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American National Standard

Setpoints for Nuclear Safety-Related Instrumentation

ANSI/ISA-S67.04, Setpoints for Nuclear Safety-Related Instrumentation, Part I

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Preface

This preface is included for informational purposes and is not part of revised ANSI/ISA-S67.04-Part I.

This standard has been prepared as part of the service of ISA, the international society for measurement and control, toward a goal of uniformity in the field of instrumentation. To be of real value, this document should not be static but should be subject to periodic review. Toward this end, the Society welcomes all comments and criticisms and asks that they be addressed to the Secretary, Standards and Practices Board; ISA; 67 Alexander Drive;P.O. Box 12277; Research Triangle Park, North Carolina 27709; Telephone (919) 549-8411; e-mail: standards@isa.org.

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The information contained in the preface, footnotes, and appendices is included for information only and is not a part of this standard.

Instrument setpoint drift is a problem that has led to numerous abnormal occurrence reports (now referred to as "Licensee Event Reports"). Section 50.36, "Technical Specifications," of Code of Federal Regulations, Title 10, Chapter 1, Part 50, Washington, D.C., 1987, requires that, where a Limiting Safety System Setting (LSSS) is specified for a variable on which a safety limit has been placed, the setting be so chosen that automatic protective action will correct the most severe abnormal situation anticipated before a safety limit is exceeded. Inappropriate selection of a setpoint that does not allow sufficient margin to account for instrument accuracy, the expected environment, and minor calibration variations can result in calculated drift allowances insufficient for the instrument used. Protective instruments are provided with setpoints where specific actions are either initiated, terminated, or prohibited. Setpoints correspond to certain provisions of Technical Specifications that are incorporated into the facility operation license.

The single most prevalent reason for the drift of a setpoint out of compliance with a technical specification has been the selection of a setpoint that does not allow a sufficient margin between the technical specification limit to account for instrument accuracy, the expected environment, and minor calibration variations. In some cases the setpoint selected was numerically equal to the technical specification limit and stated as an absolute value, thus leaving no apparent margin for uncertainties. In other cases, the setpoint was so close to the upper or lower limit of the instrument's range that instrument drift placed the setpoint beyond the instrument's range thus nullifying the trip function. Other causes for drift of a setpoint out of conformity with the technical specifications have been instrumentation design inadequacies and questionable calibration procedures.

ISA sponsored a review of the setpoint drift problem in April, 1975, by establishing the SP67.4 Subcommittee (now renumbered as S67.04). The Committee's review indicated that a more thorough consideration of setpoint drift was necessary in the design, test, purchase, installation, and maintenance of nuclear safety-related instrumentation.

The 1987 revision was made to provide clarification and to reflect current industry practice. The term "trip setpoint" was made consistent with the terminology used in the NRC Standard Technical Specifications and reflected what previously was known as "upper setpoint limit."

Many of the changes provided in this revision reflect the Improved Technical Specification program (a cooperative effort between industry and the USNRC). With the issuance of ISA-RP67.04, Part II, Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation, this document will become Part I. Additional changes were made to reflect the inclusion of the Recommended Practice, Part II to this standard.

This document was developed to specifically address the establishment and maintenance for individual safety-related instrument channels.

This standard is intended for use primarily by the owners of nuclear power plant facilities or their agents (nuclear steam system suppliers, architect/engineers, etc.) in establishing procedures for determining setpoints, setpoint margins, and test routines in safety-related instrument channels. However, it is equally applicable to large-scale nuclear production reactors.

This standard uses statistical nomenclature, which is customary and familiar to personnel responsible for nuclear power plant setpoint calculations and instrument uncertainty evaluation. It should be noted that this nomenclature may have different definitions in other statistical applications and is not universal, nor is it intended to be. Furthermore, in keeping with the conservative philosophy employed in nuclear power plant calculations, the combination of uncertainty methodology for both independent and dependent uncertainty components is intended to be bounding. That is, the resultant uncertainty should be correct or overly conservative to insure safe operation. In cases where more precise estimation of measurement uncertainty is required, more sophisticated techniques should be employed.

Adherence to this standard will not itself suffice to protect the public health and safety because it is the integrated performance of the structures, the mechanical systems, the fluid systems, the instrumentation, and the electrical systems of the plant that limit the consequences of design-basis events. On the other hand, failure to meet these requirements may be an indication of system inadequacy. Each application for a construction permit or an operating license for a nuclear power plant is required to develop these items to comply with Title 10, Code of Federal Regulations, Chapter 1, Part 50. Applicants have the responsibility to assure themselves and others that this integrated performance is adequate.

ISA Standards Subcommittee SP67.04 operates under SP67, the Nuclear Power Plant Standards Committee, R. Weigle, Chairman.

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Contents

1 Purpose

The purpose of the standard is to develop a basis for establishing setpoints for nuclear safety-related instrumentation (as defined in Section 3). This standard addresses known contributing errors in the channel from the process (including the primary element and sensor) through and including the final setpoint device.

2 Scope

This standard defines the requirements for assuring that setpoints for nuclear safety-related instrumentation (as defined in Section 3), are established and maintained within specified limits in nuclear power plants and nuclear reactor facilities.

Part II of this standard is a recommended practice that provides guidance for the implementation of Part I. This guidance is in the following areas:

a) Methodologies, including sample equations, to calculate total channel uncertainty

b) Common assumptions and practices in instrument uncertainty calculations

c) Equations for estimating uncertainties for commonly used analog and digital modules

d) Methodologies to determine the impact of commonly encountered effects on instrument uncertainty

e) Application of instrument channel uncertainty in setpoint determination

f) Sources and interpretation of data for uncertainty calculations

g) Discussion of the interface between setpoint determination and plant-operating procedures, calibration procedures, and accident analysis

h) Documentation requirements

3 Definitions

3.1 allowable value: A limiting value that the trip setpoint may have when tested periodically, beyond which appropriate action shall be taken.

3.2 analytical limit: Limit of a measured or calculated variable established by the safety analysis to ensure that a safety limit is not exceeded.

3.3 as found: The condition in which a channel, or portion of a channel, is found after a period of operation and before recalibration (if necessary).

3.4 as left: The condition in which a channel, or portion of a channel, is left after calibration or final setpoint device setpoint verification.

3.5 design basis: The design basis for protection systems is as defined in Part 4, Safety System Design Basis, of IEEE Standard 603-1980. (See IEEE, Std. 603.)

3.6 drift: An undesired change in output over a period of time where change is unrelated to the input, environment, or load. (See ANSI/ISA-S51.1.)

3.7 error: The algebraic difference between the indication and the ideal value of the measured signal. (See ANSI/ISA-S51.1.)

3.8 final setpoint device: A component, or assembly of components, that provides input to the process voting logic for actuated equipment.

> **NOTE —** Examples of final setpoint devices are bistables, relays, pressure switches, and level switches.

3.9 foldover: A device characteristic exhibited when a further change in the input produces an output signal that reverses its direction from the specified input-output relationship.

3.10 instrument channel: An arrangement of components and modules as required to generate a single protective action signal when required by a plant condition. A channel loses its identity where single protective action signals are combined. (See IEEE, Std. 603.)

3.11 instrument range: The region between the limits within which a quantity is measured, received, or transmitted and is expressed by stating the lower and upper range values. (See ANSI/ISA-S51.1.)

3.12 limiting safety system setting (LSSS): Limiting safety system settings for nuclear reactors are settings for automatic protective devices related to those variables having significant safety functions. [See CFR, 50.36(c)(1)(i)(A).]

3.13 nuclear safety-related instrumentation: That which is essential to the following:

a) Provide emergency reactor shutdown
b) Provide containment isolation
c) Provide reactor core cooling
d) Provide for containment or reactor heat removal
e) Prevent or mitigate a significant release of radioactive material to the environment

or is otherwise essential to provide reasonable assurance that a nuclear power plant can be operated without undue risk to the health and safety of the public.

3.14 primary element: The system element that quantitatively converts the measured variable energy into a form suitable for measurement. (See ANSI/ISA-S51.1.)

3.15 reference accuracy (also known as Accuracy Rating as defined in S51.1): A number or quantity that defines a limit that errors will not exceed when a device is used under specified operating conditions. (See ANSI/ISA-S51.1.)

3.16 safety limit: A limit on an important process variable that is necessary to reasonably protect the integrity of physical barriers that guard against the uncontrolled release of radioactivity. [See CFR, 50.36(c)(1)(i)(A).]

3.17 saturation: A device characteristic exhibited when a further change in the input signal produces no additional change in the output.

3.18 sensor: The portion of a channel that responds to changes in a plant variable or condition and converts the measured process variable into a signal, e.g., electric or pneumatic. (See IEEE, Std 603.)

3.19 test interval: The elapsed time between the initiation (or successful completion) of tests on the same sensor, channel, load group, safety group, safety system, or other specified system or device. (See ANSI/IEEE, Std. 338.)

3.20 trip setpoint: A predetermined value for actuation of the final setpoint device to initiate a protective action.

3.21 uncertainty: The amount to which an instrument channel's output is in doubt (or the allowance made therefore) due to possible errors, either random or systematic, that have not been corrected. The uncertainty is generally identified within a probability and confidence level.

Additional definitions related to instrumentation terminology and uncertainty may be found in ANSI/ISA-S51.1-1979 and ANSI/ISA-S37.1-1969.

4 Establishment of setpoints

Trip setpoints in nuclear safety-related instruments shall be selected to provide sufficient allowance between the trip setpoint and the safety limit to account for uncertainties. Detailed requirements for safety-related instrument setpoint relationships are given in the following sections, as illustrated in Figure 1.

The importance of the various types of safety-related setpoints differ, and as such it may be appropriate to apply different setpoint determination requirements. For automatic setpoints that have a significant importance to safety, for example, those required by the plant safety analyses and directly related to Reactor Protection System, Emergency Core-Cooling Systems, Containment Isolation, and Containment Heat Removal, a stringent setpoint methodology should consider all of the items noted in 4.1 - 4.4.2. However, for setpoints that may not have the same level of stringent requirements, for example, those that are not credited in the safety analyses or that do not have limiting values, the setpoint determination methodology could be less rigorous.

In general, all uncertainty terms for a particular setpoint methodology may not be required for all setpoint calculations. The methodologies utilized shall be documented and appropriate justification shall be provided.

4.1 Safety

Physical barriers are designed to prevent the uncontrolled release of radioactivity. Safety limits are chosen to maintain the integrity of these physical barriers. For this standard, design limits for engineered safety features are treated the same as safety limits. Safety limits can be defined in terms of directly measured process variables such as pressure or temperature. Safety limits can also be defined in terms of a calculated variable involving two or more measured process variables. An example of a calculated variable is the departure from nucleate boiling ratio.

4.2 Safety analysis

The safety analysis establishes (1) an analytical limit in terms of a measured or calculated variable and (2) a specific time after that value is reached to begin protective action. Satisfying these two constraints will ensure that the safety limit of Section 4.1 will not be exceeded during anticipated operational occurrences and design-basis events.

4.3 Limiting safety system setting (LSSS)

The purpose of an LSSS is to assure that protective action is initiated before the process conditions reach the analytical limit, thereby limiting the consequences of a design-basis event to those predicted by the safety analyses. The LSSS is derived from the analytical limit in a manner determined by the setpoint calculation methodology. Depending on the methodology, the LSSS may be the allowable value, the trip setpoint, or both. The LSSS is maintained by either the technical specifications or the plant-operating procedures. Figure 1 illustrates the relationships between an analytical limit and an LSSS. Detailed requirements for developing trip setpoints and allowable values are given in 4.3.1 - 4.4.2.

4.3.1 Trip setpoint

The trip setpoint should be the value that the final setpoint device is set to actuate. Data used to select the trip setpoint may be taken from any of the following sources: operating experience, equipment qualification tests, vendor design specifications, engineering analysis, laboratory tests, and engineering drawings.

An allowance shall be provided between the trip setpoint and the analytical limit to ensure a trip before the analytical limit is reached. The allowance used shall account for all applicable design-basis events and the following process instrument uncertainties unless they were included in the determination of the analytical limit. Figure 1 illustrates the relationships between the trip setpoint and other parameters. Region A represents the uncertainties allowed between the analytical limit and the trip setpoint. Region B denotes the difference between the allowable value and the trip setpoint. Region D illustrates the difference between the expected value of the process variable during normal operation and the trip setpoint. Region E notes an allowance for calibration tolerance about the trip setpoint.

The following uncertainties are not all-inclusive:

(Additional uncertainties that may apply to a particular instrument channel shall be accounted for in determining the trip setpoint allowance. Not all of the uncertainties listed apply to every measurement channel.)

a) Instrument calibration uncertainties caused by the

   1) calibration standard;
   2) calibration equipment; or
   3) calibration method.

b) Instrument uncertainties during normal operation caused by

   1) reference accuracy, including:*

      (a) conformity (linearity);
      (b) hysteresis;
      (c) dead band; and
      (d) repeatability.

   2) power supply voltage changes;

   3) power supply frequency changes;

   4) temperature changes;

   5) humidity changes;

   6) pressure changes;

   7) vibration (inservice);

   8) radiation exposure;

   9) analog-to-digital (A-D) conversion; and

   10) digital-to-analog (D-A) conversion.

c) Instrument drift

All instruments may not have the same calibration interval. The drift used shall be based on instrument-specific calibration intervals.

d) Instrument uncertainties caused by design-basis events

Only uncertainties specific to the event and required period of service should be used. The use of different uncertainty components for the same process equipment for different events is permitted. Any residual effects of a design-basis event shall also be included. The following are examples of these effects (but are not limited to them):

   1) Temperature effects

   The uncertainties associated with event-specific temperature profiles shall be used where possible. If these are not available, use the uncertainty associated with a limiting temperature.

*Definitions of these terms are provided in ANSI/ISA-S51.1-1979, Process Instrumentation Terminology.

2) Radiation effects

The uncertainties associated with event-specific radiation exposure shall be used where possible. If these are not available, use the uncertainty associated with a limiting radiation exposure (including Total Integrated Dose and rate effects).

3) Seismic/vibratory effects

The uncertainties associated with a safe shutdown or operating basis earthquake shall be used, as appropriate.

e) Process-dependent effects

The determination of the trip setpoint allowance shall account for uncertainties associated with the process variable. Examples are (but are not limited to) the effect of fluid stratification on temperature measurement, the effect of changing fluid density on level measurements, and process oscillations or noise.

f) Calculation effects

The determination of the trip setpoint allowance shall account for uncertainties resulting from the use of a mathematical model to calculate a variable from measured process variables. An example is (but is not limited to) the determination of primary side power via the secondary side power calorimetric.

g) Dynamic effects

The behavior of a channel's output as a function of the input with respect to time shall be accounted for, either in the determination of the trip setpoint or included in the safety analyses. Normally, these effects are accounted for in the safety analyses.

h) Calibration and installation bias accounting

Any bias of fixed magnitude and known direction due to equipment installation or calibration method shall be either eliminated during calibration or accounted for in the setpoint calculation.

4.3.2 Allowable value

The purpose of the allowable value is to identify a value that, if exceeded, may mean that the instrument has not performed within the assumptions of the setpoint calculation. A channel whose trip setpoint as-found condition exceeds the allowable value should be evaluated for operability, taking into account the setpoint calculation methodology. The uncertainties included in the allowance between the allowable value and the trip setpoint (see Region B of Figure 1) are a function of the portion of the instrument channel being tested and the setpoint calculation methodology. These uncertainties may include the following:

a) Instrument calibration uncertainties [4.3.1 (a)]
b) Instrument uncertainties during normal operation [4.3.1 (b)]
c) Instrument drift [4.3.1 (c)]

The assumptions, data, and methods used to determine the allowable value shall be documented and consistent with those used to determine the trip setpoint. The determination of an allowable value is only applicable to setpoints subjected to periodic surveillance requirements specified by the plant's licensing basis.

4.4 Combination of uncertainties

The following methods are acceptable for combining uncertainties: square-root-sum-of-squares (SRSS) and algebraic. Alternate methods, including probabilistic or stochastic modeling, or a combination of SRSS and algebraic methods may also be used.

4.4.1 Square-root-sum-of-squares method (SRSS)

It is acceptable to combine uncertainties that are random, normally distributed, and independent by the SRSS method. When two independent uncertainties, (± a) and (± b), are combined by this method, the resulting uncertainty is (± c), where $c = (a^2 + b^2)^{1/2}$.

4.4.2 Algebraic method

It is acceptable to combine uncertainties that are not random, not normally distributed, or are dependent by the algebraic method. In this method, the combination of two dependent uncertainties, (+a, -0) and (+0, -b), results in a third uncertainty distribution with limits (+a, -b).

5 Documentation

The various aspects of the uncertainty calculation, (e.g., instrument uncertainties, process effects, calculation methods, data sources, and assumptions) shall be documented.

a) The method(s) by which setpoints are calculated shall be documented. The documentation may include, as appropriate, the following:

   1) The relationship between the analytical limit, the allowable value, the setpoint, the as-found limit, and the as-left limit

   2) The uncertainty terms that are addressed

   3) The method used to combine uncertainty terms

   4) Justification of statistical combination methods (other than SRSS or algebraic combination).

b) The setpoint calculations shall be documented. The documentation may include, as appropriate, the following:

   1) A description of the instrument channel, including the manufacturer and model number of all devices that contribute to the channel uncertainty

   2) The relationship between instrument and process measurement units

   3) The safety limit

   4) The basis for selection of the trip setpoint

   5) Data used to select the trip setpoint, including the source of the data

   6) Assumptions used to select the trip setpoint, e.g., ambient temperature limits for equipment calibration and operation

7) Known installation and calibration bias values that could affect the setpoint

8) Correction factors used to determine the setpoint, e.g., pressure compensation to account for elevation difference between the trip measurement point and the sensor physical location.

c) Instrument test data shall be documented. The documentation may include as-left data and as-found data.

6 Maintenance of safety-related setpoints

The following sections address those aspects of safety-related instrument setpoint maintenance necessary to support the trip setpoints as described in Section 4. Information in this section is supplemental to other industry standards that give guidance in maintenance of safety-related setpoints. (See Section 8.)

6.1 Testing

Periodic channel tests shall be performed at an appropriate test interval to ensure that the instrument channel is functioning in compliance with the safety analysis and to verify that trip setpoints remain within their established limits during operation. Formal documentation is necessary to support the investigation and documentation of any occurrence where a limit is exceeded, in the high or low direction as applicable. This verification shall be achieved by recording sufficient as-found data to determine the setpoint in terms of the measured or derived process variables, prior to any adjustment. As-found data shall be the data taken during the first traverse in the direction of concern during the test.

If as-found data indicates that no instrument adjustment is necessary, documentation of the testing and as-found data is all that is required. If there is a need for adjustment, documentation of the as-found and as-left data is required.

If as-found data indicates that an allowable value was exceeded, appropriate action shall be taken. This action shall include investigation to determine the cause of the finding, evaluation of operability, and appropriate corrective action to prevent a re-occurrence. Possible corrective actions for consideration are

a) adjustment of testing frequency;
b) setpoint revision (in the conservative direction);
c) reevaluation of the trip setpoint or allowable value (as applicable);
d) evaluation of equipment installation and environment;
e) evaluation of calibration (equipment and technique); or
f) repair or replacement of the device.

6.2 Replacement

The performance of replacement materials, parts, and components shall be evaluated with respect to instrument uncertainties and the continued validity of the trip setpoint.

7 References

INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS (IEEE)

Standard 338	Standard Criteria for the Periodic Testing of Nuclear Power Generating Station Class 1E Power and Production Systems
Standard 603	Standard Criteria for Safety Systems for Nuclear Power Generating Stations
Available from:	**Institute of Electrical and Electronic Engineers** 345 East 47th Street New York, NY 10017 Tel: (800) 678-4333

ISA

ANSI/ISA-S51.1	Process Instrumentation Terminology, pgs. 18 and 25.
Available from:	**ISA** 67 Alexander Drive P.O. Box 12277 Research Triangle Park, NC 27709 Tel: (919) 549-8411

UNITED STATES CODE OF FEDERAL REGULATIONS (CFR)

Title 10	
Part 50	Paragraphs 50.36(c)(1)(i)(A) and 50.36(c)(1)(ii)(A)
Available from:	**Superintendent of Documents** U.S. Government Printing Office Washington, D.C. 20402

8 Informative references

ISA has developed standards for the nuclear industry through SP67, Nuclear Power Plant Standards Committee (NPPSC). ISA and other standards of possible interest to the reader are listed below.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

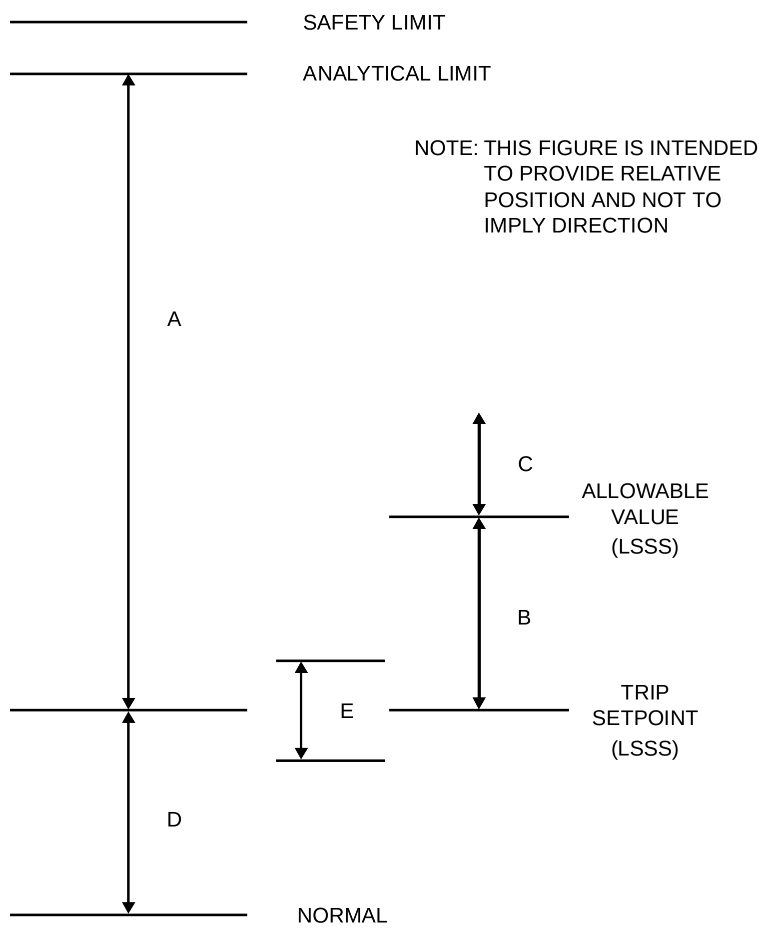
ANSI/ASME NQA-1	Quality Assurance Program Requirements for Nuclear Facilities
Available from:	**ANSI** 11 West 42nd Street New York, NY 10036 Tel: (212) 642-4900

INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS (IEEE)

Standard 352	Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Protection Systems
Standard 498	Standard Requirements for the Calibration and Control of Measuring and Test Equipment Used in the Calibration and Maintenance of Nuclear Power Generating Stations
Available from:	**IEEE** 345 East 47th Street New York, NY 10017 Tel: (800) 678-4333

ISA — THE INTERNATIONAL SOCIETY FOR MEASUREMENT AND CONTROL

ANSI/ISA-S67.02	Nuclear-Safety-Related Instrument Sensing Line Piping and Tubing Standards for Use in Nuclear Power Plants
ANSI/ISA-S67.01	Transducer and Transmitter Installation for Nuclear Safety Applications
Available from:	**ISA** 67 Alexander Drive P.O. Box 12277 Research Triangle Park, NC 27709 Tel: (919) 549-8411



A. ALLOWANCE DESCRIBED IN PARAGRAPH 4.3.1
B. ALLOWANCE DESCRIBED IN PARAGRAPH 4.3.2
C. REGION WHERE CHANNEL MAY BE DETERMINED INOPERABLE
D. PLANT OPERATING MARGIN
E. REGION OF CALIBRATION TOLERANCE (ACCEPTABLE AS LEFT CONDITION) DESCRIBED IN PARAGRAPH 4.3.1

Figure 1 — Nuclear safety-related setpoint relationships

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