a part of IEEE Std 384-1981, 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 1981 revision of IEEE Std 384-1977, Standard Criteria for Independence of Class 1E Equipment and Circuits, reflects an expansion in scope responsive to various expressed needs to address the following:

(1) Exposure fires (those caused by ignition sources external to the raceway) and their effects on the safe shutdown capability of the plant

(2) Associated circuits—more definitive explanation.

For item (1), a new Section 8 has been added to the standard. The working group has identified the underlying criteria for the separation of redundant circuits required for the safe shutdown of the plant. Generally, this separation is more stringent than that for other Class 1E circuits. American National Standard on Generic Requirements for Light Water Power Plant Fire Protection have been considered in these new requirements.

For consideration of the effect on safe shutdown circuits, the working group has taken the position that the fire can occur in any area of the plant (whether or not the area contains ignition sources or combustibles), with two notable exceptions:

(1) A fire in the containment is postulated only in those areas containing installed combustible liquids or material. It is not postulated in other areas of the containment, since the building is sealed during plant operation, except for limited access under strict administrative control, precluding the introduction of transient combustibles.

(2) A fire is not postulated in the control room, since this area is continuously occupied and conditions leading to fire would be detected and responded to quickly.

For the action item (2) above regarding associated circuits, Section 5 of this standard has been reworked. The working group has attempted to improve the presentation of associated circuits—their creation and criteria for the attached loads. New Figs 1, 2, and 3 are provided to illustrate the criteria.

Other sections of this standard have been reviewed, and many editorial improvements have been made. One rather substantive change has been made in the designation of areas in Section 6. Many concerns have been expressed to us and comments written regarding this area of the standard. Therefore, the following changes have been made to clarify the intent of the standard:

- | | |
|--|----------------------------|
| (1) Cable Spreading Room is now referred to as | Nonhazard Area |
| (2) General Plant Area is now called | Limited Hazard Area |
| (3) Hazard Area is still to be called | Hazard Area |

The Institute of Electrical and Electronics Engineers (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. Each applicant for a construction permit or an operating license for a nuclear power generating station in the United States is required to develop these items to comply with the Code of Federal Regulations, Title 10—Energy, Chapter I NRC (Parts 0-199).

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 the 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.

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 IEEE will maintain this standard current with the state of the technology. Comments are invited on this standard as well as suggestions for additional material that should be included in future revisions. These should be addressed to:

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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, including those required for safe shutdown. It sets forth criteria for the independence that can be achieved by physical separation and electrical isolation of circuits and equipment which are redundant but does not address the determination of what is to be considered redundant.

2. Purpose

This standard established the criteria for implementation of the independence requirements of IEEE Std 603-1980, [12]¹; ANSI/IEEE Std 279-1971 [3]; IEEE Std 308-1980 [9]. In addition, this standard provides interim criteria for implementation of independence requirements for safe shutdown systems.

3. 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 as defined in ANSI/IEEE Std 100-1977 [2].

auxiliary supporting features. Systems or components which provide services (such as cooling, lubrication, and energy supply) which 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.

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.

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.

exposure fire. Fire initiated by other than electrical means or supported by fuel other than cable insulation.

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 which prevents malfunctions in one section of a

¹The numbers in brackets correspond to the references listed in Section 4 of this standard.

circuit from causing unacceptable influences in other sections of the circuit or other circuits.

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 which 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.

4. References

4.1 Standards References

- [1] ANSI/ANS 59.4-1979, Generic Requirements for Light Water Nuclear Power Plant Fire Protection²
- [2] ANSI/IEEE Std 100-1977, IEEE Standard Dictionary of Electrical and Electronics Terms
- [3] ANSI/IEEE Std 279-1971, IEEE Standard Criteria for Protection Systems for Nuclear Power Generating Stations
- [4] ANSI/IEEE Std 383-1974, IEEE Standard for Type Test of Class 1E Electric Cables; Field Splices and Connections for Nuclear Power Generating Stations
- [5] ANSI/IEEE Std 494-1974, IEEE Standard Method for Identification of Documents Related to Class 1E Equipment and Systems for Nuclear Power Generating Stations

²ANSI documents are available from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

- [6] ASTM E 84-80, Test for Surface Burning Characteristics of Building Materials³
 - [7] ASTM E 119-80, Fire Tests of Building Construction and Materials
 - [8] ASTM E 136-79, Test for Behavior of Materials in a Vertical Tube Furnace at 750 °C
 - [9] IEEE Std 308-1980, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations
 - [10] IEEE Std 420-1973, IEEE Trial-Use Guide for Class 1E Control Switchboards for Nuclear Power Generating Stations
 - [11] IEEE Std 422-1977, IEEE Guide for the Design and Installation of Cable Systems in Power Generating Stations
 - [12] IEEE Std 603-1980, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations
 - [13] NEMA VE 1-1979, Cable Tray Systems⁴
 - [14] NFPA 80A-1976, Protection from Exposure Fires⁵
 - [15] NFPA 321-1976, Basic Classification of Flammable and Combustible Liquids
- 4.2 Applicable Document in Preparation⁶

5. General Independence Criteria

5.1 Required Independence. Physical separation and electrical isolation shall be provided to maintain the independence of Class 1E circuits

³ASTM documents are available from American Society for Testing and Materials, 1916 Race St, Philadelphia, Pa 19103

⁴NEMA documents are available from the National Electrical Manufacturers Association (NEMA), 2101 L. Street, N W, Washington, DC 20037.

⁵NFPA documents are published by the National Fire Protection Association, 470 Atlantic Avenue, Boston, Mass 02210. Copies are available from the Sales department of American National Standards Institute, 1430 Broadway, New York, NY 10018.

⁶When the following document is completed, approved, and published it will become part of the reference Section.

Design Basis for Protection of Light Water Nuclear Power Plants Against Effects of Postulated Pipe Rupture (ANSI/ANS 58.2).

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 ANSI/IEEE Std 494-1974 [5] for guidance in identification.)

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 or the non-Class 1E cable being in an enclosed raceway. (See Fig 2.)

(4) Proximity to associated circuits and equipment without the required physical separation or barriers or the non-Class 1E cable being in an enclosed raceway. (See Fig 2.)

(5) Sharing a Class 1E or associated signal source without the use of an isolation device. (See Figs 3 and 8.)

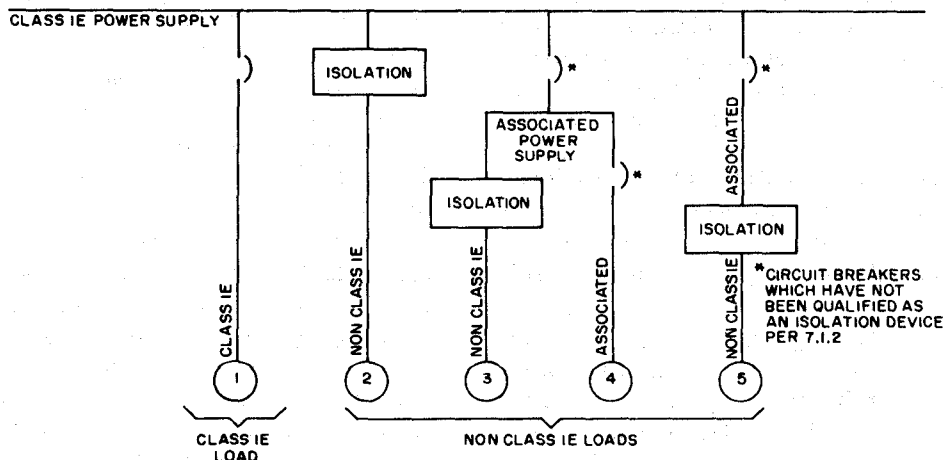
5.5.2 Criteria. Associated circuits shall comply with one of the following requirements:

(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.

(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 not subject to the requirements of this standard 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.

Fig 1
Examples of Association by Connection and Application of Isolation Devices



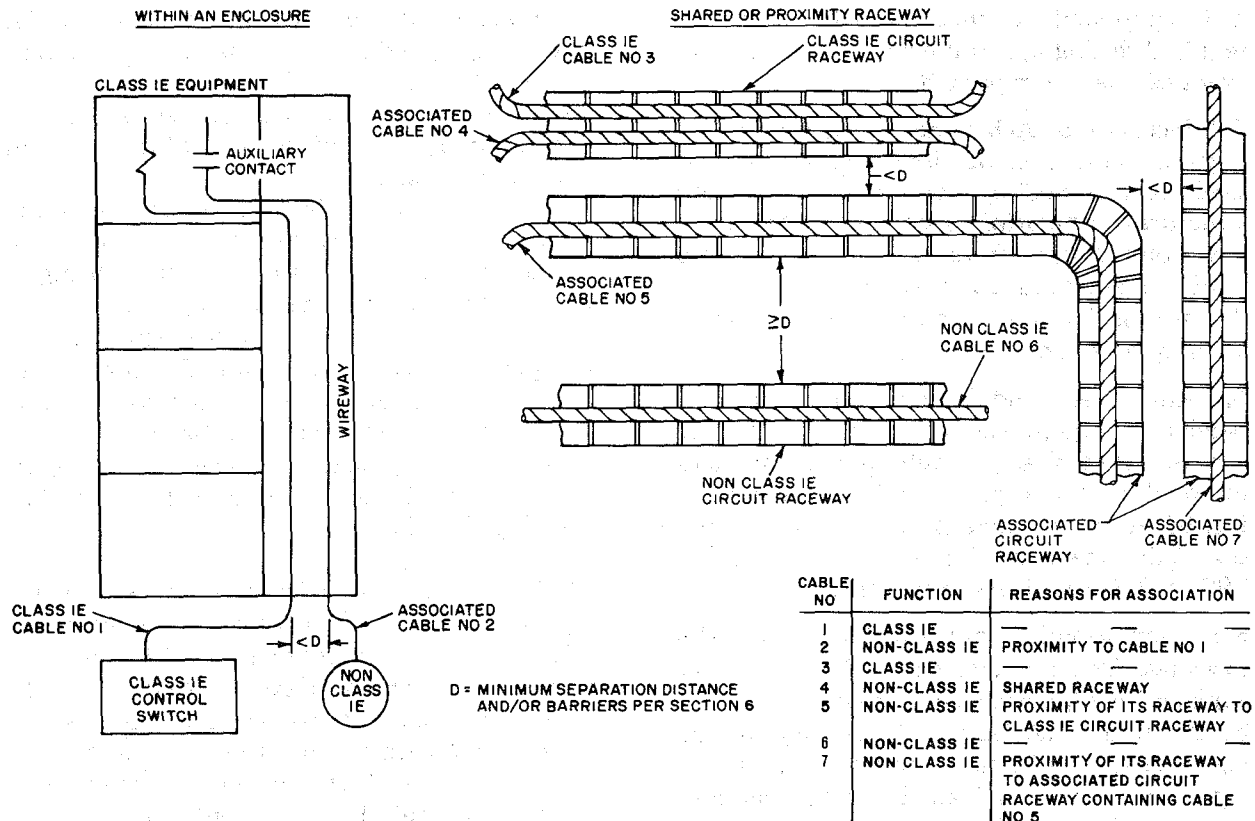


Fig 2
Examples of Association by Proximity

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 5.6.1 (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 5.6.1 (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 low level instrumentation signal and control circuits (see IEEE Std 422-1977 [11]) 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 Class 1E circuits are analyzed to demonstrate that

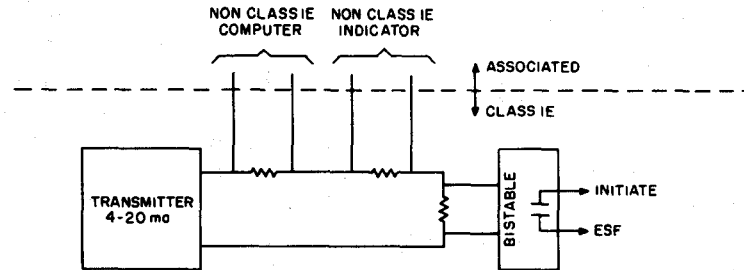


Fig 3
Association by Shared Signal Source

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

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.

5.10.3 The independence of Class 1E safe shutdown circuits and equipment shall be such that postulated exposure fires shall not prevent the capability to achieve and maintain safe shutdown conditions.

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 are based on open ventilated cable trays of either the ladder or the trough types as defined in NEMA VE 1-1979 [13]. These distances 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 ANSI/IEEE Std 383-1974 [4]

(2) Exposed raceways shall be noncombustible per ASTM E 136-79 [8]

(3) Raceway fire stops through fire barriers shall have a fire resistance rating commensurate with the fire hazards being protected against

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.

(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 422-1977 [11] 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/ANS 59.4-79 [1] 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

(1) The minimum separation distance between cable trays containing circuits requiring separation per Section 5 shall be 1 ft (0.3 m) between trays separated horizontally and 3 ft (0.9 m) between trays separated vertically.

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.

(2) Where termination arrangements preclude maintaining the minimum separation distance, the circuits requiring separation per Section 5 shall be run in enclosed raceways or barriers shall be provided between those circuits. The minimum distance between these enclosed raceways shall be 1 in (25mm). Figures 4 through 7 illustrate examples of acceptable arrangements of barriers and trays where

the minimum separation distance cannot be maintained.

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, exposure fires, and pipe whip are excluded. The minimum separation distance between cable trays containing circuits requiring separation per Section 5 shall be 3 ft (0.9 m) between trays separated horizontally and 5 ft (1.5 m) between trays separated vertically.

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.

Where the plant arrangements preclude maintaining the minimum separation distance, the circuits requiring separation shall be run in enclosed raceways, or barriers shall be provided between circuits. The minimum distance between these enclosed raceways shall be 1 in (2.5 cm). Figures 4 through 7 illustrate examples of acceptable arrangements of barriers and trays where 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 circuit cable trays and Class 1E or associated

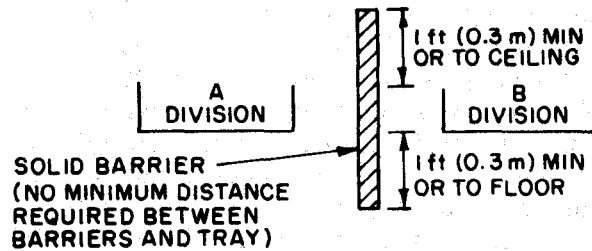


Fig 5
Example of Vertical Barrier

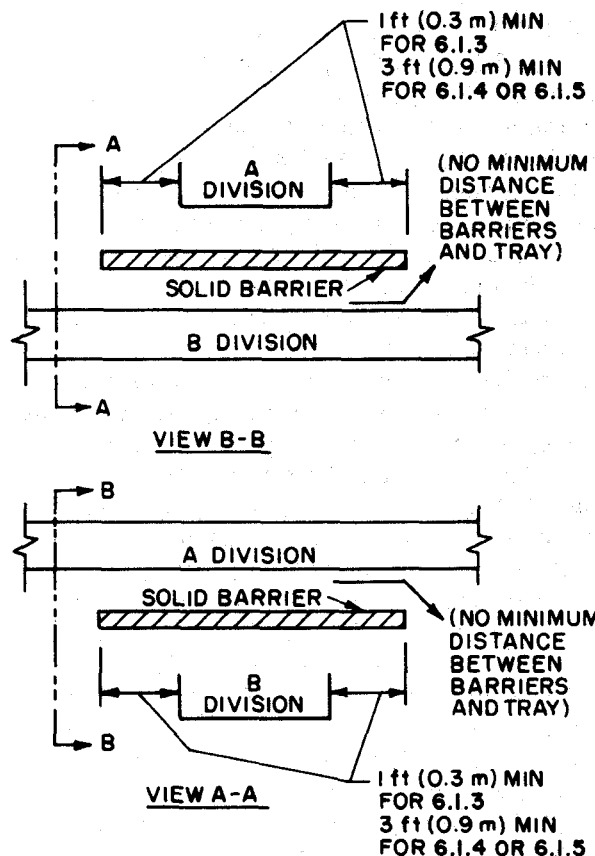


Fig 6
Example of Horizontal Barrier

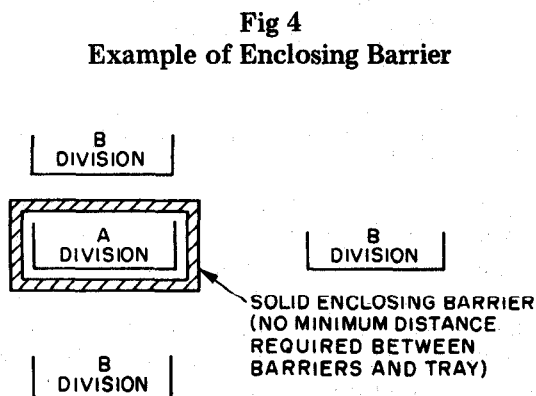


Fig 4
Example of Enclosing Barrier

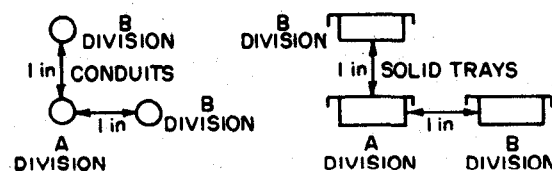


Fig 7
Example of Enclosed Raceway Separation

circuit cable trays shall be 3 ft (0.9 m) between trays separated horizontally and 5 ft (1.5 m) between trays separated vertically. Where the plant arrangements preclude maintaining this minimum distance, the circuits requiring separation shall be run in enclosed raceways or barriers shall be provided between these circuits. The minimum distance between these enclosed raceways shall be 1 in (2.5 cm). Figures 4 through 7 illustrate examples of acceptable arrangements of barriers and trays where the minimum separation distance cannot be maintained.

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 4.2.

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 non-hazard 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:

(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) which 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 which 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 non-hazard 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) which 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 which 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.

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 NFPA 321-1976 [15].

(2) Solids⁷ exhibiting a flame spreading classification of 26 or higher per ASTM E 84-80 [6].

(3) Coatings exhibiting a flame spread classification of 50 or higher per ASTM E 84-80 [6].

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 non-hazard 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 non-hazard and limited hazard areas in feet, and B is the fire barrier fire resistance rating per ASTM E 119-80 [7] in hours (derived from NFPA 80A-1976 [14]).

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:

⁷ Excluding cables

(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 which 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 which 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.

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 6.1.4. Where operational considerations 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 redundant Class 1E equipment and wiring 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 separation distance shall

be 6 in (0.15 cm). In the event the above separation distances are not maintained, barriers shall be installed between redundant Class 1E equipment and wiring.

6.6.3 Internal Wiring Identification. Class 1E wire bundles or cables internal to the control boards 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 cabinet or compartment containing only Class 1E wiring of a single division, no distinctive identification is required.

6.6.4 Common Terminations. Where redundant Class 1E wiring is 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 420-1973 [10] for additional criteria regarding control switchboards.

6.6.6 Cable Entrance. Redundant Class 1E cable entering the control board enclosure shall meet the requirements of 6.1.3.

6.7 Instrumentation Cabinets. Redundant Class 1E instruments shall be located in separate cabinets or compartments of a cabinet complying with the requirements of 6.6.

Where the redundant Class 1E instruments 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 and Sensor to Process Connections. Redundant Class 1E sensors and their connections to the process system shall be independent and sufficiently separated that capability of the protection system will be maintained despite any single design basis event or result therefrom. If a protective function is required for a design basis event, the remaining equipment not damaged by the event must meet the single failure criterion. Consideration shall be given to secondary effects of design

basis events such as pipe whip, steam release, radiation, missiles, or flooding.

Large components such as the reactor vessel can be considered a suitable barrier if the sensor to process connecting lines are brought out at widely divergent points and routed so as to keep the component between the redundant lines. Redundant pressure taps located on opposite sides of a large pipe may be considered to be separated by the pipe, but the lines leaving the taps must be protected against damage from a credible common cause unless other redundant or diverse instrumentation not vulnerable to damage from the same cause is provided. The power supply divisional assignment shall be consistent with that of the sensors to assure the maintenance of sensor independence.

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 redundant Class 1E 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 422-1977 [11] 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.

(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 which 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.

7.2 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 422-1977 [11] for definitions of control and instrumentation cables.

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 between input and output terminals and from these terminals to ground. Transient voltages that may appear in the non-Class 1E side must also be considered.

The separation of the wiring at the input and output terminals of the isolation device may be less than 6 in (0.15 m) 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) Each fuse shall be tested (for example, resistance measurement) to verify overcurrent protection as designed

(2) Fuses shall provide the design overcurrent protection capability for the life of the fuse

(3) 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

(4) The power source shall supply the necessary fault current to ensure the proper coordination without loss of function of Class 1E loads.

8. Class 1E Safe Shutdown Circuits and Equipment

8.1 General. Class 1E safe shutdown circuits and equipment shall comply with requirements of previous sections of this standard and the following additional requirements.

The independence of redundant Class 1E safe shutdown equipment and circuits shall be maintained for postulated exposure fires.

8.2 Postulated Exposure Fires

8.2.1 A single exposure fire shall be postulated in those areas of the plant (excluding main control room) which contain cables or equipment necessary to provide shutdown capability in the event of fire.

This applies regardless whether or not the area contains ignition sources or combustible materials. Therefore in consideration of safe shutdown systems, exposure fires are postulated in more areas than only those defined in 6.1.8 as fire hazard areas.

However, in the containment a single exposure fire shall be postulated only in those areas designated fire hazard areas per 6.1.8.

8.2.2 Exposure fires shall not be postulated concurrent with non-fire related failures in safety systems, accidents (for example, LOCA) or natural phenomena (for example, earthquakes, tornado).

8.3 Separation Criteria

8.3.1 Redundant Class 1E equipment and

circuits required for safe shutdown, except those in containment and control room, shall be separated from each other by a 3-hour fire barrier.

8.3.2 Redundant Class 1E equipment and circuits required for safe shutdown and located in containment shall be separated from each other per 6.1.4 or 6.1.5, as applicable.

8.3.3 Redundant Class 1E circuits and equip-

ment required for safe shutdown located in the main control room shall be separated from each other per 6.1.3.3 and 6.6.2.

8.3.4 Lesser separation may be used if test or analysis, taking into consideration the duration and intensity of the fire source, demonstrates that the effects of lesser separation do not degrade the Class 1E safe shutdown circuits and equipment below an acceptable level.

Fig 8
Examples of Isolation Device Application
In Control and Instrumentation Circuits
(a) Protection and Controls. (b) Redundant Logic
(c) Power and Control Instrumentation. (d) Relay Isolation

