Summary of Technical and Functional Requirements for the Control System Modernization of the Idaho National Laboratory Advanced Test Reactor Critical Facility (ATRC) DRAFT

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1.5.1 Objectives of Reactor Shutdown System (RSS) and Rod Control System (RCS):

1. Provide nuclear instrumentation information to operator.
2. Automatically reduce reactor power when limits are exceeded.
3. Neutron sensing elements include fission chambers and ion chambers.
4. Two startup channels utilize high-sensitivity fission chambers and pulse amplifiers.
5. Four Log N / Period channels detect and monitor both the log and the derivative of the log (inverse period) of the neutron flux and provide signals for protective actions and visual indicators.
6. Instrumentation in Log N/Period channels provides withdrawal control for safety rod interruption, reversal, or scram.
7. The period indication scales have hyperbolic calibrations and range from minus 30 seconds to plus 3 seconds.
8. Four neutron level channels are linear power level channels.
9. Control of rods and drives, must be performed through a logic system which contains an electrical interlock plan.
10. The logic system shall be designed with no possibility of an incident resulting from a single failure of any component installed in sensitive locations.

2. REQUIREMENTS

2.1 FUNCTIONAL AND PERFORMANCE

2.1.1 Reactor Shutdown System (RSS) and Rod Control System (RCS) {safety class}

1. Initiate protective actions based on the detection of abnormal plant conditions.
2. Safely shut down the reactor and mitigate the consequences of postulated accidents.
3. Provide control interlocks unless specific required conditions have been met.
4. Provide operators with sufficient information to readily determine the status of the protection system.
5. Provide operators with sufficient information to operate the reactor within the prescribed range and to initiate safety-related actions when required.

2.1.2 Design Basis Values of the RSS and RCS

1. A reactor scram shall be initiated when the neutron output level exceeds the setpoint of 1.45 NF with a $\pm$ 1.0 % uncertainty. {safety class}
2. Time response of the neutron level instrument shall be less than 25 mSec from the time a signal from the neutron sensor exceeds the equivalent of 1 .45 NF until rod release. {safety class}
3. A reactor scram shall be initiated when the reactor period is less than 4.5 Sec with a $\pm$ 0.5 Sec uncertainty. {safety class}
4. The time response of the period trip shall be less than 225 mSec from the time the reactor period is less than 4.5 Sec as sensed from the neutron sensor until rod release. {safety class}
5. An insertion of Outer Shim Control Cylinders (OSCC) shall be initiated when the reactor period is less than 15 seconds with a $\pm$ 0.5 Sec uncertainty. {safety significant}
6. The time response of the reverse function shall be less than 1 Sec from the time the reactor period is less than 15 seconds as sensed from the neutron sensor until initiation of rod motion. {safety significant}
7. A reactor scram shall be initiated when a seismic event with a horizontal acceleration greater than 0.01 g is detected. {safety significant}
8. The time response of the seismic trip shall be less than 25 mSec from the time the trip signal is received from the seismic sensor until rod release including uncertainties. {safety significant}

2.1.3 Reactivity Control Function

The reactivity control function of the system is performed by those portions of the system that control the neutron multiplying characteristics of the reactor core in order to ensure safe operation and shut down of the reactor. This includes the safety rods, outer shims and necks shims and their related controls. {safety class}

2.1.4 Reactor Protection Function

The reactor protection function of the system is performed by those electrical portions of the system that measure process variables and generate signals involved with protective functions. Protective function signals include those that initiate a reactor scram. {safety class}

2.1.5 Nuclear Instrumentation Function

The nuclear instrumentation function of the system is performed by those electrical portions of the system that measure process variables and provide indication of those variables to operators. {safety class}

2.1.6 Displays of Safety Related Facility Parameters

Displays of safety related facility parameters (generally derived from the same sensors associated with protective functions but electrically isolated) and protection system status (e.g., tripped, not tripped, interlocked, bypassed, operable) that are required in order to provide the operator with sufficient information to operate the reactor within prescribed range and to perform manual safety functions, should such action be required. {safety class}

2.1.7 RSS Subsystem Circuitry

1. Safety Rod circuitry performs the following functions:
    a. Prevents withdrawal of safety rods unless all outer and neck shims are at their inner limit. There are no bypasses of this interlock. {safety class}
    b. Override rod withdrawal signals when safety rod insertion or reverse signals are applied. {safety class}
    c. Control movement of safety rods as either individual rods or combinations of individual of rods including all safety rods. {safety significant}
    d. Removes insertion signal to a safety rod that is fully inserted. {safety class}
    e. Prevents withdrawal of safety rods when the neutron start-up source is in motion. {safety significant}
    f. Prevent accidental shorting of 3 phase power supplied to the safety rod drive. {other safety requirement}
    g. Provide indication of safety rod position. {safety significant}
    h. Provide indication of safety rod "clutch". {safety significant}
2. Outer Shim circuitry performs the following functions:
    a. Prevent withdrawal of outer shims unless all safety rod drives are at their upper limits and no safety rods are seated. There are no bypasses of this interlock. {safety class}
    b. Prevents withdrawal of outer shims and neck shims simultaneously. {safety class}
    c. Control movement of outer shims either individually or as a combination of individual shims including all shims. {safety significant}
    d. Prevents withdrawal of outer shims when the neutron start-up source is in motion. {safety class}
    e. Removes insertion signal to an outer shim that is fully inserted. {safety significant}
    f. Override shim withdrawal signals when shim reverse signals are applied. {safety significant}
    g. Provide indication of shim position. {safety significant}A new requirement is being added to insert rods at high neutron levels above 1.1 NF but below 1.45 NF or when reactor period is between 15 seconds and 4.5 Seconds. {safety significant}
3. Neck Shim circuitry performs the following functions:
    a. Prevents withdrawal of outer shims and neck shims simultaneously. {safety class}
    b. Prevent withdrawal of neck shims unless all safety rod drives are at their upper limits and no safety rods are seated. There are no bypasses of this interlock. {safety class}

   c. Control withdrawal of as many as four neck shims simultaneously, while preventing no more than one shim per neck to be withdrawn. {safety class}
   d. Control insertion of neck shims either individually or as a combination of individual shims including all shims. {safety significant}
   e. Prevents withdrawal of neck shims when the neutron start-up source is in motion. {safety class}
   f. Removes insertion signal to a neck shim that is fully inserted. {safety significant}
   g. Override shim withdrawal signals when shim reverse signals are applied. {safety significant}
   h. Provide indication of shim position. {safety significant}
   i. A new requirement is being added to insert rods at high neutron levels above 1.1 NF but below 1.45 NF or when reactor period is between 15 seconds and 4.5 Seconds. {safety significant}
4. Source Control circuitry performs the following functions:
   a. Control movement of the neutron start-up source. {other safety requirement}
   b. Removes insertion signal to the source drive when the source is fully inserted. {other safety requirement}
   c. Removes withdrawal signal to the source drive when the source is fully withdrawn. {other safety requirement}
   d. Provide indication of neutron start-up source position. {other safety requirement}

2.1.8 Non-safety functions of RSS and RCS (safety significant):

1. Provide indication to monitor variables and system performance over the anticipated ranges for normal operation, Anticipated Operational Events (AOEs), and Design Basis Accidents (DBAs) as appropriate to ensure adequate safety.
2. Provide adequate controls to maintain variables and system performance within prescribed ranges.

2.2 RSS SYSTEM, SUBSYSTEMS AND MAJOR COMPONENTS

2.2.1 The Log Count Rate Meter Subsystem {safety significant}

This subsystem is used to bring the reactor critical by providing indication of neutron level. Two channels, each using fission chambers, amplifiers, and a two channel strip-chart recorder. This system also provides indication to ensure the reactor remains shut down during core alterations.

2.2.2 Neutron Level Subsystem {safety class}

Monitors neutron level when the reactor is critical. This is presently accomplished by two channels using ionization chambers, amplifiers, comparators, filter modules and indicators. A buffered output of the neutron level amplifier is continuously displayed on strip-chart recorders.

2.2.3 Log-N/Period Subsystem {safety class}

Monitors neutron level and the rate of change of neutron level when the reactor is critical. This is presently accomplished by two channels using ionization chambers, a log-N/period amplifier, comparator and filter module. A power supply provides a high voltage as well as a compensating voltage for the ionization chamber. The ionization chamber output, a current proportional to neutron flux, is converted in the log-N amplifier to a voltage proportional to the natural logarithm of the neutron flux. This signal is differentiated and inverted in a period amplifier whose output is then a voltage, inversely proportional to reactor period, which is connected to a comparator, which provides an output to the Scram Logic Subsystem through the filter module. Outputs from the log-N/Period amplifier (proportional to log-N and inverse reactor period, respectively) are continuously displayed on strip-chart recorders.

2.2.4 Four (4) ion chambers (safety significant)

The replacement system will utilize four ion chamber located approximately 90º apart from each other to permit better special sensing of neutron flux. The signal from each of these detectors will be amplified and then passed to a linear neutron level channel and a logarithmic level channel that are electrically isolated from each other. The neutron level channels will perform the same function as the existing neutron level channels and the logarithmic level channels will perform the same function as the existing logarithmic level channels.

2.2.5 Manual Scram Subsystem {safety significant}

This subsystem permits operators to manually scram the reactor.

2.2.6 Scram Logic Subsystem {safety class}

This subsystem monitors signals from other subsystems and will initiate a scram when required. This is presently accomplished by monitoring signals from the RSS protective channels and from buffered non-RSS channels and switches the current on or off to each safety rod electromagnet. The subsystem consists of two logic train modules (channels A & B) and five Actuator Controllers (one for each safety rod). Whenever a trip signal is received from any one input, the Scram Logic Subsystem will interrupt the current to all safety rod electromagnets. The replacement system will utilize two-out-of-four-logic such that two scram signals are required to initiate a scram. A new requirement is also being added to also interrupt power to withdraw all outer and neck shim drives to ensure the reactor remains shut down during reactivity addition events.

2.2.7 Non-RSS Scram Subsystem {safety significant}

This subsystem monitors signals from circuits not directly related to reactor control and provides an output to the Scram Logic Subsystem. This is presently accomplished by monitoring the contacts of Console Key Control Power relays, Safety Rod, Neck Shim and Outer Shim Circuit Breakers relays, Loss of Three Phase Power relay, and Seismic Scram relays. When any of these relays open, inputs are provided to the Scram Logic Subsystem.

2.2.8 Other Requirement Considerations. {safety significant}

Consideration should be given to including a new subsystem to permit real time indication of fast neutron flux in 10 different locations distributed through the core. The locations of sensors will be similar to that of the existing N-16 system in ATR.

2.2.9 Rod Control Subsystem

Provide means for controlling movement of the reactor control rods, safety rods, outer shim cylinders, and the neck shim rods as well as movement of the Start-up neutron source. The subsystem functions are presently accomplished by the following circuits:

1. The Safety Rod circuitry performs the following functions:
    a. Prevents withdrawal of safety rods unless all outer and neck shims are at their inner limit. There are no bypasses of this interlock. {safety class}
    b. Override rod withdrawal signals when safety rod insertion or reverse signals are applied. { safety class }
    c. Control movement of safety rods as either individual rods or combinations of individual of rods including all safety rods. {safety significant}
    d. Removes insertion signal to a safety rod that is fully inserted. { safety significant }
    e. Prevents withdrawal of safety rods when the neutron start-up source is in motion. { safety significant }
    f. Prevent accidental shorting of 3 phase power supplied to the safety rod drive. {other safety requirement}
    g. Provide indication of safety rod position. { safety significant }
    h. Provide indication of safety rod “clutch”. { safety significant }
2. The Outer Shim circuitry performs the following functions:
    a. Prevent withdrawal of outer shims unless all safety rod drives are at their upper limits and no safety rods are seated. There are no bypasses of this interlock. { safety class }
    b. Prevents withdrawal of outer shims and neck shims simultaneously. { safety class }
    c. Control movement of outer shims either individually or as a combination of individual shims including all shims. { safety significant }
    d. Prevents withdrawal of outer shims when the neutron start-up source is in motion. { safety class }
    e. Removes insertion signal to an outer shim that is fully inserted. { safety significant }
    f. Override shim withdrawal signals when shim reverse signals are applied. { safety significant }
    g. Provide indication of shim position. { safety significant }
    h. A new requirement is being added to insert rods at high neutron levels above 1.1 NF but below 1.45 NF or when reactor period is between 15 seconds and 4.5 Seconds. { safety significant }
3. The Neck Shim circuitry performs the following functions:
    a. Prevents withdrawal of outer shims and neck shims simultaneously. { safety class }
    b. Prevent withdrawal of neck shims unless all safety rod drives are at their upper limits and no safety rods are seated. There are no bypasses of this interlock. { safety class }
    c. Control withdrawal of as many as four neck shims simultaneously, while preventing no more than one shim per neck to be withdrawn. { safety class }
    d. Control insertion of neck shims either individually or as a combination of individual shims including all shims. { safety significant }
    e. Prevents withdrawal of neck shims when the neutron start-up source is in motion. { safety class }

f. Removes insertion signal to a neck shim that is fully inserted. { safety significant }
g. Override shim withdrawal signals when shim reverse signals are applied. { safety significant }
h. Provide indication of shim position. { safety significant }
i. A new requirement is being added to insert rods at high neutron levels above 1.1 NF but below 1.45 NF or when reactor period is between 15 seconds and 4.5 Seconds. { safety significant }

4. The Source Control circuitry performs the following functions:
   a. Control movement of the neutron start-up source. {other safety requirement}
   b. Removes insertion signal to the source drive when the source is fully inserted. { other safety requirement }
   c. Removes withdrawal signal to the source drive when the source is fully withdrawn. { other safety requirement }
   d. Provide indication of neutron start-up source position. {other safety requirement}

2.3 BOUNDARIES AND INTERFACES

2.3.1 The following major component interfaces are identified:

1. Each Safety Rod is “latched” by the control system to its respective drive mechanism by means of a 50 Henry electric magnet coil. The coil has a nominal 65-80 mA current flow with a nominal 150 VDC applied across the coil. A reactor scram is initiated by de-energizing the electric magnet which permits the safety rod to insert in the core. This magnet is sized to lift a control rod weighing approximately 100 pounds.
2. The safety rod drives are supplied with 208V 3 phase power from the control system. The control system interfaces with the drive motors through relays to control rod movement.
3. The outer and neck shim drives are supplied with 120V single phase power from the control system. The control system interfaces with the drive motors through relays to control shim movement.
4. The neutron source drive is supplied with 120V single phase power. The control system interfaces with the coil of control relays in the control circuitry to control shim movement.
5. The safety rod drive position is sensed by a synchro-generator geared directly to the rod drive. The control system interfaces with this generator to display each of the 5 safety rod positions.
6. The safety rod inner and outer drive limit is sensed by micro-switches.
7. The outer shim drive position is sensed by a mechanical counter geared to the shaft of the outer shim drive motor. An electrical signal is derived from the counter by using a 10 position rotary switch for each of the four digit wheels of the counter with each contact position corresponding to a number on the wheel. The control system interfaces with these switches to display each of the 8 outer shim drive positions.
8. The OSCC inner and outer drive limit is sensed by micro-switches.
9. The neck shim drive position is sensed by a three-turn precision potentiometer. The control system interfaces with this potentiometer to display the position of each of the 24 neck shim drive positions. Each drive also has outer and inner limit micro-switches that the control system interfaces with to sense fully withdrawn or fully inserted position.
10. The neck shim inner and outer drive limit is sensed by micro-switches.

11. The neutron source drive position is sensed by a three-turn precision potentiometer. The control system interfaces with this potentiometer to display the position of the neutron source drive position.
12. The neutron source inner and outer drive limit is sensed by micro-switches.
13. The safety rod "clutch" condition is sensed by a coil in each of the safety rod magnetic cans. The control system interfaces with each coil.
14. The safety rod "seat" condition is sensed by a coil in the base of each of the safety rod snubber tubes. The control system interfaces with each coil. The present control system applies a 1 kHz signal to the coil and detects an impedance increase when the coil is near a magnetic material (the safety rod) by an increase in signal.
15. Fission chamber neutron detectors. The detectors are located in moisture resistant instrument thimbles and are located in the core support tank.
16. Ion chamber neutron detectors. The detectors are located in moisture resistant instrument thimbles and are located external to the core.

2.4 OPERATING ENVIRONMENT

2.4.1 Natural Environmental Phenomena

The ATRC RSS and RCS shall be designed to withstand the effects of earthquakes, tornadoes, and floods without loss of capability to perform their safety functions. {safety class}

1. Appropriate consideration of the most severe of the natural phenomena, historically reported for the site and surrounding area.
2. Reactor scram when a seismic event with a horizontal acceleration greater than 0.01 g is detected.
3. The time response of the seismic trip shall be less than 25 mSec from the time the trip signal is received from the seismic sensor until rod release.

2.4.2 Normal Operation, Maintenance, Testing, Accident Environments

The ATRC RSS and RCS are required to accommodate effects of and be compatible with:

1. Environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents. {safety class}
2. Temperature 55 ºF - 120 ºF, pressure of Atmospheric @ 5000 ft, humidity of 0-90%, and Radiation of 0-10 mR /Hr. {Other safety requirement}

2.5 ENGINEERING DESIGN REQUIREMENTS OF RSS AND RCS

2.5.1 Civil and Structural {other safety requirement}

1. Shall be installed within the foot print of the existing control system.
2. Cabinets shall consist, essentially, of a suitable metal frame, supporting the necessary panel contained in an outer sheet metal enclosure having hinged doors in the rear.
3. Shall be enclosed in Instrument Racks of the floor mounted type and be self-supporting, using an all welded angle or channel steel frame to provide rigid construction.

2.5.2 Electrical: Electronics Cabinet and Panel

1. 480V 3 phase 60Hz commercial input power from a single source. {other safety requirement}
2. 480V 3 phase is stepped down to 208V 3 phase and 120 V single phase. {other safety requirement}
3. Equipment source line voltage must be approximately 115 VAC and the regulation must be at least + 2% for a +10% / -20% change in input voltage. Regulation shall be at least 3% for variations of 0-100% of load. Common mode noise shall be attenuated at least 120 db and transverse mode noise shall be attenuated at least 100 db. {mission critical requirement}
4. This power source is not required to meet Class 1E requirements. Other design features will place the reactor in a safe shutdown condition on a loss of electrical power and no active, electric-powered systems are required for shutdown cooling of the reactor. {other safety requirement}
5. The RSS and RCS shall not be sensitive to AC power frequency variation within the range of 57 to 63 Hz. {other safety requirement}
6. Protective features of the system will prevent accidental shorting of 3 phase power supplied to the safety rod drives. {other safety requirement}
7. The ATRC RSS and RCS shall comply with the requirements of NFPA 70 §409 for Industrial Control Panels. {safety significant}
8. Power conditioning equipment shall be used on all AC power to prevent noise on the electrical distribution system from adversely impacting ATRC operations.
9. May operate in the proximity of or from the same power source as equipment that generates electromagnetic, electric, and magnetic interference signals. {safety class}
10. Shall be assembled and wired to minimize interference pickup from external sources. {safety class}
11. Power supplies, regulators, and other power leads shall be decoupled to minimize conducted interference through power leads. {safety class}
12. Blank panels shall be used to fill all unused spaces in the Electronic Cabinets. {safety class}
13. Provision shall be made to route power and signal cables with as much physical separation as practicable. {safety class}
14. Provision shall be made to separate analog cables from digital cables. {safety class}
15. Signal cables from the neutron detectors and remote pre-amplifiers shall incorporate braided and foil shields. {safety class}
16. Low noise power supplies, amplifiers and resistors shall be used and use lower value resistors in amplifier circuits. {safety class}
17. Circuit board configurations shall incorporate the use of ground planes. {safety class}
18. Switching power supplies should be avoided or compensatory measures added to ensure the supply will not introduce excessive noise. {safety class}

2.5.3 Mechanical and Materials: Electronics Cabinet and Panel {other safety requirement}

1. Shall contain electrical, electronic and electrical mechanical control and instrumentation equipment used for controlling and measuring various operating or safety related parameters.
2. Shall consist of steel enclosures or structures.
3. All instruments shall be flush mounted to a vertical front surface through cut-outs contained on the surface.
4. Shall consist of a standard type multi-bay enclosure with industry standard wide bays to fit in existing locations.

5. Shall be installed on a concrete curb or floor and anchored to the curb by bolting to unistrut embedded in the curb.
6. Shall have structural reinforcement to protect equipment and limit vibration.
7. Shall be of neat appearance outside and inside, with no welds, rivets or bolt heads apparent from front faces of panels.
8. All surfaces, exterior and interior shall be finished and painted.
9. Exterior surfaces shall have a final appearance of a smooth and uniform textured surface, free from pinholes, sags, runs, skips, scratches, dents, orange peel, or any other imperfections.
10. The remaining surfaces shall be uniformly coated, free from pinholes, sags, runs, and skips.
11. The finish shall be nonglare type to minimize light reflections.
12. The finish shall be of the following color:
    a. Interior surface shall be finished in white enamel in accordance with NEMA Standard for type 12 enclosures.
    b. Outside surface shall be painted with enamel and colored ANSI No. 61 Light Gray.

2.5.4 Instrumentation and Control

Shall be designed to perform all required safety functions for a design basis event in the presence of the following: {safety class}

a. Any single detectable failure within the safety systems concurrent with all identifiable, but non-detectable failures
b. All failures caused by the single failure
c. All failures and spurious system actions that cause, or are caused by, the design basis event requiring the safety function as identified in IEEE 603-1998 and IEEE Std 379-2000.

2.5.5 Instrumentation and Control Requirements

1. A systematic analysis of the final design shall be performed to confirm that violations of the single-failure criterion do not exist. The analysis shall be performed in a manner similar to that identified in IEEE Std 352-1987. The requirements of IEEE 7.4.3.2-2003 are also applicable for designs that utilize digital technology. {safety class}
2. Additionally, where a single random failure in a non-safety system can result in a design basis event, and also prevent proper action of a portion of the safety system designed to protect against that event, the remaining portions of the safety system shall be capable of providing the safety function even when degraded by any separate single failure. (DOE 5480.30, GDC Criterion 21, 25) {safety class}
3. Once initiated automatically or manually, the intended sequence of protective actions of the execute features shall continue until completion as identified in IEEE 603-1998. Deliberate operator action shall be required to return the safety systems to normal. (DOE 5480.30, GDC Criterion 20, 29, BNL-50831-III) {safety class}
4. Components and modules shall be of a quality that is consistent with minimum maintenance requirements and low failure rates to ensure an extremely high probability of accomplishing their safety functions in the event of AOEs as identified in IEEE 603-1998.
5. The system equipment shall be designed, manufactured, inspected, installed, tested, operated, and maintained in accordance with ASME NQA-1-2004. (DOE 5480.30, GDC Criterion 21) {safety class}

6. Redundant portions of the system, provided for a safety function shall be independent of, and physically separated from each other to the degree necessary to retain the capability of accomplishing the safety function during and following any design basis event requiring that safety function as identified in IEEE 603-1998. (DOE 5480.30, GDC Criterion 24) {safety class}
7. Equipment required to mitigate the consequences of a specific design basis event shall be independent of, and physically separated from the effects of the design basis event to the degree necessary to retain the capability of meeting the requirements of IEEE 603-1998. {safety class}
8. Credible failures in and consequential actions by other systems of the design basis, such as faults, loss of electrical input power, shall not prevent the safety systems from meeting the requirements of IEEE 603-1998. (DOE 5480.30, GDC Criterion 23, BNL-50831-III) {safety class}
9. Equipment that is used for both safety and non-safety functions shall be classified as part of the safety systems as identified in IEEE 603-1998. Isolation devices used to affect a safety system boundary shall be classified as part of the safety system. (DOE 5480.30) {safety class}
10. No credible failure on the non-safety side of an isolation device shall prevent any portion of the systems from meeting its minimum performance requirements during and following any design basis event requiring that safety function as identified in IEEE 603-1998. A failure in an isolation device shall be evaluated in the same manner as a failure of other equipment in a safety system. (DOE 5480.30, GDC Criterion 24, BNL-50831-III) {safety class}
11. Equipment in other systems that is in physical proximity to the ATRC RSS and RCS equipment, but is not an associated circuit shall be physically separated from the safety system equipment to the degree necessary to retain the safety system's capability to accomplish their safety functions in the event of the failure of non-safety equipment as identified in IEEE 603-1998. Physical separation may be achieved by physical barriers or acceptable separation distance. (DOE 5480.30, BNL-50831-III) {safety class}
12. Capability for testing and calibration of the ATRC RSS and RCS equipment shall be provided while retaining the capability of the safety systems to accomplish their safety functions as identified in IEEE 603-1998. The capability for testing and calibration of safety system equipment shall duplicate, as closely as practicable, performance of the safety function. (DOE 5480.3, GDC Criterion 21) {safety class}
13. Display instrumentation shall provide accurate, complete, and timely information pertinent to safety system status as identified in IEEE 603-1998. This information shall include indication and identification of protective actions of the sense and command features and execute features. {safety class}
14. Instrumentation shall monitor the values of safety-related facility parameters and system performance over their anticipated ranges for normal operation, anticipated operational events (AOE), and design basis accident (DBA) as appropriate to ensure adequate safety. {safety class}
15. Instrumentation design shall minimize the possibility of ambiguous indications that could be confusing to the operator. The display instrumentation provided for safety system status indication need not be part of the safety systems. (DOE 5480.30, GDC Criterion 13, BNL-50831-III) {safety class}

16. If the protective actions of some part of a safety system have been bypassed or deliberately rendered inoperative for any purpose other than an operating bypass, continued indication of this fact for each affected safety group shall be provided in the control room as identified in IEEE 603-1998. {safety class}
    a. This display instrumentation need not be part of the safety systems.
    b. This indication shall be automatically actuated if the bypass or inoperative condition is expected to occur more frequently than once a year, and is expected to occur when the affected system is required to be operable.
    c. The capability shall exist in the control room to manually activate this display indication.
17. Information displays shall be located accessible to the operator as identified in IEEE 603-1998. (DOE 5480.30, GDC Criterion 13, BNL-50831-III) {safety class}
18. The design shall permit the administrative control of access to safety system equipment as identified in IEEE 603-1998. These administrative controls shall be supported by provisions within the safety systems, by provision in the ATRC design, or by a combination thereof. Power to the ATRC RSS and RCS will be controlled by a switch with key control to maintain positive control of the reactor when the facility is not manned. {safety class}
19. The safety systems shall be designed to facilitate timely recognition, location, replacement, repair, and adjustment of malfunctioning equipment as identified in IEEE 603-1998. (GDC Criterion 21, 22) {safety significant}
20. In order to provide assurance that the requirements given in IEEE 603-1998 can be applied during the design, construction, maintenance, and operation of the plant, the following requirements shall be met: {other safety requirement}
    a. Safety system equipment shall be distinctly identified for each redundant portion of a safety system in accordance with the requirements of IEEE Std 420-2001.
    b. Components or modules mounted in equipment or assemblies that are clearly identified as being in a single redundant portion of a safety system do not themselves require identification.
    c. Identification of safety system equipment shall be distinguishable from any identifying markings placed on equipment for other purposes (e.g., identification of fire protection equipment, phase identification of power cables).
    d. Identification of safety system equipment and its divisional assignment shall not require frequent use of reference material.
    e. The versions of computer hardware, programs, and software shall be distinctly identified in accordance with IEEE Std 7-4.3.2-2003.
21. Human factors shall be considered at the initial stages and throughout the design process to assure that the functions allocated in whole or in part to the human operator(s) and maintainer(s) can be successfully accomplished to meet the safety system design goals, in accordance with IEEE Std 1023-2004 as identified in IEEE 603-1998. ISA-RP60.3–1985, Human Engineering for Control Centers, NUREG-700, Human-System Interface Design Review Guidelines, INEL-95/117, Human Factors Engineering Checklists for Application in the SAR Process, and EDF-TRA-ATR-1738, Human Factors Engineering Analyses of ATRC for the ATRC SAR shall be considered during the design development. {safety class}
22. Appropriate analysis of the design shall be performed in order to confirm that PRA reliability goals have been achieved. IEEE Std 352-1987 and IEEE Std 577-2004 provide guidance for

reliability analysis. Guidance on the application of these criteria for safety system equipment employing digital computers and programs or firmware is found in IEEE Std 7-4.3.2-2003. The probability of a component failure that prevents the RSS and RCS from performing its required function shall be less than 10^{-7} failures per year. {safety class}

23. Plant parameters shall be maintained within acceptable limits established for each design basis event in the presence of a single common cause failure (See IEEE 379-2000). IEEE Std 7-4.3.2-2003 provides guidance on performing an engineering evaluation of software common cause failures, including use of manual action and non-safety-related systems, or components, or both, to provide means to accomplish the function that would otherwise be defeated by the common cause failure. (DOE 5480.30, GDC Criterion 25) {safety significant}
24. Means shall be provided to automatically initiate and control all protective actions as identified in IEEE 603-1998. (DOE 5480.30, GDC Criterion 20) {safety class}
25. Means shall be provided in the control room to implement manual initiation at the division level of the automatically initiated protective actions as identified in IEEE 603-1998. The means provided shall minimize the number of discrete operator manipulations and shall depend on the operation of a minimum of equipment consistent with the redundancy constraints previously identified. {safety significant}
26. Where a single credible event, including all direct and consequential results of that event, can cause a non-safety system action that results in a condition requiring protective action, and can concurrently prevent the protective action in those sense and command feature channels designated to provide principal protection against the condition, one of the following requirements shall be met as identified in IEEE 603-1998: (DOE 5480.30, GDC Criterion 20, 21, 22, 23, 24, 25, BNL-50831-III) {safety class}
27. Alternate channels not subject to failure resulting from the same single event shall be provided to limit the consequences of this event to a value specified by the design basis. Alternate channels shall be selected from the following:
    a. Channels that sense a set of variables different from the principal channels.
    b. Channels that use equipment different from that of the principal channels to sense the same variable.
    c. Channels that sense a set of variables different from those of the principal channels using equipment different from that of the principal channels.
    d. Both the principal and alternate channels shall be part of the sense and command features.
    e. Equipment not subject to failure caused by the same single credible event shall be provided to detect the event and limit the consequences to a value specified by the design bases. Such equipment is considered a part of the protection system.
28. To the extent feasible and practical, sense and command feature inputs shall be derived from signals that are direct measures of the desired variables as specified in the design basis as identified in IEEE 603-1998. {safety significant}
29. Means shall be provided for checking, with a high degree of confidence, the operational availability of each sense and command feature input sensor required for a safety function during reactor operation as identified in IEEE 603-1998. This may be accomplished in various ways; for example: (DOE 5480.30, GDC Criterion 21, 22) {safety significant}
    a. By perturbing the monitored variable,

   b. Within the constraints of operating bypasses by introducing and varying, as appropriate, a substitute input to the sensor of the same nature as the measured variable, or
   c. By cross-checking between channels that bear a known relationship to each other and that have readouts available.
30. One of the following means shall be provided for assuring the operational availability of each sense and command feature required during the post-accident period as identified in IEEE 603-1998: {safety significant}
   a. Checking the operational availability of sensors by use of the methods described above.
   b. Specifying equipment that is stable and the period of time it retains its calibration during the post accident time period.
31. Whenever the applicable permissive conditions are not met, a safety system shall automatically prevent the activation of an operating bypass or initiate the appropriate safety function(s) as identified in IEEE 603-1998. If plant conditions change so that an activated operating bypass is no longer permissible, the safety system shall automatically accomplish one of the following actions: (DOE 5480.30, GDC Criterion 20, 21, 22) {safety class}
   a. Remove the appropriate active operating bypass(es).
   b. Restore plant conditions so that permissive conditions once again exist.
   c. Initiate the appropriate safety function(s).
   d. Capability of a safety system to accomplish its safety function shall be retained while sense and command features equipment is in maintenance bypass as identified in IEEE 603-1998. During such operation, the sense and command features should continue to meet the above requirements. (DOE 5480.30, GDC Criterion 20, 21, 22) {safety class}
32. Capability shall be incorporated in the execute features to receive and act upon automatic control signals from the sense and command features as identified in IEEE 603-1998. (DOE 5480.30, GDC Criterion 20, 21, 22) {safety class}
33. If manual control of any actuated component in the execute features is provided, the additional design features in the execute features necessary to accomplish such manual control shall not defeat the requirements of single failure criteria and manual control requirements as identified in IEEE 603-1998. Capability shall be provided in the execute features to receive and act upon manual control signals from the sense and command features consistent with the design basis. {safety class}
34. Protection system instrumentation and controls sufficient for placing the reactor in a safe shutdown condition should be provide in a location remote from the control room for use during any condition which may make the control room uninhabitable. (e.g., fire). As a minimum, this should include the ability to scram the reactor from a remote location. (BNL-50831-III) {safety significant}
35. The reactivity control circuits shall be capable of reliably controlling reactivity changes to ensure that under conditions of normal operation, including AOEs, and with appropriate margin for malfunctions such as stuck rods, specified acceptable design limits are not exceeded. {safety class}
36. The reactivity control circuits shall be capable of reliably controlling the rate of reactivity changes resulting from planned, normal power changes to ensure acceptable design limits are not exceeded. The circuits shall be capable of holding the reactor core subcritical under cold conditions. (DOE 5480.3, GDC Criterion 26) {safety class}

37. The ATRC RSS and RCS shall be designed to remove power from the outer shim control cylinder (OSCC) and/or neck shim rod drives when a reactor scram is initiated to ensure termination of reactivity addition events. (TRA-ATRC-1759) {safety class}
38. The ATRC RSS and RCS shall be designed to detect neutron levels and calculate the reactor period from detected neutron levels. Release of the Safety Rods and removal of power to reactivity addition circuitry shall occur upon high neutron level or low reactor period. A manual initiation backup shall also be provided which shall consist of a single large Red Scram button. Once initiated, the protective actions shall go to completion (e.g., the release of safety rods cannot be stopped in mid-sequence) (BNL-50831-III) {safety class}
39. The Outer Shim Control Cylinder Drives shall be capable of operating at the present speed and multiple lower speeds to permit varying the speed / amount of reactivity changes. The speed shall be selectable by the operator. Features shall be included to preclude excessive positive reactivity additions. {mission critical requirement}
40. The Logarithmic Count Rate Source Range neutron flux monitoring instrument shall be used to continuously monitor neutron flux level in the range of 1 (10^0) to 1 (10^4) nv while the detector is in the presence of gamma fluxes up to 2 (10^6) R/hr. The instrument shall have a response time of <7 sec for a step change from 1 cps to 10 cps and <50 msec for a step change from (10^3) cps to (10^4) cps. The instrument uncertainty shall be < 2% at (10^4) cps and a linearity and repeatability of 2% of full scale. The instrument shall have two independent channels that consist of a fission chamber neutron detector, a remote pre-amplifier, and an electronic chassis providing proper signal conditioning, display, internal methods to permit channel calibration, methods to permit monitoring of instrument performance and provide detector excitation power. The lowest measurable neutron flux shall be limited by the allowable statistical fluctuations in the signal from the detector. The circuit shall not be switched in any manner to produce the required range. This instrument shall meet the following requirements: {safety significant}
    a. Neutron Detectors shall be fission chamber thermal neutron detectors. The detectors shall be capable of operating in a maximum neutron flux of (10^5) nv and in the presence of gamma flux up to 2 (10^6) R/hr. The neutron sensitivity of the fission chamber is 0 .7 counts/sec per nv .The detector shall have a counting loss <2% at 10 cps from a random source. The design temperature of the detectors shall be at least 175 ºF. The Fission Chamber shall be designed to operate in conditions of high humidity and must fit in the existing instrument thimbles. The detector must be guarded; that is, there shall be no direct leakage path from the high voltage electrode to the signal electrode. The detector shall have separate signal and high voltage connections. To minimize the effects of induced noise in the cable, the detector shall be supplied with integral cables and the cables and detector shall be independently sealed. The detector and cables shall be enclosed in, but electrically isolated from, a cylindrical electrostatic shield can and conduit or outer triaxial sheath. The shield can and conduit or triaxial sheath shall be designed to allow the addition of ceramic or equivalent insulators to prevent the detector and signal cable grounds from touching the reactor ground. The insulated conduit surrounding the cables shall be rigidly and electrically connected to the detector electrostatic shield can to provide a continuously shielded assembly. The chamber shall be connected to the pre-amplifier through a low leakage shielded cable so as not to impair pulse resolution at 10 counts per second.

b. The output signals from the fission chamber neutron detectors will input to a remote pre-amplifier. Leakage resistance at the signal end shall be greater than (10^{11}) ohms. Amplifier response rise time shall be no greater than 9.2 micro-second. The noise level of the preamplifier shall not be more than 15 micro-volts referenced to the input terminal. The preamplifier shall accept pulses from the fission chamber over a cable length of 50 feet and shall be capable of driving the output pulses over a cable length of 180 feet.

c. The output signals from the remote pre-amplifier will input to a linear amplifier. The input sensitivity of the amplifier shall not be less than 1 millivolt. The rise time - bandwidth of the amplifier shall be selected by a panel switch as follows:

Rise Time	Decay	Time Bandwidth
5.0 μ sec	25.0 μ sec	0.1 MHz
0.8 μ sec	4.0 μ sec	0.5 MHz
0.2 μ sec	0.4 μ sec	2.0 MHz

The maximum amplification of the amplifier for each bandwidth shall be as follows:

Bandwidth	Maximum Voltage Gain
0.1 MHz	15,000
0.5 MHz	10,000
2.0 MHz	6,000

The amplifier shall be provided with an input attenuator adjustable from 0 to 30 db. The linearity of the amplifier shall be within $\pm$1% throughout its range. The amplifier shall be supplied with a pulse height selector adjustable through the full range of amplification. The linearity of the pulse height selector shall be within $\pm$1%. Built in adjustable count rate and period calibration circuits for instrument alignment shall be provided for periodic testing. The system outputs shall be a linear function of neutron flux from the lowest measurable value up to at least 1 (10^5) nv and a non-decreasing function of neutron flux up to at least 3 (10^{10}) nv in order to meet fold-over requirements.

d. The instrument power supply shall supply fission chamber high voltage with $\pm$ 0.1% regulation for a 10% change in load or input voltage and peak to peak ripple less than 5 mV. The power supply shall also provide other required DC voltage including that to the remote pre-amplifier with $\pm$ 0.1% regulation for a 10% change in load or input voltage and peak to peak ripple less than 5 mV. Indication of the high voltage for each channel shall be available.

e. The Logarithmic Count Rate indicator will be driven by the linear amplifier pulse height selector output. The minimum signal to trigger the rate indicator shall be a 1.0 volt, 0.3 micro second pulse. The standard deviation of the Logarithmic Count Rate indicator shall be no greater than 3.0% gross. The count rate zero shall not drift more than five percent of scale per day.

f. The Instrument shall be capable of determining the reactor period and linear rate of change of neutron level.
g. The system shall provide an audible output of the pulses for use at a remote location. This signal shall consist of a sharp "pop" (for each pulse) and shall be effective up to 500 cps. {SS}
h. Built in adjustable count rate and period calibration circuits for alignment shall be provided for automatic periodic circuit testing.

41. The neutron flux monitoring instrument shall be used to continuously monitor neutron flux level in the range of 1 (10^2) to 1 (10^{10}) nv while the detector is in the presence of gamma fluxes up to (10^5) R/hr to permit an Operator to raise the Critical Facility's neutron flux level through the intermediate power range to a desired final level at a controlled rate. The instruments shall provide an output signal to initiate a reactor scram whenever the neutron level or period signals exceed identified setpoints. The instrument uncertainty shall have a linearity and repeatability of 0.2% of full scale. The instruments shall have four separate channels that consist of a gamma-compensated ionization chamber to give reliable measurements of the neutron flux over a wide range in the presence of gamma radiation, a power supply for the ionization chamber and an electronic chassis providing proper signal conditioning, display, internal methods to permit channel calibration, methods to permit monitoring of instrument performance, provide detector excitation power, feed the protection system scram logic and provide buffered outputs to calculate reactivity based on in-hour equation methodologies. This instrument shall meet the following requirements: {safety class}
    a. Thermal Neutron Detectors to be used in the intermediate range neutron instruments shall be gamma compensated ionization chambers designed to operate with fixed electrical compensation and an electrostatic shield can and cable conduit capable of withstanding a maximum operating flux of 5 (10^{11}) nv while simultaneously exposed to incident gamma fluxes of up to 10^5 R/hr. The sensitivity of the chamber shall be no less than 3 (10^{-14}) amps per nv. The sensitivity of the chamber to gamma rays shall be no greater than 5 (10^{-13}) amps per R/hr. The detector design temperature is 175ºF and the detector shall be designed to operate in conditions of high humidity. The detector shall be of a guard-ring design and construction to minimize inter-electrode leakage currents. Cables shall be attached to the detector to allow the excitation voltages to be applied to the electrodes and to extract the direct current output signal. The detector and cables shall be enclosed in but electrically isolated from a cylinder electrostatic shield can and conduit to prevent electrical contact of the entire assembly with reactor internals. The detector assembly output current signal shall be a linear function of neutron flux from the lowest measurable value up to at least (10^{11}) nv and a non-decreasing function of neutron flux up to at least (10^{12}) nv in order to meet foldover requirements. Four separate sensors are required to ensure adequate redundancy and spatial sensing from locations outside the core.
    b. The neutron detectors shall provide a signal to a linear amplifier. The amplifier shall be capable of receiving signals from 5 (10^{-13}) to 1.5 (10^{-4}) amps. The dynamic range of the

amplifier shall be 3 (10^6) to 1. The amplifier shall have an uncertainty of less than 1% and a drift of less than 1% of full scale. The output of the amplifier shall range from 0 at (10^{-12}) amps to a maximum at (10^{-4}) amps. The time response of the amplifier output shall meet the following requirements:

Current Change	Time response
(10^{-12}) to (10^{-11})	< 0.5 second
(10^{-11}) to (10^{-4})	< 0.2 millisecond

c. The instrument power supply shall provide detector high voltage with $\pm$ 0.1% regulation for a 10% change in load or input voltage and peak to peak ripple less than 5 mV. The power supply shall also provide other required DC voltage including detector compensating voltage from minus 0 to 300 VDC adjustable over the full range with $\pm$ 0.1% regulation for a 10% change in load or input voltage and peak to peak ripple less than 5 mV. Indication of the detector high voltage and compensating voltage for each channel shall be available.

d. The amplifier shall provide an output signal to the RSS for automatic protective actions. The output of the amplifier shall be adjustable to permit increases in level to account for changes in N_F. The Log N amplifier shall contain an internal current calibration source to supply at a minimum, (10^{-10}) amperes and ($^{10-5}$) amperes. A buffered output of each channel shall be provided to permit non-safety related conditioning of the neutron flux level.

42. The RSS shall consist of four channels that receive inputs from the four neutron flux monitoring instrument linear amplifiers, condition these signals and cause the release of all safety rods when either the neutron flux level has exceeded 1.45 N_F or reactor period is less than 4 seconds as sensed from two or more channels. The release of the safety rods shall occur within 25 msec of a high neutron flux being sensed at the neutron detector or within 225 msec of a low reactor period being sensed at the neutron detector. This system shall meet the following requirements:
    a. Receive signals from the neutron flux monitoring instrument linear amplifiers and determine the logarithm of neutron flux and the derivative of the log (inverse period) of neutron flux.
    b. Electrically isolated output signals of linear flux level, logarithmic flux level and reactor period shall be provided for display of these parameters for all four channels.
    c. Output signals shall be provided to current interrupting devices to cause a release of all safety rods. The output signal shall use positive logic such that two or more channels changing to zero logic will cause rod release. Current interrupting devices shall be circuit breakers or vacuum relays that are capable of withstanding the voltage transient associated with collapsing the electromagnetic field of the Safety Rods electric magnet 50 Henry coil. Related circuitry shall also be protected as necessary to withstand this voltage transient and comply with rod release requirements.
43. The RCS shall consist of a power supply and necessary control features to provide power and interrupt power to the Safety Rod electro-magnetic coils, and necessary control features to

provide power to the Outer Shim Control Cylinder and Neck Shim drive mechanisms to permit normal reactor operations and minimize challenges to the RSS. This system shall meet the following requirements:

a. Provide a source of 150 VDC power to Safety Rod electro-magnetic coils capable of regulating and monitoring current to the individual coils from 0-175 mA.
b. Provide the following Safety Rod control features:
   i) Safety Rods can not be withdrawn unless the following conditions exist:
      1) The neutron source is not in motion {safety significant}
      2) The Reactor Period is greater than 15 seconds {safety significant}
      3) A Rod Reverse or insertion is not in progress {safety significant}
      4) Safety Rods are not already fully withdrawn {safety significant}
      5) All Outer Shim Control Cylinders are fully inserted {safety class}
      6) All Neck Shim Rods are fully inserted {safety class}
      7) Neutron flux levels are high enough to be reliably indicated {safety class}
   ii) An override of the above interlocks will be provided to permit withdrawal of the drive mechanism if all Safety Rods are not latched. {other safety requirement}
   iii) Movement of safety rods will be selectable as a single rod or as multiple rods including the entire group. {safety significant}
   iv) Insertion of a Safety Rod may occur unless the rod is seated. {safety significant}
c. Provide the following Outer Shim Control Cylinders (OSCC) control features:
   i) OSCC cannot be withdrawn unless the following conditions exist:
      1) All Safety Rods drives are at their upper limit {safety class}
      2) No Safety Rods are seated {safety class}
      3) A Rod Reverse or insertion is not in progress {safety significant}
      4) Neutron flux levels are high enough to be reliably indicated {safety class}
      5) Reactor period is greater than 20 seconds {safety significant}
      6) The neutron source is not in motion {safety significant}
      7) Neck Shim Rods are not being withdrawn {safety class}
      8) OSCCs drive are not at their upper limit {safety significant}
   ii) Movement of OSCCs will be selectable as a single drive or as multiple drives including the entire group. {safety significant}
   iii) An automatic reversal of the OSCCs will occur if any of the following conditions exist:
      1) Neutron flux is greater than 1.15 N_F {safety significant}
      2) Period is less than 15 seconds {safety significant}
   iv) Insertion of a OSCC may occur unless the drive is at the lower limit {other safety requirement}
d. Provide the following Neck Shim Rods control features:
   i) Neck Shim Rods can not be withdrawn unless the following conditions exist:
      1) All Safety Rods drives are at their upper limit {safety class}
      2) No Safety Rods are seated {safety class}

3) A Rod Reverse or insertion is not in progress {safety significant}
4) Neutron flux levels are high enough to be reliably indicated {safety class}
5) Reactor period is greater than 20 seconds {safety significant}
6) The neutron source is not in motion {safety significant}
7) OSCCs are not being withdrawn {safety class}
8) Neck Shim Rod drives are not at their upper limit {other safety requirement}

ii) Withdrawal of Neck Shim Rods will be selectable as a single shim or as multiple shims up to one shim per neck. Insertion of Neck Shim Rods will be selectable as a single shim or as multiple shims including the entire group. {safety significant}

iii) An automatic reversal of the Neck Shim Rods will occur if any of the following conditions exist:
1) Neutron flux is greater than 1.1 NF {safety significant}
2) Period is less than 15 seconds {safety significant}

iv) Insertion of a Neck Shim Rod may occur unless the drive is at the lower limit {other safety requirement}

e. The Neutron Source will have the following interlocks:
  i) The Neutron Source can be withdrawn unless the drive is at the upper limit {other safety requirement}
  ii) Insertion of the Neutron Source may occur unless the drive is at the lower limit {other safety requirement}

f. Provide a means of automatically and periodically testing the above interlocks and functionally testing the system.

g. Provide a means of displaying the conditions of the above interlocks

44. The following displays of RSS and RCS parameters shall be provided:
  a. A display shall include a graphic of the ATRC and will include the following information with links to additional details:
    i) Display of the ATRC components and relative locations. Links shall be available to track components / experiments loaded in each available location.
    ii) Display status of each rod drive inner and outer limit switch.
    iii) Display when a Rod drive is selected and status of motion interlocks. Links shall be available to identify condition of the complete motion logic.
    iv) Display Safety Rod warning when any of the following conditions exist:
      i. All Safety Rod drives not at the outer limit and an OSCC or a Neck Shim drive not at the inner limit.
      ii. Safety Rod drive greater than 6 inches and clutch not seated.
    v) Digital value display of the eight OSCC drive positions with 0.1^{o} uncertainty.
    vi) Display shall include indication of a reactor Scram.
    vii) Bar graph and digital value display of both Logarithmic Count Rate instruments
    viii) Bar graph and digital value display of neutron source position
    ix) Bar graph and digital value display of the four logarithmic neutron level instruments.

x) Bar graph and digital value display of the four reactor period instruments.
xi) Bar graph and digital value display of the four linear neutron level instruments.

b. Displays shall be available for each channel of the Logarithmic Count Rate system and shall include the following:
   i) The display shall include four cycle logarithmic scale trend graphs to display one hour of data, four cycle logarithmic scale bar graphs and digital indicators.
   ii) The logarithmic scale displays shall be four decades, from one count per second to 10^4 counts per second.
   iii) The trend graph shall display the Logarithmic Count Rate for its respective channel and the difference between the two channels.
   iv) Two bar graphs shall display the Logarithmic Count Rate for its respective channel and the difference between the two channels.
   v) Two digital indicators shall display the Logarithmic Count Rate for its respective channel and the difference between the two channels.
   vi) The Instrument shall be capable of displaying the reactor period or linear rate of change of neutron level. Period should be displayed on a hyperbolic scale from -30 to infinity to +3. The linear rate of change of neutron level should also be able to be displayed in decades per minute (DPM) from -1 to zero to +3. Information shall be presented as a graphical trend, a bar graph and an instantaneous digital value.

c. Displays shall be available for each channel of the neutron level system and shall include the following:
   i) Displays shall include six cycle logarithmic scale trend graphs to display one hour of data, six cycle logarithmic scale bar graphs and digital indicators.
   ii) The logarithmic scale displays shall be six decades, from (10-3) to 300. Omit the 1.0 division marker and substitute the letters NL. Omit the 100 division marker and substitute the letters NF.
   iii) The logarithmic scale trend graph shall display the neutron level for its respective channel and the difference between the maximum of the four channels from the minimum of the four channels.
   iv) Two logarithmic scale bar graphs shall display the logarithmic neutron level for its respective channel and the difference between the maximum and minimum channels.
   v) Two digital indicators shall display the logarithmic neutron level for its respective channel and the difference between the maximum and minimum channels.
   vi) Displays shall include hyperbolic scale trend graphs to display one hour of data, hyperbolic scale bar graphs and digital indicators.
   vii) The hyperbolic scale displays shall be from -30 to infinity to +3.
   viii) The hyperbolic scale trend graph shall display the reactor period for its respective channel and the difference between the maximum of the four channels reactor period from the minimum of the four channels reactor period.

ix) The hyperbolic scale bar graphs shall display the reactor period for its respective channel and the difference between the maximum of the four channels reactor period from the minimum of the four channels reactor period.
x) Two digital indicators shall display the reactor period for its respective channel and the difference between the maximum and minimum channel reactor periods.
xi) Displays shall include linear scale trend graphs to display one hour of data, linear scale bar graphs and digital indicators.
xii) The linear scale displays shall be from -1 to +3.
xiii) The linear scale trend graph shall display the linear rate of change of neutron level for its respective channel and the difference between the maximum of the four channels linear rate of change of neutron level from the minimum of the four channels linear rate of change of neutron level.
xiv) The linear scale bar graphs shall display the linear rate of change of neutron level for its respective channel and the difference between the maximum of the four channels linear rate of change of neutron level from the minimum of the four channels linear rate of change of neutron level.
xv) Two digital indicators shall display the linear rate of change of neutron level for its respective channel and the difference between the maximum and minimum channel linear rate of change of neutron level.
xvi) Displays shall include linear scale trend graphs to display one hour of data, linear scale bar graphs and digital indicators.
xvii) The linear scale displays shall be from 0 to 120.
xviii) The linear scale trend graph shall display the neutron level for its respective channel and the difference between the maximum of the four channels neutron level from the minimum of the four channels neutron level. The display shall be of one color when neutron level is increasing between 0-12 and change to a different color when level is between 12 and 120. When neutron levels are decreasing from the high level, the color change will occur at 10. The display will include indication of which channel is the highest indicating channel and which is the lowest indicating channel.
xix) The linear scale bar graphs shall display the neutron level for its respective channel and the difference between the maximum of the four channels neutron level from the minimum of the four channels linear rate of change of neutron level. Color changes will occur as described above.
xx) Two digital indicators shall display the neutron level for its respective channel and the difference between the maximum and minimum channels.

d. Displays shall be available for the neutron source drive and shall include the following:

   i) Displays shall include a linear scale bar graph and digital indicator.
   ii) The linear scale display shall be from 0 to 50 Inches.
   iii) Displays shall indicate when the source drive is at the inner or outer limit and when the drive is being inserted or withdrawn.

e. Displays shall be available for status of the RSS and shall include the following:

i) Display shall include indication of a reactor Scram from high neutron level, low reactor period or high seismic activity. This indication shall remain "Locked in" until acknowledged by the Operator.

f. Displays shall be available for status of the RCS and shall include the following:
   i) A display of Safety Rod conditions shall include the following:
      1) Display status of each rod drive inner and outer limit switch.
      2) Display digital value of each rod drive position
      3) Bar graph display of each rod drive position from 0-36".
      4) Display Rod selected
      5) Display insertion and withdrawl motion of each drive.
      6) Display when a safety rod is not at the outer limit and a OSCC or a Neck Shim is not at the inner limit, a Safety Rod is withdrawn greater than 6 inches and the respective clutch is not seated, and if interlocks for motion are not met. Links shall be available to identify condition of the complete motion logic.
      7) Display Rod clutch engaged
      8) Display Rod seat engaged
   ii) A display of Neck Shim conditions shall include the following:
      1) Display status of each rod drive inner and outer limit switch.
      2) Display digital value of each rod drive position
      3) Bar graph display of each rod drive position from 0-48".
      4) Display Rod selected
      5) Display insertion and withdrawl motion of each drive.
   iii) Display shall include indication of a rod reversal from high neutron level or low reactor period. This indication shall remain "Locked in" until acknowledged by the Operator.

g. Acceptable displays are included as attachments.

45. Consideration should be given to 10 Fast Neutron Detectors being installed in the reactor to permit real time monitoring of the flux imbalance and provide a diverse method of monitoring neutron flux and rate of flux change in the core. Detectors must be capable of being installed within existing locations within the core. The detector must be able to withstand wetted conditions or be placed in thimbles that will fit in existing locations. If thimbles are required, they must be constructed and routed in a manner that will not impact inisertion of experiments in the ATRC. 8 existing locations are 3/4 inch diameter and 2 locations are 5/8 inch diameter. The response time of the detectors must be fast enough to permit use of the signals in protection circuitry. The system must be capable of performing calculations to determine quadrant power levels. {safety significant}
46. A method shall be provided to digitally record RSS and RCS data. Data records may be continuously updated, stored in computer memory, displayed on demand and / or exported in a typical format. {mission critical requirement}

2.5.6 Fire Protection

The ATRC RSS and RCS shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and heat resistant materials shall be used wherever practical throughout the unit, particularly in locations such as the control room. Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on SSC important to safety. {safety significant}

2.5.7 Testing and Maintenance Requirements

1. Testability

The safety systems shall be designed to be testable as identified in Section 5 of ANSI/IEEE Std 338-1987 during operation of the reactor as well as during those intervals when the station is shut down. This testability shall permit the independent testing of redundant channels and load groups while (1) maintaining the capability of these systems to respond to valid signals, or (2) tripping the output of the channel being tested, if required, or (3) bypassing the equipment consistent with safety requirements and limiting conditions for operation. {safety significant}

2. TSR-Required Surveillance {safety class}
3. Non-TSR Inspections and Testing
    a. Test Requirements specify that periodic tests are performed to verify protection system interlocks. {safety significant}
    b. The ATRC RSS and RCS shall be designed to automatically determine Safety Rod release times and Rod Drop times {other safety requirement}.
    c. The ATRC RSS and RCS shall be designed to semi-automatically determine minimum required Safety Rod Magnet Current {other safety requirement}
    d. Computer systems shall include a normally active internal audit circuit which shall present an appropriate signal to Operators in the event of a malfunction or failure. {safety significant}