ANSI 3.5

NUCLEAR POWER PLANT SIMULATORS FOR USE IN OPERATOR TRAINING AND EXAMINATION

FOREWORD

Nuclear power plant simulators have become important tools in training nuclear power plant operators. The acceptance of the value and use of simulators in operator training and examination programs has resulted in the need for a standard describing their configuration and performance. The objective of this standard is to specify the simulator configuration and performance criteria necessary to support effective training and examination programs. As such simulation of the nuclear core performance is to be considered only so long as the design geometry is maintained.

The value of simulators in the training and examination of nuclear power plant operators has been recognized by the U. S. Nuclear Regulatory Commission in its regulations and regulatory guidance. It is the responsibility of the individual organization which utilizes a simulator to establish a training program and to prepare personnel to properly operate and maintain their nuclear facility.

The details of accomplishing this are determined by each organization. This standard has been revised to incorporate knowledge derived from extensive application of the 1985 revision of this standard.

When a simulator is used for operator training or examination, it shall meet the requirements set forth in this standard.

The Working Group 3.5 of the Standards Committee of the American Nuclear Society had the following membership:

N. S. Elliott, Chairman, Westinghouse
P. J. Swanson, Vice Chairman, Concord Associates, Inc.
G. H. Wanner, Secretary, Exitech Corporation
J. M. Black, Northeast Utilities
R. J. Bruno, Wisconsin Electric Power Company
T. Dennis, Consultant
R. A. Felker, S3 Technologies
W. B. Geise, Carolina Power & Light
F. C. Grams, General Physics Corporation
J. H. Harris, S3 Technologies
S. M. Halverson, Union Electric Company
N. K. Hunemuller, US Nuclear Regulatory Commission
T. E. James, Southern California Edison
R. A. Johnson, Alternate Secretary, Exitech Corporation
T. J. Kerwin, CAE Electronics, Ltd.
J. W. Lehner, Tennessee Valley Authority
G. P. Mecchi, Public Service Electric & Gas
M. F. Reisinger, Reisinger Technology
D. C. Roessner, General Physics Corporation
J. P. Sursock, Electric Power Research Institute

J. A. Wachtel, US Nuclear Regulatory Commission
K. P. Welchel, Duke Power Company

Certain highly technically qualified individuals provided additional expert assistance and advice to the working group during the development of this standard. They were:

R. Colley, Electric Power Research Institute
J. D. Vandergrift, Arkansas Power & Light
R. M. Wyatt, Institute of Nuclear Power Operation

Subcommittee ANS-3, Reactor Operations, had the following membership at the time of its approval of this standard:

D. Roth, Chairman, General Physics Corporation
L. Davis, Vice Chairman, Commonwealth Edison
P. F. Walzer, Secretary, Public Service Electric & Gas
F. A. Dougherty, Tenera, L.P.
N. S. Elliott, Westinghouse
R. Gallo, US Nuclear Regulatory Commission
J. M. Gisclon, Pacific Gas & Electric Company
W. Hollinger, Institute of Nuclear Power Operations
J. A. Honey, American Nuclear Insurers
C. R. Hutchinson, Mississippi Power & Light
C. H. Moseley, Jr., Carolina Power & Light
S. M. Quennoz, Florida Power & Light
J. E. Smith, J. Ed's Nuclear Service Corporation
R. N. Smith, Argonne National Lab
W. T. Ullrich, Philadelphia Electric Company

1. Scope and Background

1.1 Scope.

This standard establishes the functional requirements for full-scope nuclear power plant control room simulators used for operator training and examination. Criteria are established for the degree of simulation, performance, and functional capability of the simulated control room instrumentation and controls. This standard does not address simulators for test, mobile and research reactors, or reactors not subject to U.S. Nuclear Regulatory Commission licensing. Also excluded are part-task or limited scope simulators intended for specialized training or familiarization. This standard does not establish criteria for application of simulators in training programs. Training criteria are established in American National Standard for Selection, Qualification and Training of Personnel for Nuclear Power Plants, ANSI/ANS-3.1.

1.2 Background.

Operating and training practices differ among the various organizations that operate nuclear power reactors; however, common goals are to ensure safety, equipment availability, and efficient operations. It is intended that this standard provide flexibility in the design and use of nuclear power plant simulators in meeting these common goals. It is intended that in meeting the criteria of this standard, the simulator possess a sufficient degree of completeness and accuracy to meet the training needs of industry and the requirements of the NRC as described in ANSI/ANS-3.1 and Title 10, Code of Federal Regulations, Part 55, "Operators' Licenses".

2. Definitions.

The following definitions are of a restricted nature for the purposes of this standard.

backtrack. The ability to reset the simulator to some prior time in its operation.

best estimate. Predicted reference unit performance data derived from engineering evaluation or operational assessment by subject matter experts for specific conditions.

computed values. Parameters representing the state of reference unit systems or components that are calculated by the simulator mathematical models.

design data base. The design documents, performance data, records, assumptions, simplifications, derivations and other definable data on which the design of the simulator hardware and software is based.

fast time. The ability to increase the rate of simulation for some or all computed values with respect to real time.

freeze. The controlled cessation of simulation.

initial condition. A set of data that represents the status of the reference unit from which real time simulation can begin.

malfunction. Any simulator feature that allows controlled degradation of performance or failure of simulated plant systems or equipment.

negative training. Training on a simulator whose configuration or performance leads the operator to incorrect response or understanding of the reference unit.

noticeable difference. Any difference in the physical attributes or dynamic response between the simulator and the reference unit that can be distinguished by an observer and confirmed by a subject matter expert.

operating procedures. Controlled copies of procedures including normal, abnormal , off-normal, emergency, surveillance and alarm response procedures, as applicable to the reference unit.

operator. A licensed operator or senior operator or a person in training to be a licensed operator or senior operator.

override. The ability to interrupt as well as modify the data transfer between the simulator mathematical models and the panel instrumentation.

passive malfunction. A failure of a component or system that does not become evident until the affected component or system is called upon to function.

physical fidelity. The degree of similarity between the simulator and the reference unit such as physical location of panels, equipment, instruments, controls, labels and their related form and function.

real time. Simulation of dynamic performance in the same time base relationships, sequences, durations, rates and accelerations as the dynamic performance of the reference unit.

reference unit. The specific nuclear power plant unit, identified by a unique docket number, from which the simulator control room configuration, system control arrangement and simulator design database are derived.

replay. The recording of a simulator training session in such a way that all or a portion of a simulator training exercise may be played back.

shall, should, and may. The word "shall" is used to denote a requirement; the word "should" is used to denote a recommendation; and the word "may" is used to denote a permission, neither a requirement nor a recommendation.

slow time. The ability to decrease the rate of simulation for some or all computed values with respect to real time.

snapshot. The storage of existing simulated reference unit status at any point in time for later recall as an initial condition.

subject matter expert - SME. An individual who can be shown, by documentation, to have the appropriate education, license, experience or unique qualifications to perform assessments and make recommendations in a particular subject area.

training value assessment. An appraisal by a subject matter expert of a simulator deviation, deficiency, or modification and its relative importance to the operator as required tasks are performed.

visually simulated hardware. Hardware that is present on the simulator control panels for realistic appearance and visual orientation, but that has no dynamic interface with the simulation models.

3. General Requirements.

A nuclear power plant simulator is intended to be used as a training device in support of initial and requalification training as well as a device for the examination of operators. The simulator shall be referenced to a specific unit. The scope of simulation shall be such that the operator is required to take the same action on the simulator to conduct an evolution as on the reference unit using the reference unit operating procedures. The scope of simulation shall permit conduct of all of the evolutions required in this Section until a stable condition is obtained. Simulator performance validation testing, as well as configuration management capabilities, shall be provided. Simulation of the control room equipment, systems, and operation shall be as described in paragraphs 3.1 through 3.4.

3.1 Simulator Capabilities.

The response of the simulator resulting from operator action, no operator action, improper operator action, automatic reference unit controls and inherent operating characteristics shall be realistic and shall not violate the physical laws of nature, such as conservation of mass, momentum and energy, within the limits of the performance validation criteria of Section 4, "Simulator Testing and Validation".

3.1.1 Real Time Simulation.

The simulator shall operate in real time while conducting any of the evolutions required in this Section.

3.1.2 Limits of Simulation.

To reduce the potential fir negative training, automatic or administrative controls shall be provided to alert the instructor when model parameters exceed values indicative of events beyond the implemented simulation scope or expected reference unit behavior.

Note: Mathematical models of physical phenomena are sometimes simplified to meet real time simulation requirements. Such simplification can limit certain evolutions conducted on the simulator. In addition, it is sometimes possible to create events on a simulator that progress beyond reference unit design limits. Simulation may not be accurate beyond these limits. Examples of such events include primary containment failure and gross core degradation.

3.1.3 Normal Evolutions.

The simulator shall support the conduct of the reference unit evolutions listed in this section in a continuous manner, without any requirement for mathematical model or initial condition changes. The simulator shall calculate system parameters corresponding to particular operating conditions, display these parameters on the appropriate instrumentation, and provide proper alarm as well as protective system actions. The minimum evolutions that shall be supported by the simulator, using only operator action normal to the reference unit, are as follows:

(1) Heatup - cold shutdown to hot standby.
(2) Unit startup from hot standby to rated power;
(3) Turbine/generator startup and generator synchronization;
(4) Operator conducted surveillance testing on safety related equipment or systems;
(5) Operations at hot standby;
(6) Load changes;
(7) Startup, shutdown and power operations with less than full reactor coolant flow;
(8) Unit shutdown from rated power to hot standby and cooldown to cold shutdown conditions;
(9) Unit performance testing such as heat balance, determination of shutdown margin, and measurement of reactivity coefficients and control rod worth using permanently installed instrumentation;
(10) Recovery to rated power following a reactor trip.

3.1.4 Malfunctions.

The determination of the type and number of malfunctions to be simulated shall be part of a systematic process for designing performance-based operator training programs. The malfunction selection process should utilize the following:

(1) Licensee Event Reports, Significant Event Report, and Significant Operating Experience Reports;
(2) Probabilistic Risk Assessment studies;
(3) Nuclear Steam Supply System and Balance Of Plant Manufacturer equipment availability and reliability data as well as technical information service bulletins;
(4) Local site considerations and reference unit-specific operating experiences;
(5) US Nuclear Regulatory Commission bulletins, circulars and generic letters;
(6) Reference unit Safety Analysis Report.

The simulator shall support the conduct of abnormal, off-normal and emergency events, including malfunctions, to demonstrate inherent reference unit response and automatic control functions. Where operator actions are a function of the degree of severity of the event, the simulator shall have adjustable malfunction severity of a sufficient range to represent the potential reference unit conditions. Consequential failures of systems and equipment due to operator action or malfunction of supporting systems, shall be simulated where supported by operating experience and training value assessment.

The malfunctions listed below shall be included:

(1) Loss of coolant:
    (a) significant Pressurized Water Reactor (PWR) steam generator tube leaks;
    (b) inside and outside primary containment;
    (c) large and small Loss of Coolant Accidents (LOCA) demonstrating multi-phase flow;
    (d) failure of safety and relief valves;
(2) Loss of instrument air to the extent that the whole system or isolable portions can lose pressure and affect the reference unit's static or dynamic performance;
(3) Degraded electrical power to the station, including loss of off-site power, loss of emergency power, loss of emergency generators, loss of power to the unit's electrical distribution buses and loss of power to the individual instrumentation buses, including AC as well as DC, that provide power to control room instrumentation or unit control functions affecting the unit's response;

(4) Loss of forced core coolant flow due to single or multiple pump failure;
(5) Loss of condenser vacuum including loss of condenser level control;
(6) Loss of service water or cooling to individual components;
(7) Loss of shutdown cooling ;
(8) Loss of component cooling system or cooling to individual components;
(9) Loss of normal feedwater or normal feedwater system failure;
(10) Loss of all feedwater, both normal and emergency;
(11) Loss of a protective system channel;
(12) Control rod failure including stuck rods, uncoupled rods, drifting rods, rod drops, and misaligned rods;
(13) Inability to drive control rods;
(14) Fuel cladding failure resulting in high activity in reactor coolant or off gas and the associated high radiation alarms;
(15) Turbine trip;
(16) Generator trip;
(17) Failure in automatic control systems that affect reactivity and core heat removal;
(18) Failure of reactor coolant pressure and volume control systems for PWRs;
(19) Reactor trip;
(20) Main steam line as well as main feed line break both inside and outside containment;
(21) Nuclear instrumentation failures;
(22) Process instrumentation, alarms, and control system failures;
(23) Passive failures of components in systems, such as engineered safety features or emergency feedwater systems;
(24) Failure of the automatic reactor trip system;
(25) Reactor pressure control system failure including turbine bypass failure for Boiling Water Reactors (BWR).

The response of the simulator shall be compared to actual reference unit response or best estimate unit response as required by Section 4. The simulator shall support operator actions to recover from or mitigate the consequences of malfunctions. The scope of simulation shall be such that a stable, controllable and safe condition is attained and can be continued to either cold shutdown conditions, or until the limits of simulation are reached. (see Section 3.1.2).

3.2 Scope of Simulation.

3.2.1 Physical Fidelity and Human Factors.

3.2.1.1 Scope of Panel Simulation.

The simulator shall include those operational panels, consoles, and operating stations required to provide the controls, instrumentation, alarms, and other human-system interfaces used by operators in the reference unit to conduct the normal evolutions of Section 3.1.3 and respond to the malfunctions of Section 3.1.4.

3.2.1.2 Instrumentation, Controls, Markings and Operator Aids.

Meters, recorders, switches, annunciators, controllers, plant computer interface hardware and other components or displays that are used during normal, abnormal, off-normal and emergency evolutions shall be included in the simulator.

3.2.1.3 Control Room Environment.

The reference unit control room environmental features that support normal, abnormal, off-normal and emergency evolutions shall be simulated. Communication systems that an operator would use to direct remote reference unit activities shall be operational at least to the extent that the simulator instructor, when performing these activities, is able to communicate over the appropriate communication system.

3.2.1.4 Simulator Control Room Deviations.

Where deviations exist between the simulator control panels and the reference plant panels in instrumentation and audio-visual cues provided to the operator, such deviations may remain if they are assessed in accordance with Section 4.2.1.4.

3.2.2 Systems to be Simulated and the Degree of Completeness

3.2.2.1 Systems Controlled or Monitored from the Control Room.

The inclusion of systems of the reference unit in the scope of simulation shall be to the extent necessary to allow the operator to perform the evolutions described in Section 3.1.3 and the malfunctions described in Section 3.1.4. These systems shall be complete to the extent that the operator can perform these control manipulations and observe simulated unit response as in the reference unit. The scope of simulation shall include system interactions with other simulated systems so as to provide a total integrated unit response.

3.2.2.2 Systems Controlled or Monitored External to the Control Room.

The systems that are operated or monitored external to the control room and are necessary to perform the evolutions described in Section 3.1.3 and malfunctions described in Section 3.1.4 shall be simulated. The operator shall be able to interface with the remote activity in a manner similar to the reference unit.

3.3 Simulator Training capabilities.

3.3.1 Initial Conditions.

The simulator shall include storage capacity for a sufficient number of initial conditions to support those evolutions identified in Section 3.1.3. A minimum of ten initial conditions shall be operational and shall include a variety of reference unit operating conditions, fission product poison concentrations, and various times in core life.

3.3.2 Malfunctions.

The simulator shall include the capability for insertion of simultaneous or sequential malfunctions. Capabilities shall be provided to insert and, as appropriate, terminate the unit malfunctions specified in Section 3.1.4. Event triggered, as well as time triggered, malfunction initiation should be included. The introduction of a malfunction shall not alert the operator to the impending events in any manner other than would occur in the reference unit. Provision shall exist to incorporate additional malfunctions.

3.3.3 Other Features.

The simulator shall include freeze, snapshot, and initial condition reset. Other features such as control room panel hardware override, relay, slow time, fast time, component failure capabilities, and backtrack capabilities may be included.

3.3.4 Instructor Interface.

The simulator shall permit the instructor to act in the capacity of an individual performing local actions external to the control room in support of 3.1.3 and 3.1.4. Examples of local actions to be supported include changing the position of valves, circuit breakers or other locally operated equipment. In addition, other features to enhance the instructor's control over the simulation of the reference unit external environment may be implemented; e.g. air temperature, circulating water temperature.

3.4 Simulator Testing.

Capabilities shall be provided for performing and monitoring tests for validation of simulator response in meeting the requirements of this Section. The simulator shall have the capability to provide hardcopy data in the form of either plots or printouts for the required unit parameters during the evolutions specified in Section 3.1.3 and the malfunctions specified in Section 3.1.4.. This monitoring capability shall provide sufficient parametric and time resolution to allow determinination of compliance with the performance validation criteria of Section 4.

4. Simulator Testing and Validation.

The intent of the following performance testing and validation criteria is to insure that no noticeable differences exist between the simulator control room and simulated systems when evaluated against the control room and systems of the reference unit. The requirements for the evaluation of each of the major elements of a simulator are set forth in oaragraphs 4.1 through 4.4.

4.1 Simulator Capabilities Criteria.

4.1.1 Real Time.

It shall be verified that the simulator software required to perform the capabilities defined in Section 3.1 completes execution within the design time interval. In addition, it shall be verified that no noticeable differences that adversely impact training exist between the simulator and the reference unit in the following respects: time base relationships, sequences, durations, rates and accelerations.

4.1.2 Limits of simulation.

It shall be verified that the limits Of simulation are identified as part of the simulator design data base and automatic or administrative means are in place for notification of the instructor that the limits of simulation have been exceeded.

4.1.3 Steady State and Normal Evolutions.

4.1.3.1 Steady State operation.

It shall be verified that the simulator correctly represents the steady state response of the reference unit at three different power levels at which reference unit data are available, e.g. 25, 75 and 100 percent power. The simulator steady state power levels at which the validation is performed shall have been attained through continuous operation over the power range.

The recorded computed values of the parameters shall be compared with the reference unit data and verified to be within the tolerances noted below. The computed values of parameters not itemized below shall be validated to match reference unit data within 10% of the reference unit instrument loop range.', In making comparisons between the simulator computed values and the reference unit data, an additional deviation may be allowed up to the documented value of the reference unit instrument error [2] , The simulator instrument error shall be no greater than that of the comparable meter, recorder, and related instrument system of the reference unit.

4.1.3.1.1. It shall be verified that the following PWR parameters match reference unit data within 1% of the reference unit instrument loop range:

T-average,
T-hot,
T-cold,
MWe,
Core MWt,
Power Range Nuclear Instrumentation readings
Reactor Coolant System (RCS) Pressure
SG Pressure,
Pressurizer Level.

4.1.3.1.2. It shall be verified that the following PWR parameters match reference unit data within 2%. of the reference unit instrument loop range:

Steam Generator Feed Flow,
RCS Flow,
SG level,
Letdown Flow,
Charging Flow,
Steam Flow,
Turbine First Stage Pressure.

4.1.3.2 Steady State Stability.

It shall be verified that the parameters specifically listed in Section 4.1.3.1 are stable and not vary by more than 2% of the initial values during a continuous 60-minute period of operation at rated power.

4.1.3.3 Normal Evolutions.

It shall be verified that the simulator performance during conduct of the normal evolutions identified in Section 3.1.3 meet the acceptance criteria stated in items 1 through 6. If these evolutions are performed during use of the simulator for operator training, credit may be taken for having performed the required verification, provided that the evolutions are performed ~~or~~ ~~sed~~ in accordance with reference unit procedures, evaluated, and documented.

Acceptance criteria shall:

1. be the same as the reference unit startup test procedure acceptance criteria;
2 be the same as the reference unit surveillance procedure acceptance criteria;
3. be the same as the reference unit normal operating procedure acceptance criteria;
4. require that the observable change in the parameters correspond in direction to those expected for a best estimate of normal unit operation;
5. require that the simulator shall not fail to cause an alarm or automatic action if the reference unit would have caused an alarm or automatic action under identical circumstances;
6. require that the simulator shall not cause an alarm or automatic action if the reference unit would not cause an alarm or automatic action, under identical circumstances.

4.1.4 Malfunctions.

It shall be verified that simulator performance during conduct of the malfunctions listed in Section 3.1.4 meets the following acceptance criteria:

(1) The simulator allows use of applicable reference unit procedures;
(2) Any observable change in simulated parameters corresponds in direction to those expected from actual or best estimate response of the reference unit to the malfunction;
(3) The simulator shall not fail to cause an alarm or automatic action if the, reference unit would have caused an alarm or automatic action under identical circumstances;
(4) The simulator shall not cause an alarm or automatic action if the reference unit would not cause an alarm or automatic action, under identical circumstances.

4.2 Scope of Simulation.

4.2.1 Physical Fidelity and Human Factors.

4.2.1.1 Scope of Panel Simulation.

It shall be verified that control panels, consoles, and operating stations which are simulated as required by Section 3.2.1.1 replicate the size, shape, color, and configuration of those of the reference unit. It shall be verified that differences are documented and that the training impact has been assessed in accordance with the criteria provided by 4.2.1.4.

4.2.1.2 Instrumentation, Controls, Markings and operator Aids.

It shall be verified that instrumentation, controls, markings, and operator aids on panels, consoles and operating stations which are simulated in accordance with Section 3.2.1.2 replicate the size, shape, color, configuration, feel and dynamic functioning of those of the reference unit. Components located on simulated panels but not used by the operator during training may be visually simulated hardware. It shall be verified that information is displayed to the operator in the same format and engineering units as in the reference unit control room. It shall be verified that differences are documented and that the training impact as been assessed in accordance with the criteria provided by 4.2.1.4. Items to be reviewed include the following:

Switches
Controllers
Meters
Recorders
Mimics
Demarcation Lines
Engravings
Color
Panel Layout
General Appearances
Plant Computer Capabilities
Lights

Annunciators
Labels
Tactile Cues
Display Systems.

4.2.1.3 Control Room Environment.

It shall be verified that the simulator control room environment replicates the reference unit control room in accordance with 3.2.1.3. It shall be verified that differences are corrected or that the training impact has been assessed in accordance with the criteria provided by 4.2.1.4. Items to be included are the following:

Floor Plan
Lighting characteristics
Communications
Furnishings
General Appearance
Audible Cues
Obstructions.

4.2.1.4 Assessment of Deviations.

A training value assessment shall be performed for each deviation identified in 3.2.1.4 or 4.2. Deviations that do not impact the actions to be taken by the operator or detract from training may be deemed acceptable.

The following factors should be evaluated to determine if the deviation has an impact on the actions to be taken by the operators:

1. The human-system interface required for normal, abnormal, off-normal, or emergency procedures;
2. The differences in performing the task on the simulator versus performing the task in the actual control room;
3. The differences in operator cues, auditory and visual information presented to the operator and the critical decisions and actions required of the operator;
4. The function of the equipment and the potential for impacting reference unit safety, tripping the reference unit, or damaging reference unit equipment;
5. The differences required by the team response to normal, abnormal, off-normal, or emergency actions;
6. Review of operational experience to identify the potential for operator error or the necessity for reinforcement of the skills required for the task.

4.2.2 Systems to be Simulated and the Degree of Completeness.

4.2.2.1 Systems Controlled or Monitored from the Control Room.

It shall be verify that the systems of the reference unit that are within the scope of simulation are adequate to perform the evolutions described in 3.1.3, and the malfunctions described in 3.1.4. The capability shall be provided to perform these control manipulations and observe unit response as in the reference unit. It shall be verified that the scope of simulation includes system interactions with other simulated systems so as to provide a total integrated unit response. A training value assessment shall be performed for each deviation identified. Deviations that do not impact the actions to be taken by them operator or do not detract from training may be deemed acceptable.

4.2.2.2 Systems Controlled or Monitored External to the Control Room.

It shall be verified that the systems that are operated or monitored external to the control room and are necessary to perform the evolutions described in 3.1.3 and malfunctions described in 3.1.4 are simulated. It shall be verified that the operator is able to interface with the remote activity in a similar manner ato that in the reference unit. A training value assessment shall be performed for each deviation identified. Deviations that do not impact the actions to be taken by them operator or do not detract from training may be deemed acceptable.

4.3 Simulator Training Capabilities.

4.3.1 Initial Conditions.

It shall be verified that the initial conditions specified in 3.3.1 are administratively controlled and are representative of reference unit conditions.

4.3.2 Malfunctions.

It shall be verified that the malfunctions specified as part of 3.3.2 are included in the simulation and that their introduction does not alert the operator to the impending events in any manner other than would occur in the reference unit.

4.3.3 Other Features.

It shall be verified the simulator includes features specified in 3.3.3.

4.3.4 Instructor Interface.

It shall be verified that the simulator permits the instructor to act in the capacity of an individual performing local evolutions external to the control room as required by 3.3.4.

4.4 Simulator Testing.

4.4.1 Simulator Validation Testing.

Simulator performance shall be verified by conducting a validation test and evaluating the results against actual or predicted reference unit performance data. This test shall include a demonstration that the simulator represents the reference unit to the scope required by Section 3. Section 4 provides the criteria for validating that these requirements are met. The order of preference for data comparison shall be as stated in 5.1.1. A record of these test results and their evaluation shall be retained.

Simulator Validation Tests shall be conducted for the following situations:

(1) Completion of simulator initial construction;
(2) Following initial construction, whenever a modification is made to the simulator that affects its fidelity relative to the reference unit or its functional operation as a simulator Modifications to the simulator design shall be validated through testing prior to use in training and examination.

4.4.2 Simulator operability Testing

A simulator operability test[3] shall be conducted once per calendar year and a record of the conduct of this test and its evaluation shall be maintained. The criteria for the operability test shall be the applicable criteria noted in Section 4. The intent of this test is to verify the following:

(1) Overall simulator model completeness and integration.
(2) Simulator steady state performance.
(3) Simulator transient performance for a benchmark set of transients.

5. Simulator Configuration Management.

A Configuration Management System (CMS) shall be established to provide a means for verifying simulator performance and demonstrating compliance to the requirements of Section 3. The CMS shall include the following:

(1) A means for establishing and maintaining a simulator design data base.

(2) A tracking system that identifies and documents differences between the simulator and its reference unit and any resolution thereof.

(3) Documentation to support simulator testing and maintenance[4].

5.1 Simulator Design Data Base.

The simulator design data base is comprised of the actual data that form the baseline for the current simulator hardware and software configuration. This data base should include the complete data from which the simulator is designed.

5.1.1 Utilization of Baseline Data.

Recognizing that multiple sources of baseline data are available, their order of preference to ensure simulator fidelity shall be:

(1) Data collected directly from the reference unit;
(2) Data generated through engineering analysis with a sound theoretical basis;
(3) Data collected from a plant which is similar in design and operation to the reference unit;
(4) Data, such as subject matter expert estimates, that does not come from any of the above sources.

For those instances where data is collected from sources other than the reference unit, the data source shall be specifically identified and shown to be applicable to the simulator.

5.1.2 Simulator Design Data Base Update.

The simulator design data base shall be periodically updated to incorporate new data as it affects the reference unit as follows:

(1) Initial Update - Any new data shall be reviewed for applicability and determination of the need for simulator modification within 18 months of the reference unit's commercial operation date or the simulator's operational date, whichever is later.
(2) Subsequent Updates - Following the initial update, any new data shall be reviewed and the simulator design data base appropriately revised once per calendar year. Any modifications made to the reference unit shall be reviewed for determination of the need for simulator modification within 12 months of their reference unit in-service dates. In addition, other observations such as student feedback, or LERs which may affect simulator configuration or performance, shall be reviewed for applicability and possible incorporation into the simulator design data base.

5.2 Revision to the Scope of Simulation.

Changes to the simulator design data base may have an effect upon the scope of simulation. The determination of need to incorporate related changes should be based primarily upon a training value assessment.

5.3 Incorporation of Simulator Changes.

Changes to the simulator fall into two principle categories:

(1) Those based upon modifications to the reference unit.
(2) Those based on items such as revised unit performance data, student feedback, LERs, and simulator performance testing.

Changes in both categories may precede actual changes to the reference unit based upon training value assessment (e.g. control board modifications, new core fuel load).

5.3.1 Modification Based Simulator Changes.

The configuration of the simulator shall be upgraded to match the reference unit on the following occasions:

(1) Initial Upgrade - Reference unit modifications that have been determined to be relevant to the training program shall be implemented on the simulator within 30 months of either the reference unit's commercial operation date or the simulator's operational date, whichever is later.
(2) Subsequent upgrades - Following the initial upgrade, reference unit modifications that have been determined to be relevant to the training program shall be implemented on the simulator within 24 months of their reference unit in-service dates.

5.3.2 Performance Based Simulator Changes.

Simulator changes based upon items such as revised reference unit performance data, student feedback, simulator performance testing, and LERs, which have been determined to be relevant to the training program as a result of a training value assessment, shall be implemented based upon their training impact.

5.4 Control of Software and Hardware configuration.

5.4.1 Software Training Load.

The configuration of the software load used for training shall be administratively controlled by the application of the requirements of 4.4.

5.4.2 Control Boards and Control Room Equipment.

The configuration of hardware that affects the physical fidelity of the control boards or control room equipment, or both, shall be administratively controlled by applying the requirements of 4.4.

Footnotes:

1. Appendix A of ANSI/ANS 3.5, Guideline for Documentation of Simulator Design and Test Performance, provides examples of acceptable design and performance documentation.
2. Appendix B of ANSI/ANS 3.5, Guidelines for the Conduct of Simulator Operability Testing, provides examples of acceptable simulator operability tests.
3. Appendix C of ANSI/ANS 3.5, Examples of the Application of the Simulator Steady State Tolerance Allowances, provides several example steady state tolerance calculations.

6. References.

American National Standard for Selection, Qualification and Training of Personnel for Nuclear Power Plants, ANSI/ANS-3.1-1987. American Nuclear Society, La Grange, Il. Title 10, Code of Federal Regulations, Part 55, "Operator's Licenses." Government Printing Office, Washington, D.C.

Only the standards explicitly referred to in this document qualify as references. Subsequent revisions of these standards shall not be substituted.

APPENDIX A

(This Appendix is not a part of the American National Standard, Nuclear Power Plant Simulators for Use in Operator Training, ANSI/ANS-3.5-1991, but is included for information purposes only.)

Guideline for Documentation of Simulator Design and Test Performance

A. Purpose.
The purpose of this appendix is to provide an acceptable format for demonstration of a simulator's conformance to the requirements of this standard. It is intended that documentation be provided to the extent necessary to form a sufficient basis for verification of simulator performance, configuration control and maintenance.

A1. Simulator Information.
The intent of this Section is to provide familiarization with the specific simulator and its general applicability as an operator training and evaluation vehicle.

A1.1 Simulator.
1. The owner, the user and the manufacturer of the simulator.
2. The reference unit's name, type and megawatt rating.
3. The simulator's operational date.

A1.2 Simulator Control Room.
A report documenting the comparison between the simulator control room and that of the reference unit, including the disposition of any identified dissimilarities.

A1.3 Instructor Station.
1. A list of the initial conditions with descriptions.
2. A list of malfunctions with descriptions of ranges, causes and immediate effects.
3. A list of remote functions.
4. A list of the limits of simulation and a description of the method by which the instructor is notified when any of these limits are exceeded.
5. A list of additional capabilities.

A1.4 Operating Procedures.
Indicate differences between the simulator operating procedures and those of the reference unit.

A1.5 Reports and Records.
Documentation supporting initial compliance with the standard together with subsequent simulator upgrades.

A2. Simulator Design Data.
Simulator design data can be categorized according to the function it fulfills. The intent is to have available the complete set of data from which the simulator is designed. For those instances where data were derived or collected from sources other than the reference unit, the data should be specifically identified and referenced as to its origination and its applicability to the reference unit. Some examples of simulator design data that serve to define the scope of simulation are:

1. Piping and instrumentation diagrams - P&IDs;
2. Control and logic system diagrams;
3. Instrumentation and control elementary diagrams;
4. Electrical distribution;
5. Instrument air distribution;
6. Annunciator book;
7. Process computer book;
8. Control room bill of materials;
9. Control room panel layout.

Some examples of simulator design data that serve to define the simulator's operational characteristics are:
1. Nuclear core physics data;
2. Heatup data;
3. Component operational characteristics;
4. Control setpoint book;

5. Technical manuals;
6. Data book.

Some examples of simulator design data that serve to validate a simulator's performance are:
1. Transient data;
2. Best estimate transient data;
3. Operating procedures;
4. Safety Analysis Report;
5. Observed operations;
6. Startup tests.

A3. Simulator Documentation.
Simulator specific documentation is required for effective configuration control and maintenance of the simulator. This documentation is controlled and updated, but is not considered to be part of the design data base.

1. Simulated systems documentation. This documentation provides design details for each simulated system model, e.g., simulation diagrams, math model description, assumptions, simplifications, etc.
2. Simulation software source code. The simulation software source code is considered to be documentation and should be updated and detailed in accordance with administrative controls.
3. Simulator hardware documentation. Simulator Hardware Documentation (e.g. bill of materials, wire lists, simulator hardware design documents, special circuits, modifications made to instrumentation) should be maintained to the extent necessary to support effective design control and maintenance.

A4. Simulator Test Documentation.
The documentation of simulator performance criteria and simulator testing should include the following basic information:

1. The initial condition;
2. The perturbation made to induce the transient, such as malfunctions, remote functions or operator actions;
3. The responses of pertinent simulator parameters;
4. An evaluation and validation of test results;
5. The update of related documentation.

APPENDIX B

(This Appendix is not a part of the American National Standard, Nuclear Power Plant simulators for Use in Operator Training, ANSI/ANS-3.5-1991, but is included for information purposes only.)

Guidelines for the Conduct of Simulator Operability Testing

B. Purpose.
The purpose of this appendix is to provide examples of tests, parameters to be recorded and time resolution for demonstration of simulator operability. The example tests documented herein will clarify the scope, and intent of simulator operability testing required by Section 4.4.2.

Bl. Categories of operability Tests.
The testing of simulator operability can be broken down into three major categories. Formal test procedures should be generated for each category and acceptance criteria established for operability validation commensurate with the requirements of 4.1.

Bl.1 Steady-state Test - This test verifies correct steady-state response through the comparison of parameters on the simulator and the reference unit. The comparison should be done for three distinct power levels for which heat balance data is available (e.g. , 25, 75 and 100 percent rated thermal power). The set of parameters to be monitored has been identified in paragraph B2 and B3. Refer to Section 4.1.3.1 for acceptance criteria.

Bl.2 Stability Test - This test consists of running the simulator at 100 percent rated thermal power for one hour and monitoring the variation in the set of parameters identified in B2 and B3. Refer to Section 4.1.3.2 for acceptance criteria.

Bl.3 Transient Performance Test - This test consists of running the transient events identified in paragraphs B2 (BWR) or B3 (PWR). The set of parameters to be monitored has been identified in paragraphs B2 (BWR) and B3 (PWR) . Many of these events are introduced via malfunctions, but the intent of Transient Performance Testing is to verify simulator response and not to test the malfunction. Refer to 4.1.4 for the performance criteria.

B2. BWR Simulator operability Test Requirements.

B2.1 Steady State and Stability Test Parameters.

1. Primary plant:
   - Core MWt
   - Reactor Pressure
   - MWe
   - Reactor Wide Range Pressure
   - Total Core Flow
   - Average Power Range Monitor readings
   - Feedwater Temperature (after last feedwater heating stage)
   - Total Steam Flow
   - Individual Recirculation Loop Flows
   - Total Feedwater Flow
   - Turbine Steam Flow
   - Condenser Vacuum
   - Individual calibrated Jet Pump Flow
   - Narrow Range Reactor Water Level
   - Control Rod Drive Hydraulic System Flow and Temperature.

2. Secondary plant:
   - Secondary plant heat balance data.

B2.2 Transient Performance Tests.

B.2.2.1 Run the following set of transients from an initial condition of approximately 100 percent power, steady state xenon and decay heat with no operator follow up action (unless otherwise noted):

(1) Manual scram;
(2) Simultaneous trip of all feedwater pumps;

(3) Simultaneous closure of all Main Steam Isolation Valves;
(4) Simultaneous trip of all recirculation pumps;
(5) Single recirculation pump trip;
(6) Main turbine trip from maximum power level which does not result in immediate reactor scram;
(7) Maximum rate power ramp (master recirculation flow controller in "manual") down to approximately 75 percent and back up to 100 percent;
(8) Maximum size reactor coolant system rupture combined with loss of all off-site power;
(9) Maximum size unisolable main steam line rupture;
(10) Simultaneous closure of all Main Steam Isolation Valves combined with single stuck open safety or relief valve. (Inhibit activation of high pressure Emergency Core Cooling Systems.)

B2.2.2 For transients B2.2.1(1), B2.2.1(2), B2.2.1(3), B2.2.1(6), and B2.2.1 (7) record the following set of test parameters simultaneously versus time with a resolution of one second or less:

* Reactor power (percent neutron flux);
* Total steam flow;
* Total feedwater flow;
* Wide range reactor pressure;
* Narrow range reactor pressure;
* Wide range reactor water level;
* Narrow range reactor water level (feedwater control);
* Generator gross electrical power;
* Turbine steam flow;
* Total core flow;
* Total recirculation loop flow.

B2.2.3 For transients B2.2.1(4) '.and B2.2.1(5) record the following set of parameters simultaneously with a resolution of one second or less:

* Reactor power (percent neutron flux);
* Total steam flow;
* Total feedwater flow;
* Narrow range reactor pressure;
* Narrow range reactor water level (feedwater control);
* Total core flow;
* Individual recirculation loop flows;
* Individual calibrated jet pump flows.

B2.2.4 For transients B2.2.1(8), B2.2.1(9), and B2.2.1(10), record the following parameters simultaneously versus time with a resolution of one second or less:

* Reactor power (percent neutron flux);
* wide range pressure;
* Wide range water level;
* Fuel zone water level;
* Total steam flow;
* Total feedwater flow;
* Containment temperature;
* Suppression pool temperature;
* Containment pressure;
* Drywell temperature;
* Drywell pressure;
* Total low pressure injection flow;
* Total low pressure core spray flow;
* Total high pressure injection flow.

B3. PWR Simulator Operability Test Requirements.

B3.1 Steady State and Stability Test Parameters.

1. Primary plant:

T-average;
T-hot;

T-cold;
MWe;
Core MWt;
Power Range Instrumentation readings;
RCS Pressure;
SG Pressure;
Pressurizer Level;
Steam Generator Feed Flow;
RCS Flow;
Containment Pressure;
SG Level;
Letdown Flow;
Charging Flow;
Steam Flow;
Turbine 1st Stage Pressure;
Boron concentration;
Pressurizer temperature;
Control rod positions.

2. Secondary plant:

Secondary plant heat balance data.

B3.2 Transient Performance Tests.

B3.2.1 Run the following set of transients from an initial condition of approximately 100 percent power, steady state xenon and decay heat with no operator follow up action unless otherwise noted:

(1) Manual reactor trip;
(2) Simultaneous trip of all feedwater pumps;
(3) Simultaneous closure of all Main Steam Isolation Valves;
(4) Simultaneous trip of all reactor coolant pumps;
(5) Trip of any single reactor coolant pump;
(6) Main turbine trip from maximum power level which does not result in immediate reactor trip;
(7) Maximum rate power ramp from 100 percent down to approximately 75 percent and back up to 100 percent;
(8) Maximum size reactor coolant system rupture combined with loss of all off-site power;
(9) Maximum size unisolable main steam line rupture;
(10) Slow primary system depressurization to saturated condition using pressurizer relief or safety valve stuck open. Inhibit activation of high pressure Emergency Core Cooling system;
(11) Load rejection.

B3.2.2 For transients B3.2.1(1), B3.2.1(2), B3.2.1(3), B3.2.1(4), B3.2.1(6), and B3.2.1(7), and B3.2.1(11) record the following parameters simultaneously versus time with a resolution of one second or less:

* Neutron flux (percent);
* Average temperature;
* Pressurizer pressure;
* Pressurizer level;
* Pressurizer temperature;
* Total steam flow (if available);
* Total feedwater flow (if available);
* Hot leg temperature (any single loop);
* Cold leg temperature (same loop as hot leg temperature);
* Steam generator secondary pressure (same loop as hot leg temperature);
* Steam generator level (same loop as hot leg temperature).

B3. 2. 3 For transient B3.2.1(5), record the following parameters simultaneously versus time with a resolution of one second or less:

* Neutron flux (percent);
* Hot leg temperature;
* Cold leg temperature;
* Steam generator secondary pressure;

* Steam generator level;
* Steam generator steam flow (if available);
* Steam generator feedwater flow;
* Loop flows.

B3.2.4 For transients B3.2.1(8) and B3.2.1(9), record the following parameters simultaneously versus time with a resolution of one second or less:

* Pressurizer pressure;
* Narrow range pressurizer pressure;
* Pressurizer level;
* Containment pressure;
* Containment temperature.

B3.2.5 For transient B3. 2. 1 (10) , record the following parameters simultaneously versus time with a resolution of one seconds or less:

* Relief valve flow (if available);
* Pressurizer pressure;
* Pressurizer temperature;
* Pressurizer level;
* Loop flow rates;
* Surge line temperature;
* Hot leg temperature (surge line leg);
* source range monitor output;
* Reactor vessel level (if available);
* Saturation margin monitor output (if available).

APPENDIX C

(This Appendix is not a part of the American National Standard, Nuclear Power Plant Simulators for Use in Operator Training, ANSI/ANS-3.5-1990, but is included for information purposes only.)

Examples of Application of the Simulator Steady State Tolerance Allowances

EXAMPLE 1

Parameter has a 1 percent tolerance as defined by ANSI/ANS 3.5
RCS Pressure (range of 1500 to 2500 psia)
Loop range 2500 - 1500 = 1000 psia
Loop Accuracy 1/2 percent (From Master Calibration Data Sheet)
At all power levels the pressure reads 2250 psia.

Therefore the tolerance applied to the simulator would be:
The range of 1000 psia x (1 percent per 4.1.3.1 tolerance + 1/2 percent loop tolerance) = 15 psia
The maximum reading could be 2250 + 15 = 2265 psia
The minimum reading could be 2250 - 15 = 2235 psia

EXAMPLE 2

Parameter has a 1 percent tolerance as defined by ANS 3.5
RCS Hot Leg Temp (range of 515'F - 615'F)
Loop range 615'F - 515'F = 100'F
Loop Accuracy 1/2 percent (From Master Calibration Data Sheet)

Therefore the tolerance applied to the simulator would be:
The range of 100'F x (1 percent per 4.1.3.1 + 1/2 percent loop accuracy) = 1.50'F

PERCENT POWER REFERENCE UNIT DATA LOW HIGH
25 572'F 570.5'F 573.5'F
50 584'F 582.5'F 585.5'F
75 596'F 594.5'F 597.5'F
100 610'F 608.5'F 611.5'F