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IEEE Std 497™

Criteria for accident monitoring instrumentation for nuclear power generating stations

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Contents

CRITERIA FOR ACCIDENT MONITORING INSTRUMENTATION FOR NUCLEAR POWER GENERATING STATIONS

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The text of this standard is based on the following documents:

IEEE Std	FDIS	Report on voting
IEEE Std 497™-2016	45A/1167/FDIS	45A/1170/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

When applied in an IEC / IAEA environment this standard is to be used in conjunction with IEC TR 63123:2017, Nuclear power plants – Instrumentation, control and electrical power systems – Guidance for the application of IEC 63147:2017 / IEEE 497-2016 in the IEC / IAEA framework.

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IEEE Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations

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Nuclear Power Engineering Committee
of the
IEEE Power and Energy Society

Approved 15 May 2016

IEEE-SA Standards Board

Abstract: Established in this standard are criteria for variable selection, performance, design, and qualification of accident monitoring instrumentation for anticipated operational, design basis events and severe accidents.

Keywords: accident monitoring, design criteria, display criteria, IEEE 497™, performance criteria, selection criteria, severe accidents, type variables

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IEEE Introduction

This introduction is not part of IEEE Std 497™-2016, IEEE Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations.

History

This standard evolved from IEEE Std 497™-2010 [B4][1]. It represents a continued effort by IEEE to support the specification, design, and implementation of accident monitoring instrumentation of nuclear power generating stations.

IEEE Std 497-2010 [B4] was developed to provide criteria for advanced instrumentation system designs and design modifications based on modern digital technology. It marked a clear path forward for the application of new technology. Though still maintaining applicability to existing systems, this version of IEEE Std 497 provides more current guidance based on historically related standards and guidance.

It was the working group's intention that the criteria of this standard address the variety of possible accident monitoring channel configurations that current technology affords. It was also the working group's intention to address the display of information using computer generated displays and calculated values. The criteria presented in this standard provide guidance in this area without limiting the types of displays that can be made available to accident management personnel.

Although written primarily for new plant designs, existing plants may also use the guidance and applicable criteria in this standard. The use of applicable plant procedures to determine the requirements of the accident monitoring instrumentation provides the necessary flexibility for useful design criteria. This standard can be used to help address the necessary changes to the plant configuration that occur over the operating life of any plant.

Historically the standard addressed accident monitoring instrumentation used for anticipated operating occurrences (AOOs) and design basis events (DBEs). To address lessons learned from various industry events, the scope of this standard has evolved to now include severe accidents. This evolution was intended to provide a broader applicability to cover both preventative and mitigative phases of potential plant events. A broader applicability of the standard was also achieved by moving to a more international, technology neutral approach to the standard. This approach was achieved by changing to International Atomic Energy Agency (IAEA) definitions of terms, where applicable; the removal, where appropriate, of U.S. specific references; and involvement in the working group of members of other standards organizations. Furthermore, the corresponding International Electrotechnical Commission (IEC) counterparts to the IEEE standards referenced were investigated and introduced as a second set of normative references. This opens the possibility to apply this standard in the IEC domain. The individual IEEE and IEC reference sets in whole are individually appropriate for use in the application of the standard, but inclusion of the IEEE and IEC references does not imply equivalency between the individual references of the two sets.

Intended use

The standard applies to instrumentation intended for use during anticipated operational occurrences (AOO), design basis events (DBE), and design extension conditions (DEC) including severe accidents.

This standard defines severe accidents as a subset of design extension conditions during which fuel damage has occurred. Operationally, severe accidents and design extension conditions without fuel damage are

[1] The numbers in brackets correspond to those of the bibliography in Annex D.

distinguished by the procedures and guidelines used to manage the event, with emergency operating procedures (EOP) used for design extension conditions without fuel damage and severe accident mitigation guidelines (SAMG) used for severe accidents (see Annex C).

The standard is to be applied to instruments designated for severe accidents (Type F variables); however, use of non-designated instruments during a severe accident is not precluded if these instruments are available and can aid in the accident mitigation. Design extension conditions that are not severe accidents are not covered by this standard.

This standard is intended to be used for both new plant designs and major modifications or upgrades of existing nuclear power generating stations. The standard can be applied to various reactor types used for power generation; however, development of the standard focused on light water reactors and application of the standard to reactor technologies beyond light water reactors should be evaluated prior to initial use.

Revision summary

Since IEEE Std 497 was approved in 2010, industry events have occurred that highlighted the need for the standard to address not just design basis events but severe accidents as well. The working group has considered and incorporated appropriate changes related to the following significant items:

— Lessons learned from industry events including Fukushima (earthquake and tsunami), Browns Ferry (tornado), Salem (loss of RPS due to CCF), and North Anna (earthquake)

— Accident monitoring instrument requirements based on emergency procedures and guidelines (EOPs and SAMGs)

— Reactor technology neutral approach

— International usability

— User feedback

— Requirements for severe accidents instrumentation

— IAEA definitions

Other minor editorial improvements throughout the standard were also incorporated.

Future work

As the use of digital technology in the nuclear plant is a dynamic area of design, the working group intends to keep this area as an ongoing future task.

Since no counterpart to this standard exists in the IEC domain, this standard was identified as a potential candidate for a dual-logo standard to be applied in both the IEEE and the IEC domain early in the course of this revision. A joint group of both organizations identified topics and aspects to be harmonized and recommended to proceed. Thus the recent revision was performed with the intent and the spirit to prepare and facilitate the application for the IEC domain. Formal involvement of the IEC was delayed. This revision of the standard is, therefore, still an IEEE standard, but may be further modified in the future after closer investigation by and discussion with IEC experts on its potential as a dual-logo standard.

Another area that the working group believes should be considered in a future revision to the standard is how to adopt risk-informed techniques into accident monitoring criteria.

Additionally, user feedback related to the implementation of the standard on non-light water reactors and implementation of Type F variables will be reviewed and considered for a future revision.

Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations

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1. Overview

1.1 Scope

This standard contains the functional and design criteria for accident monitoring instrumentation for new plant designs and nuclear power generating stations desiring to perform design modifications.

1.2 Purpose

The purpose of this standard is to establish selection, design, performance, qualification, and display criteria for accident monitoring instrumentation for anticipated operational occurrences, design basis events, and severe accidents.

1.3 Application

This standard applies to accident monitoring instrumentation intended for use during the following operations:

— As required for planned operator action related to accident mitigation

— For assessing plant conditions, safety system performance, and making decisions related to plant response to abnormal events

— For achieving and maintaining safe shutdown following an accident

This standard does not apply to the following:

— Accident monitoring instrumentation that is intended solely for historical recording or solely for maintenance purposes

— Other instrumentation that may be available during accident conditions

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

2.1 Normative references for IEEE domain

ASME NQA-1-2008, Quality Assurance Requirements for Nuclear Facility Applications.[2]

IEEE Std 7-4.3.2™-2016, IEEE Standard Criteria for Programmable Digital Devices in Safety Systems of Nuclear Power Generating Stations.[3,4]

IEEE Std 308™-2012, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations.

IEEE Std 323™-2003, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.

IEEE Std 344™-2013, IEEE Standard for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.

IEEE Std 352™-1987, IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Stations.

IEEE Std 379™-2014, IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems.

IEEE Std 384™-2008, IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits.

IEEE Std 577™-2012, IEEE Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Power Generating Stations.

IEEE Std 603™-2009, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations.

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2.2 Normative references for IEC domain

IAEA GS-R-3:2006, The Management System for Facilities and Activities.[5]

IEC 60880:2006, Nuclear power plants—Instrumentation and control systems important to safety—Software aspects for computer-based systems performing category A functions.[6]

IEC 61225:2005, Nuclear power plants—Instrumentation and control systems important to safety—Requirements for electrical supplies.

IEC 60780:1998, Nuclear power plants—Electrical equipment of the safety system—Qualification.

IEC 60980:1989, Recommended practices for seismic qualification of electrical equipment of the safety system for nuclear generating stations.

IEC 60812:2008, Analysis techniques for system reliability—Procedure for failure mode and effects analysis (FMEA).

IEC 62340:2007, Nuclear power plants—Instrumentation and control systems important to safety—Requirements for coping with common cause failure (CCF).

IEC 60709:2004, Nuclear power plants—Instrumentation and control systems important to safety—Separation.

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.[7]

accident analysis licensing basis: The portions of the licensing basis documentation that describe the design basis events (including anticipated operational occurrences), the thermal-hydraulic response of the nuclear power generating station, and the subsequent response of the safety systems.

accident management personnel: The personnel authorized to make command and control decisions during an accident.

accuracy: A measure of the degree by which the actual output of a device approximates the output of an ideal device nominally performing the same function.

anticipated operational occurrence (AOO): An operational process deviating from normal operation which is expected to occur at least once during the operating lifetime of a facility but which, in view of appropriate design provisions, does not cause any significant damage to items important to safety or lead to accident conditions.

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

[5] IAEA publications are available from the International Atomic Energy Agency, Vienna International Centre, PO Box 100, A-1400 Vienna, Austria

[6] IEC publication are available from the International Electrotechncial Commission, 3, rue de Varembe, PO Box 131, CH-1211 Geneva 20, Switzerland

[7] *IEEE Standards Dictionary Online* subscription is available at: http://ieeexplore.ieee.org/xpls/dictionary.jsp.

common cause failure: Failure of two or more structures, systems, or components due to a shared root cause.

contingency actions: Alternative actions taken to address unexpected responses of the plant or conditions beyond its licensing basis (e.g., actions taken for multiple equipment failures).

current value: That magnitude of a variable that is associated with the present time and is available for display within the response time limits of an information display channel.

design basis event (DBE): Postulated events specified by the safety analysis for the station to establish the acceptable performance requirements of the structures and systems.

design extension conditions (DEC): Postulated accident conditions that are not considered for design basis accidents, but that are considered in the design process of the facility in accordance with best estimate methodology, and for which releases of radioactive material are kept within acceptable regulatory limits.

NOTE—Design extension conditions include conditions in events without significant fuel degradation and conditions with core melting. Severe accidents are included in design extension conditions.[8]

display channel: An arrangement of electrical and mechanical components or modules, or both, from the measured process variable to the display device as required to sense, process, and display conditions within the nuclear power generating station.

NOTE—See Figure 1.

display segment: The electrical components or modules in an information display channel that receive the processing electronics output and process the signal for input to the applicable display device, such as a video display unit (VDU) or indicator (IND). The display segment may include data validation algorithms, storage of digital display graphics, and analog or digital display devices.

NOTE—See Figure 1.

instrument channel range: The region between the limits within which a quantity is measured, received, or transmitted and is expressed by stating the lower and upper instrument channel range value.

isolation device: 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.

licensing basis documentation (LBD): The set of regulatory requirements applicable to a specific nuclear power generating station and a licensee's written commitments for complying with and operation within applicable regulatory requirements and the plant specific licensing basis (including all modifications and additions to such commitments over the life of the license) that are documented and in effect.

The LBD may include the following:

— The latest version of the Safety Analysis Report (SAR)
— Safety Evaluation Reports (SER)
— Operating license including the technical specifications, final design certification
— Correspondence between the regulator and the licensee that contains licensing requirements or commitments for the design or operation of the nuclear power generating station or standard plant design

[8] Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

power sources: The electrical and mechanical equipment and their interconnections necessary to generate or convert power.

NOTE—Power source and power supply are considered interchangeable in this standard.

precision: The degree of mutual agreement between individual measurements, namely repeatability and reproducibility.

processing segment: The electrical components or modules in an information display channel that receive the sensing segment outputs and perform various conversions and compensation on the sensed signal. The processing electronics may include sensor power supply, analog-to-digital (A/D) conversion, signal compensation, signal validation, electrical to engineering unit conversion, digital-to-analog (D/A) conversion, and electrical isolation devices for signal interfacing between safety systems and other systems.

NOTE—See Figure 1

rate: The first time derivative of the current value.

response time: Duration between the instant of a step change in the measured quantity and the instant when the output signal reaches for the first time a specified percentage of its final value.

safe shutdown: Bringing the nuclear generating station to controlled stable shutdown conditions specified in licensing basis documentation.

safety function: One of the processes or conditions essential to maintain plant parameters within acceptable limits established for a design basis event.

NOTE—A safety function is achieved by the completion of all required protective actions by the reactor trip system or the engineered safety features concurrent with the completion of all required protective actions by the auxiliary supporting features, or both.

safety system: A system relied upon to remain functional during and following design basis events to ensure: **(A)** the integrity of the reactor coolant pressure boundary; **(B)** the capability to shut down the reactor and **(C)** maintain it in a safe shutdown condition, or the capability to prevent or mitigate the consequences of accidents that could result in potential off-site exposures beyond applicable regulatory limits.

sensing segment: The electrical and mechanical components or modules in an information display channel from measured process variable to the input of the processing electronics.

NOTE—See Figure 1.

sensor: The portion of a channel that responds to changes in a plant variable or condition and converts the measured process variable into a corresponding signal.

severe accident: A subset of design extension conditions during which fuel damage has occurred.

spatially dedicated continuously visible: Characteristic of a human system interface that always appears in the same fixed location and is always visible.

trend: The general tendency of the current value (i.e., increasing, constant, or decreasing) over time.

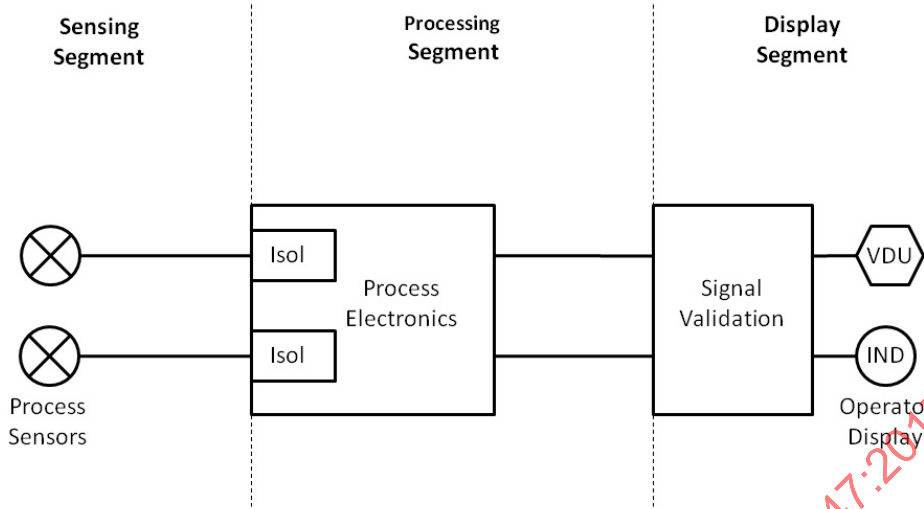

Figure 1—Display channel example

4. Selection criteria

This clause provides criteria for identifying the plant-specific variables for accident monitoring. The variable types shall be referred to as Type A, Type B, Type C, Type D, Type E, and Type F. Criteria for the selection of each type of variable are given below and summarized in Table 1. If a variable meets the selection criteria of multiple variable types, the requirements of all the selected variable types shall be met.

4.1 Type A variables

Type A variables shall be those variables that provide the primary information required to permit the operating staff to:

a) Take specific planned manually-controlled actions for which no automatic control is provided and that are required for safety systems to perform their safety functions as assumed in the plant accident analysis licensing basis.

b) Take specific planned manually-controlled actions for which no automatic control is provided and that are required to mitigate the consequences of an anticipated operational occurrence (AOO) as assumed in the plant accident analysis licensing basis.

Type A variables provide information essential for the direct accomplishment of specific safety functions that require manual action during design basis events (DBEs). These variables are a subset of those necessary to implement the plant specific emergency procedure guidelines (EPGs), the plant specific emergency operating procedures (EOPs), or the plant abnormal operating procedures (AOPs). Type A variables do not include those variables that are associated with contingency actions that may also be identified in written procedures. Use of a variable as an entry condition for an EOP, EPG, or AOP does not by itself require it to be a Type A variable.

4.2 Type B variables

Type B variables shall be those variables that provide primary information to the accident management personnel to assess the plant safety functions. These are accomplishing or maintaining the following:

— Reactivity control
— Core cooling
— Reactor coolant system integrity
— Containment integrity (including radioactive effluent control)

Any plant safety function addressed in the EPGs or the plant specific EOPs that are in addition to those identified above shall also be included.

The Type B variables shall be those necessary to implement the plant functional restoration EPGs, plant specific EOPs, and the plant critical safety function status trees, if applicable.

4.3 Type C variables

Type C variables shall be those variables that provide primary information to the accident management personnel to indicate the potential for breach or the actual breach of fission product barriers (e.g., fuel cladding, reactor coolant system pressure boundary, and containment pressure boundary).

The selection of these variables represents a minimum set of plant variables that provide the most direct indication of the integrity of fission product barriers and provide the capability for monitoring beyond the normal operating range.

4.4 Type D variables

Type D variables shall be those variables that provide primary information to the accident management personnel and are required in the plant's procedures and licensing basis documentation (LBD) to:

a) Indicate the performance of those safety systems and auxiliary supporting features necessary for the mitigation of DBEs.

b) Indicate the performance of other systems and auxiliary supporting features necessary to achieve and maintain a safe shutdown condition.

c) Verify safety system status.

The Type D variables shall be based upon the plant accident analysis licensing basis and those necessary to implement the following procedures (as applicable to the plant design):

— Event specific EPGs or EOPs (plant specific)
— Functional restoration EPGs or EOPs (plant specific)
— Plant AOPs

4.5 Type E variables

Type E variables shall be those variables that provide primary information to the accident management personnel and are required for use in determining the magnitude of the release of radioactive materials and continually assessing such releases.

The selection of these variables shall include, but not be limited to, the following:

a) Monitoring the magnitude of releases of radioactive materials through identified pathways (e.g., secondary safety valves and condenser air ejector).

b) Monitoring the environmental conditions used to determine the impact of releases of radioactive materials through identified pathways (e.g., wind speed, wind direction, and air temperatures).

c) Monitoring radiation levels and radioactivity in the plant environs.

d) Monitoring radiation levels and radioactivity in the control room and selected plant areas where access may be required for plant recovery.

4.6 Type F variables

Type F variables shall be those variables that provide primary information to accident management personnel to indicate fuel damage and the effects of fuel damage.

The selection of these variables represents a minimum set of plant variables that provides the most direct indication of the parameters needed to execute the severe accident mitigation guidelines (SAMGs) and/or variables needed to mitigate those accidents postulated in a plants severe accident analysis.

4.7 Documentation of selection criteria

Documentation shall be developed and maintained for the selection bases of the accident monitoring variables consistent with the plant LBD.

Table 1—Summary of accident monitoring variable types/source documents

Referenced subclause in standard	Selection criteria for the variable type	Potential source documents
4.1	Type A —Planned manually controlled actions for accomplishment of safety functions for which there is no automatic control	—Plant accident analysis licensing basis —EPGs or plant specific EOPs —Plant AOPs
4.2	Type B —Assess the process of accomplishing or maintaining plant safety functions	—Functional restoration EPGs —Plant specific EOPs —Plant critical safety function status trees
4.3	Type C —Indicate potential for a breach of fission product barriers —Indicate an actual breach of fission product barriers	—Plant accident analysis licensing basis —Design basis documentation for the fission product barriers —EPGs or plant specific EOPs
4.4	Type D —Indicate performance of safety systems —Indicate the performance of required auxiliary support features —Indicate the performance of other systems	—Plant accident analysis licensing basis —Event specific EPGs or EOPs (plant specific) —Functional restoration EPGs or EOPs (plant specific) —Plant AOPs

Referenced subclause in standard	Selection criteria for the variable type	Potential source documents
	necessary to achieve and maintain a safe shutdown condition —Verify safety system status	
4.5	Type E —Monitor the magnitude of releases of radioactive materials through identified pathways —Monitor the environmental conditions used to determine the impact of releases of radioactive materials through identified pathways —Monitor radiation levels and radioactivity in the plant environs —Monitor radiation and radioactivity levels in the control room and selected plant areas where access may be required for plant recovery	—Procedures for determining radiological releases through plant identified pathways —Procedures for determining the impact of the release of radioactive materials —Procedures for determining plant environs radiological concentration —Procedures for determining plant habitability
4.6	Type F —Indicate fuel damage —Monitor the direct effects (e.g., combustible gases concentration, radiation, pressure, or temperature of fuel damage)	—Plant SAMGs —Plant severe accident analysis

5. Performance criteria

5.1 Range

The range of a monitoring channel shall be established to cover the accidents identified in the plant LBD.

The ranges for Type C variables shall encompass those limits that would indicate a breach in a fission product barrier. These variables shall have extended ranges and address a source term that considers fuel damage. For example, measurement of reactor pressure shall include the capability of measuring, with margin, up to Level D service limits of the reactor vessel (see ASME Boiler and Pressure Vessel Code, an American National Standard [B3]).

The ranges for Type F variables shall encompass those limits that would result from fuel damage. These variables shall have extended ranges and address a source term that considers fuel damage.

5.2 Accuracy

The required accuracy of accident monitoring instrument channels shall be established based on the assigned function. See Annex A for useful guidance.

5.3 Response time

Accident monitoring instruments shall be designed to provide real time and timely information. Typically, the displayed information will lag behind actual conditions because of sensor location, thermal heat transfer time lag, information processing cycle times, degree of severity of environmental conditions, and other potential effects on instrument response times.

In general, these response times may not be as critical as in the case when the instrument provides a signal for automatic reactor protection system or engineered safeguard system action.

For some displays, the indicated variable will additionally lag real time conditions depending on the update frequency of the display. The update frequency shall be fast enough to avoid the potential of misleading the information recipient with respect to plant conditions within human factors guidelines.

5.4 Required operating time

The required operating time for each variable shall be defined as follows:

a) The required operating time for Type A variable instrument channels shall be the duration for which the measured variable is required by the plant's LBD.

b) The required operating time for Type B variable instrument channels shall be at least the duration associated with the longest-duration design basis event for that variable.

c) The required operating time for Type C variable instrument channels shall be the duration for which the measured variable is required by the plant's LBD or at least 100 days.

d) The required operating time for Type D variable instrument channels shall be the duration for which the measured variable is required by the plant's LBD.

e) The required operating time for Type E variable instrument channels shall be the duration for which the measured variable is required by the plant's LBD.

f) The required operating time for Type F variable instrument channels shall be sufficient to implement mitigation guidance based on the longest duration analyzed severe accident event in addition to any design basis event that may precede it.

A shorter operating time may be acceptable if equipment replacement or repair can be accomplished within an acceptable out-of-service time, taking into consideration the location and accessibility of the equipment during the event and during the recovery from the event.

5.5 Reliability

For those systems for which reliability goals have been established, appropriate analysis of the design shall be performed to confirm that such goals have been achieved. IEEE Std 352-1987/IEC 60812:2008 provides guidance for performing the reliability analysis and IEEE Std 577-2012 provides reliability analysis requirements.

5.6 Documentation of performance criteria

An assessment for each of the performance criteria shall be conducted. This assessment shall be done to confirm the as-designed performance meets or exceeds the performance criteria. The results of this assessment shall be documented and shall consider:

a) Allowances for calibration uncertainties, loop errors, and drift (consistent with the methodology given in ANSI/ISA Std 67.04.01-2006 [B2]).

b) The magnitude and direction of errors imposed on the accident monitoring instrumentation by environmental and/or seismic conditions during and after the postulated event.

6. Design criteria

6.1 Single failure

Accident monitoring instrument channels for Type A, Type B, and Type C variables shall satisfy the single failure requirements of IEEE Std 379-2014/IEC 62340:2007.

The accident monitoring instrumentation shall be capable of providing the information required for the accident management personnel to perform their role in bringing the plant to, and maintaining it in, a safe shutdown condition during an accident in the presence of the following:

a) Any single detectable failure within the accident monitoring instrumentation concurrent with identifiable but non-detectable failures.

b) Failures occurring as a result of the single failure.

c) Failures and spurious system actions that cause or are caused by the accident requiring the accident monitoring function.

Any systems or components that provide services (e.g., cooling, illumination, and energy supply) that are required by the accident monitoring instrumentation to perform their function shall be included in the single failure analysis of the accident monitoring instrumentation they support.

Systems required to meet the single failure criterion of this clause are not required to meet the single failure criterion during channel maintenance, test, or calibration provided the duration of such testing satisfies the applicable requirements of the plant's LBD. For example, the time interval required for a test, calibration, or maintenance operation could be shown to be so short that it would have an insignificant effect on overall availability of the accident monitoring instrumentation system.

6.2 Common cause failure

Design of Type A, Type B, and Type C instrumentation shall address common cause failures, as described in IEEE Std 379-2014 and IEEE Std 603-2009/IEC 62340:2007 consistent with the plant's LBD. For instrumentation using digital devices, guidance to address common cause failures can be found in IEEE Std 7-4.3.2-2015/IEC 60880:2006.

6.3 Independence and physical separation

The accident monitoring instrument channels for Type A, Type B, and Type C variables shall be independent and physically separated in accordance with the following criteria:

a) Instrumentation shall be physically separated from non-safety system equipment and circuits so that a failure in, or spurious action by, non-safety system equipment and circuits shall not prevent the accident monitoring equipment from meeting the requirements of this standard.

b) Redundant segments shall be independent of, and physically separated from, each other to the degree necessary to retain the capability of accomplishing the accident monitoring function during and following any design basis event requiring that function. This shall also include data communication independence requirements of IEEE Std 7-4.3.2-2015/IEC 60880:2006.

c) Accident monitoring equipment required to monitor a specific design basis event should be independent of, and physically separated from, the effects of the design basis event in order to retain the capability to meet the requirements of this standard.

d) Independence and physical separation shall meet the requirements of IEEE Std 384-2008/IEC 60709:2004.

The accident monitoring instrument channels for Type F variables should be independent of and physically separated from, the effects of the severe accident in order to retain the capability to meet the requirements of this standard. Where redundant or diverse channels are provided, they shall be isolated and separated from each other to the degree necessary to perform its function.

These requirements do not preclude the association of accident monitoring instrument channels with safety system channels, provided this association does not compromise the ability of the safety system channel to meet the applicable safety system requirements or the ability of the accident monitoring instrument channels to meet the requirements of this standard.

Independence and physical separation shall meet the applicable guidance on electromagnetic compatibility (EMC).

6.4 Isolation

For Type A, Type B, Type C, and Type F variables, the transmission of signals between accident monitoring instrumentation and any system not meeting the minimum design requirements for the variable type shall be through isolation devices. These isolation devices shall be classified as part of the accident monitoring instrumentation and shall meet the requirements of this standard. No credible failure external to the accident monitoring instrumentation shall be transmitted through the isolation device in such a way as to prevent the accident monitoring channel from meeting the performance requirements. A failure of an isolation device is evaluated in the same manner as a failure of other equipment in the accident monitoring instrumentation. Isolation devices shall meet the requirements of IEEE Std 384-2008/IEC 60709:2004.

6.5 Information ambiguity

For Type A, Type B, and Type C variables, the failure of an accident monitoring instrument channel shall not result in information ambiguity that could lead the accident management personnel to defeat or fail to accomplish a required safety function (e.g., the redundant displays disagree and the accident management personnel cannot readily deduce which channel has failed). If analysis shows that credible failures can result in information ambiguity, measures to resolve the ambiguity shall be provided. If measures to resolve the ambiguity cannot be automatically accomplished, additional information shall be provided to allow the accident management personnel to deduce the actual conditions so that they may properly perform their role.

Examples of how this may be accomplished are as follows:

a) Having the capabilities of being able to perturb the measured variable and determine which channel has failed by observing the instrument channel.

b) Cross checking the value with an independent channel that monitors a different variable that bears a known relationship to the instrument channel.

c) Providing an additional independent channel of instrumentation.

6.6 Power supply

The electrical power supplies for accident monitoring instrumentation shall be considered an auxiliary supporting feature. Instrumentation that monitors Type A, Type B, and Type C variables shall be powered by safety electrical power systems. Each instrumentation channel power supply shall be designed to be continuously available during plant accidents unless short interruptions are evaluated and found acceptable in the plant's LBD.

If an interruption in power is not tolerable, a continuously available source of power shall be used for Type D, Type E, and Type F variables. For Type F variables, a separate stand-alone power supply protected from common-cause events shall be available. This stand-alone power supply shall be in addition to and independent from the design basis power supplies.

Instruments that obtain their power from the process, such as potential transformers, current transformers, and some instruments in a two-wire instrument loop, shall be exempted from this requirement.

The power supplies for the accident monitoring instrument channels shall be capable of providing power with the necessary voltage, frequency, and duration to allow the accident monitoring channels to perform with the required accuracy and reliability. Power supplies shall be designed to prevent transients that would adversely impact a monitoring channel from performing its required function or the monitoring channel's accuracy.

Where safety system power supplies are used, refer to IEEE Std 308™-2012/IEC 61225:2005 for the applicable requirements.

6.7 Calibration

Capability shall be provided for calibration of each accident monitoring instrument channel during normal plant power or shutdown operation or both as determined by the required interval between calibrations.

Means shall be provided for validating instrument calibration during the accident. One or more of the following may accomplish this:

— Recalibration
— Selection of a calibration interval so that the accident duration shall fall within the specified equipment calibration interval
— Selection of equipment that does not require periodic calibration
— Cross-calibration with other channels that bear a known relationship to the information display channel

6.8 Testability

Accident monitoring instrument channels shall have testing capability to verify, on a periodic basis during normal operation, operability requirements in accordance with the plant's LBD. The periodic test shall follow a predetermined method, and results shall be documented.

Capability shall be provided for testing the operability of each accident monitoring instrument channel during normal and accident states. Examples of how this may be accomplished include the following:

a) By observing the effect of perturbing the monitored variable

b) By observing the effect of introducing and varying, as appropriate, a substitute input to the sensor of the same nature as the measured variable

c) By cross checking between channels that bear a known relationship to each other

d) By automatic on-line diagnostics of channel availability

6.9 Direct measurement

A direct variable should be selected to monitor the related function. A less direct variable may be substituted for the most direct variable if justified by analysis. The analysis shall account for misinterpretation of the less direct variable as well as availability of reliable instrumentation for the more direct variables.

6.10 Control of access

The design shall facilitate control of access to instrument channel calibration adjustments, test points, and controls used to remove an accident monitoring channel from service. Access control shall be maintained by administrative means.

6.11 Maintenance and repair

Accident monitoring instrumentation shall be designed to facilitate maintenance, repair, and adjustment. Consideration shall be given to potential inaccessibility during the accident in determination of equipment selection and location.

6.12 Minimizing measurements

The same variables and displays should be used for accident monitoring as are used for normal operation of the plant to enable the accident management personnel to use, during an accident situation, variables and displays with which they are most familiar.

6.13 Auxiliary supporting features

Systems or components that provide services that are required for the accident monitoring instrumentation to accomplish its functions shall meet the applicable requirements of that instrumentation. Auxiliary supporting features for accident monitoring instrumentation are part of the related display channel and shall meet applicable criteria.

For example, a cabinet cooling fan required to maintain signal conditioning modules within design temperature range is an auxiliary supporting feature.

Other components, equipment, and systems that perform a function that is not required for the accident monitoring instrumentation to provide required information to the accident management personnel, and are part of the accident monitoring instrumentation by association (that is, not isolated from the accident monitoring instrumentation) shall be designed so that these components, equipment, and systems do not degrade the capability of the accident monitoring instrumentation to function.

6.14 Portable instruments

When required for accident management, portable instruments may be used to obtain data. In such cases, the instruments, the means of delivering data to the recipient, and the means of analyzing data to obtain information, or any part of these three, shall be considered part of the accident monitoring channels. The equipment that forms part of this accident monitoring instrumentation shall meet the criteria for the applicable variable type.

6.15 Documentation of design criteria

Documentation shall be developed and maintained for the design criteria for the accident monitoring variables.

7. Qualification criteria

The requirements for equipment qualification (seismic and environmental qualification) of accident monitoring instruments shall be consistent with the assigned function of that variable during and following a design basis event, severe accident, or following a seismic event.

7.1 Type A variables

Instrument channels that are required for a planned manually-controlled operator action as a result of a seismic event, either directly or indirectly, shall be seismically qualified. These instrument channels shall be seismically qualified in accordance with IEEE Std 344-2013/IEC 60980:1989.

Instrument channels required for planned manually-controlled operator action to terminate or mitigate an accident shall be environmentally qualified for that accident's postulated environment at the installed location in accordance with the plant's LBD and IEEE Std 323-2003/IEC 60780:1998.

7.2 Type B variables

These instrument channels shall be seismically qualified in accordance with IEEE Std 344-2013/ IEC 60980:1989.

Instrument channels shall be environmentally qualified for the worst-case postulated accident environment at the installed location of the equipment in accordance with the plant's LBD and IEEE Std 323-2003/ IEC 60780:1998. Environmental qualification of instrument channels shall consider performance testing to the maximum process conditions while subjected to the worst-case postulated accident environment.

7.3 Type C variables

These instrument channels shall be seismically qualified in accordance with IEEE Std 344-2013/ IEC 60980:1989.

Instrument channels shall be environmentally qualified for the worst-case postulated accident environment at the installed location of the equipment in accordance with the plant's LBD and IEEE Std 323-2003/ IEC 60780:1998. In addition, environmental qualification of instrument channels shall consider performance testing to the full range of the instrument channels while subjected to worst-case postulated harsh environmental conditions in accordance with the plant's LBD.

NOTE—The above environmental qualification requirements for extended range instrument channels does not account for steady-state elevated levels that may occur in other environmental parameters associated with the extended range. Since extended ranges are non-mechanistically determined, extension of associated environmental parameter levels is not justifiable and has, therefore, not been required. Confidence that the equipment would continue to provide information if conditions degrade beyond those design basis events postulated in the safety analysis is provided by addressing the extended range requirements. Proof of performance that instrumentation provides information to the accident management personnel for severe accident mitigation may be done by analysis.

7.4 Type D variables

Instrument channels that monitor systems that are expected to be operable following a seismic event shall be seismically qualified in accordance with IEEE Std 344-2013/IEC 60980:1989.

Instrument channels shall be environmentally qualified for the particular accident's postulated environment at the installed location in accordance with the plant's LBD and in accordance with IEEE Std 323-2003/IEC 60780:1998.

7.5 Type E variables

These instrument channels are not required to be environmentally or seismically qualified.

If an instrument channel that is used to determine the magnitude of a radiological release meets the selection criteria of Type A, Type B, Type C, or Type D, then that instrument channel shall meet the qualification requirements for that particular type of variable.

7.6 Type F variables

Instrument channels shall be type tested to the anticipated severe accident environmental conditions. Type testing may be done sequentially.

If during testing the required test conditions are not reached due to test equipment limits, and the tested equipment does not experience a failure, then a survivability analysis shall be performed for the anticipated severe accident conditions.

The survivability analysis shall determine the constraints for the reliable use of the instrument data, and these constraints shall be provided to the end user.

7.7 Portable instruments

Portable instruments are excluded from seismic qualification requirements. Administrative controls of storage and access to portable instruments shall meet the performance requirements of the instrument. Storage locations shall provide protection from the effects of the event for which the portable instrument is to be used.

7.8 Operating time

Accident monitoring instrumentation shall be qualified, as a minimum, for the length of time its function is required (see 5.4).

Type F variables may have a qualified operating time shorter than the length of time its function may be required for the severe accident, but at a minimum as long as the design basis accident that may precede the severe accident. Shorter operating times for Type F variables shall be documented to support the evaluation of the constraints for the reliable use.

7.9 Documentation of qualification criteria

The basis for the qualification criteria for the accident monitoring instrumentation channels shall be documented as part of the equipment qualification program.

8. Display criteria

8.1 Display characteristics

8.1.1 Information characteristics

The basis for display characteristics for accident monitoring variables shall include the results of an analysis of the system functions required to respond to an accident and analysis of the tasks required of the accident management personnel to implement those functions. Display characteristics shall be identified that include, as a minimum; range, instrument accuracy, precision, display format (e.g., status, value, or trend), units, and response time, consistent with the performance characteristics of Clause 5.

8.1.2 Human factors

Accident monitoring displays shall be designed through application of accepted human factors, methods, and principles.

8.1.3 Anomalous indications

The design of accident monitoring instrumentation shall not cause indications on meters, annunciators, recorders, or video display units to give anomalous readings, which can mislead or confuse operators and accident management personnel.

8.1.4 Continuous vs. on-demand display

At least one of the redundant display segments for Type A and Type B accident monitoring variables shall be a spatially dedicated continuously visible display of either a validated digital display or a dedicated analog display.

Other redundant displays for Type A and Type B accident monitoring variables and displays for other accident monitoring variables may be accessible on demand.

8.2 Trend or rate information

For Type A variables where immediate trend or rate information is essential for operator action, the trend information shall be continuously available on dedicated trend displays (with corresponding recording device) and selectively available on another redundant trend display (with corresponding recording device). Both the dedicated and redundant displays shall have the capability of providing at least 30 min of data.

For Type B, Type C, Type D, Type E, and Type F variables where trend and rate information is essential, the display shall have the capability of providing sufficient trend or rate information as determined by the use of the variable.

8.3 Display identification

Control room indication of Type A, Type B, and Type C variables shall be uniquely identified as accident monitoring variables with a characteristic designation so that the accident management personnel can easily discern information intended for use under accident conditions. On a multi-variable video display containing both accident monitoring and non-accident monitoring variables, the accident monitoring variables shall be uniquely identified within the display.

Type D and Type E variables do not require unique identification.

Type F variables shall be uniquely identified as severe accident variables.

8.4 Type of monitoring channel display

Monitoring channel displays may use several configurations to provide the display channel information to the accident management personnel (see Annex B).

8.5 Display location

Control room indication of accident monitoring variables should be placed in appropriate function or system related locations. The basis for display locations should include functional task analysis results and accepted human factors principles.

The same displays used for normal plant operation should be used for the on-demand accident monitoring displays.

Type F variables shall be displayed in locations used for command and control during implementation of the severe accident mitigation guidelines.

8.6 Information ambiguity

Displays provided for the sole purpose of resolving information ambiguity are not required to be of the same type and are not required to be continuously displayed.

8.7 Recording

Recording shall be provided for at least one channel of each Type A, Type B, and Type C variable. Recording shall also be provided for Type E variables. For Type F variables recording shall be provided when trend information is necessary.

For Type A, Type B, Type C, and Type E variables, accident monitoring data records shall be continuously updated, stored (by digital or analog means), and accessible on-demand. Recording may be performed using non-safety related recording devices that do not fully meet the requirements given in IEEE Std 7-4.3.2-2015/IEC 60880:2006. Recording capability shall be provided for at least 30 min pre-event and 12 h post-event.

Recording capability for Type F variables shall be provided sufficient to implement the severe accident mitigation guidelines and at a minimum as long as the operating time (see 5.4) associated with the instrument channel.

8.8 Digital display signal validation

Signal validation may use channels that monitor the same variable but may not be designated as accident monitoring channels, or different variables with a known relationship to the displayed variable. This provides accident management personnel with credible information if the validation result is consistent with corresponding accident monitoring instrument channels. If signal validation is used, the validity of the indication shall be provided as part of the display, for example, through use of unique color coding.

8.9 Documentation of display criteria

Documentation shall be developed and maintained for the display criteria for the accident monitoring variables.

9. Quality assurance

Accident monitoring instrumentation for Type A, Type B, and Type C variables shall be designed, manufactured, inspected, installed, operated, and maintained under a quality program that meets the requirements of ASME NQA-1-2008/IAEA GS-R-3:2006. The level of quality assurance to be applied to accident monitoring instrumentation for Type D, Type E, and Type F variables shall be selected and documented by the designer to meet the specified requirements of the standard.

Digital device-based instrumentation development including software validation and verification shall be in accordance with the requirements of IEEE Std 7-4.3.2-2015/IEC 60880:2006 for Type A, Type B, and Type C.

Annex A

(informative)

Accident monitoring instrument channel accuracy

A.1 Introduction

As stated in 5.2, the required accuracy of an accident monitoring instrument channel is established based on the channel's assigned function.

A.2 Accuracy requirement groupings according to usage

In general, accident monitoring instrument variables fall into one or both of the following groups according to how the displayed function is to be used by control room personnel.

The first group consists of those variables where the corresponding channel accuracy is specified in the plant's licensing basis documentation (LBD). Typically, a tight (narrow band) accuracy will have been established to enable timely operator action.

The second group consists of those variables that provide trend or plant stability information (i.e., it is of primary importance for the accident management personnel to know whether the monitored variable is increasing, decreasing, or constant). It is of secondary importance to know the exact value of the variable.

A.3 Typical accuracy requirements

For the first group of variables, the level of importance of the monitored information will dictate the required accuracy to be achieved. Typically, this accuracy can be on the order of ±1% or even as high as ±10% of full span. The assumptions made in developing the plant's LBD will govern the value to be met. Historically, the required accuracy for instrument channels relied upon to monitor containment pressure and hydrogen concentration has been ±10% of full span (ANSI/ANS Std 4.5-1980 [B1]).

For linearly derived display instruments (i.e., display range is two decades or less) within the second group of variables, the typical required accuracy, based on historical use, has been ±20%. For instruments with a logarithmic scale, this required accuracy has been ±50% of the reading or alternatively plus/minus a half decade.

For instrument variables that fall into both groups, the more restrictive accuracy requirements would apply.