GUIDANCE ON THE ASSESSMENT OF A BWR SLC SYSTEM FOR pH CONTROL

Introduction

The purpose of this document is to provide the staff with guidance for assessing the acceptability of reliance on the Standby Liquid Control (SLC) system to control the pH of the water in a boiling water reactor (BWR) suppression pool following a loss-of-coolant-accident (LOCA).

The SLC system was originally designed as a backup system to shut down the reactor if the control rods failed to function. The SLC system is also used to shut down the reactor during an anticipated transient without scram (ATWS) event. The system injects sodium pentaborate into the reactor vessel. At some facilities, a new function has been proposed for the SLC system. This function results from the licensees' desire to implement the Alternative Source Term (AST) as their design basis for accident analyses. This new function is the control of the pH in the suppression pool following the plant's design-basis LOCA. The design basis LOCA is a double-ended guillotine break of a recirculation line.

The development of the AST resulted in a change in the assumption in the distribution of the chemical forms of iodine. The AST postulates that the chemical form of iodine released from the fuel would be approximately 95% particulate (CsI) and 5% elemental. Previously these distributions had been 5% and 91%, respectively. Following a LOCA, the water in the suppression pool is expected to become acidic (pH < 7) unless a chemical is added to the pool within 24 hours following the initiation of the LOCA. If the pool water remains acidic, the CsI in the pool will dissociate and the resulting elemental iodine will be released from the suppression pool. This would result in airborne concentrations of radioactive iodine in the containment atmosphere. It is preferable to maintain the suppression pool basic (pH > 7) so that the iodine remains in a more soluble form as CsI .

Most licensees of BWRs have designated the SLC system as the system that will be used to maintain the water in the suppression pool basic. This new function for SLC is an accident mitigation function. Associated with the performance of an accident mitigation function are: (1) high reliability, usually demonstrated by the capability to overcome a single **"**active**"** failure and (2) an expected quality (safety-related) for the system and components designated to perform such a function. AST amendment requests have been submitted in which the SLC system was credited for pH control even though the SLC system could be considered susceptible to a single **"**active**"** failure. Hence, its reliability is not readily established and, in some cases, the system is not designated as safety-related.

An AST amendment requires the staff to conclude that the dose criteria of GDC 19 , "Control room," and 10 CFR 50.67, "Alternate source term," are met. The licensee's calculations to demonstrate that these criteria are met would require a different analysis approach if pH control of the suppression pool could not be demonstrated.

This document has been developed to provide the staff with guidance for assessing those applications where the SLC system is susceptible to single failure, where the system may not be safety-related or any other case where the SLC system is missing a quality commonly required of an engineered safety function (ESF) grade system.

Background

As part of the original operating license review, the SLC system was generally reviewed using guidance provided in SRP 9.3.5, "Standby Liquid Control System (BWR)." The review was performed to determine the adequacy of the SLC shutdown function to assure compliance with the requirements of GDC 2, "Design bases for protection against natural phenomena," GDC 26, "Reactivity control system redundancy and capability," and GDC 27, "Combined reactivity control systems capability." The effects of abnormal operational conditions and accident conditions, such as a LOCA, were considered during the review. The SLC system was also reviewed for the effects of natural phenomena (flooding, tornados, and earthquake) - SRPs 3.3.1, 3.3.2, 3.5.3, 3.7.1 through 3.7.4, 3.8.4 and 3.8.5; for the design of components, piping and structures in accordance with applicable codes and standards - SRPs 3.9.1 through 3.9.5, and the seismic and quality group classification - SRPs 3.2.1 and 3.2.2; for inservice inspection of pipes and valves - SRPs 3.9.6 and 6.6; for the adequacy of the design, installation inspection and testing of electrical components - SRPs 7.1 and 8.1; and for fire protection, technical specification, quality assurance and equipment qualification for mechanical and electrical systems - SRPs 9.5.1, 16.0, 17.0 and 3.11. In addition, the SLC system is also now reviewed against 10 CFR 50.62(c)(4), "Requirements for reduction of risk from anticipated transients without scram (ATWS) events for light-water-cooled nuclear power plants."

Regulatory Evaluation

In developing the guidelines for reviewing the SLC reliability and quality for AST, the staff considered the following guidance from Regulatory Guide 1.183 (RG 1.183), "Alternative Radiological Source Terms For Evaluating Design Basis Accidents At Nuclear Power Reactors":

> "*5.1.2 Credit for Engineered Safeguard Features*
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> *Credit may be taken for accident mitigation features that are* ***classified as safety-related****, are required to be operable by technical specifications, are powered by emergency power sources, and are either automatically actuated or, in limited cases, have actuation requirements explicitly addressed in emergency operating procedures.* ***The single active component failure that results in the most limiting radiological consequences should be assumed.*** *Assumptions regarding the occurrence and timing of a loss of offsite power should be selected with the objective of maximizing the postulated radiological consequences.*"
> (Emphasis added)

The regulatory guide contains guidance on what is generally acceptable to the staff. This paper discusses alternative approaches for demonstrating reliability and quality when the regulatory guide is not literally met.

The staff also considered those aspects of GDC 1, "Quality standards and records," and GDC 4, "Environmental and dynamic effects design bases," which apply to the expected quality of safety systems, and GDC 41, "Containment atmosphere cleanup," as it applies to the new SLC function for suppression pool pH control. Like RG 1.183, GDC 41 includes consideration of a single failure[1] ("*Each system shall have suitable redundancy in components and features, and suitable interconnections, leak detection, isolation, and containment capabilities to assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) its safety function can be accomplished, assuming a single failure*.")

Since pH control of the suppression pool following the design basis LOCA is a new safety function, no individual SLC design was originally reviewed for this new safety function against either quality-related GDCs or GDC 41, and they are not strictly applicable. However, 10 CFR 50.92, "Issuance of amendments" states in part:

> "*(a) In determining whether an amendment to a license or construction permit will be issued to the applicant, the Commission will be guided by the considerations which govern the issuance of initial licenses or construction permits to the extent applicable and appropriate.....*"

Therefore, in accordance with the language in 50.92(a), the staff should consider these GDCs "to the extent applicable and appropriate" for the new safety function. (Since these GDCs are not explicitly part of the current licensing basis for SLC, consideration of exemptions under 10 CFR 50.12, "Specific exemptions," is not required.) The appropriate consideration of GDC 41 is to apply the intent of the single failure clause in the context of reviewing the SLC system as a system performing a safety function[2], in meeting the dose criteria in 10 CFR 50.67.

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[1] *Single failure:* A single failure means an occurrence which results in the loss of capability of a component to perform its intended safety functions. Multiple failures resulting from a single occurrence are considered to be a single failure. Fluid and electric systems are considered to be designed against an assumed single failure if neither (1) a single failure of any active component (assuming passive components function properly) nor (2) a single failure of a passive component (assuming active components function properly), results in a loss of the capability of the system to perform its safety functions. (Single failures of passive components in electric systems should be assumed in designing against a single failure. **The conditions under which a single failure of a passive component in a fluid system should be considered in designing the system against a single failure are under development.)** [10 CFR 50 Appendix A - emphasis added]

[2] *Safety Function*: Any function that is necessary to assure (1) the integrity of the reactor coolant system pressure boundary, (2) the capability to shut down the reactor and maintain it in a safe shutdown condition, or (3) the capability to prevent or mitigate the consequences of conditions of design which could result in potential offsite exposures that are a significant fraction of Title 10, Code of Federal Regulations, part 100, "Reactor Site Criteria guidelines exposures. [Taken from: ANSI/ANS-58.9-1981, "American National Standard Single Failure Criteria for Light Water Reactor Safety-Related Fluid Systems."]

Reliability Guidance

Both RG 1.183 and GDC 41 contain consideration of a single active failure that could prevent performance of the safety function. SECY-77-439, "Single Failure Criterion," August 17, 1977 states: "*The Single Failure Criterion, as a design and analysis tool, has the direct objective of promoting reliability through the enforced provision of redundancy in those systems which must perform a safety-related function*." Thus, the single failure criterion is not considered to be an end in itself, but a means to achieve adequate reliability. SECY-77-439 further notes that "... *it is not assumed that any conceivable failure could occur... . In general, only those systems or components which are judged to have a credible chance of failure are assumed to fail when the Single Failure Criterion is applied*."

SECY-77-439 also makes a distinction between single active failure, the term used in RG 1.183, and single passive failure in application of the single failure criterion. For GDC 41, SECY-77-439 states:

> "*General Design Criterion 41 - Containment Atmospheric Cleanup - requires systems to control fission product, hydrogen, oxygen, and other substances which may be released into containment. These systems must be capable of functioning with either onsite or offsite power. Contaminants can enter containment due to a variety of events, such as a LOCA. The Single Failure Criterion is applied subsequent to the postulated event and, in evaluating these systems,* ***only active failures are considered*** *(emphasis added), except in instances where components may be shared with ECCS systems. In such cases, the possibility of seal leakage is considered in the long-term ECCS recirculation mode.*"

The narrowing of the application of the single failure to include only single active failures, when considered along with the objective of achieving adequate reliability, supports the inference that passive single failures were judged to have a low enough probability that they need not be considered (postulated) in reviewing the design of systems. Thus, the essential issue is again one of reliability, and classification of active or passive was a rule-of-thumb way to establish a qualitative reliability threshold to refine the application of the single failure criterion in the absence of operating experience and quantitative reliability analysis.

With the objective of demonstrating high reliability, the SLC system should be reviewed to identify any component whose failure to perform its intended safety function alone could fail the SLC safety function of injecting sodium pentaborate for suppression pool pH control. Piping and structures such as tanks may be excluded; all components which change position, energize, or actuate to accomplish the injection function should be included, including simple check valves even if they were previously excluded from single failure criterion review as "passive" (see Appendix A for a further discussion of single failure considerations including check valve failures). If no such components or failures are identified (i.e., the SLC consists of two or more independent 100% capacity subsystems with independent injection paths) then the system is presumed to have high reliability based on redundancy. If single failure components are identified, then the licensee has the option of (1) demonstrating that the single failure

components do not materially degrade the overall reliability of the SLC system to inject sodium pentaborate for suppression pool pH control, (2) demonstrating another (additional) success path for suppression pool pH control, or (3) performing the AST analysis without credit for suppression pool pH control (as indicated in RG 1.183). Option (1) requires a reliability evaluation of the system, with special attention to any single failure components. The details are provided in the "Review Guidelines" below.

Quality Guidance

GDC 1 and GDC 4 address quality standards: (1) Structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed, and (2) Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents.

GDC 2, "Design bases for protection against natural phenomena," also addresses quality and was considered during the initial review of the SLC system (see SRP 9.3.5). Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

The SLC system should be classified as ESF grade in accordance with 10 CFR 50.34(b) or as a safety-related system as defined in 10 CFR 50.2, and satisfy the regulatory requirements for such systems.

There may be plants with an SLC system that is not classified as safety-related or as ESF grade. In such instances, the staff reviewer will determine whether the SLC system is comparable to a system classified as safety-related or ESF. An SLC system meeting items (a)-(e) below would result in its acceptance in support of a 10 CFR 50.67 request even if the system is not classified as safety-related or as ESF grade.

(a) The SLC system should be provided with standby AC power supplemented by the emergency diesel generators.

(b) The SLC system should be seismically qualified in accordance with Regulatory Guide 1.29 and Appendix A to 10 CFR Part 100.

(c) The SLC system should be incorporated into the plant's ASME Code ISI and IST Programs based upon the plant's code of record (10 CFR 50.55a).

(d) The SLC system should be incorporated into the plant's Maintenance Rule program consistent with 10 CFR 50.65.

(e) The SLC system should meet 10 CFR 50.49 and Appendix A (GDC 4) to 10 CFR 50.

These considerations have been consolidated into the “Review Guidelines” for reviewing licensee’s submittals requesting use of the SLC system for suppression pool pH control as part of an AST amendment.

Review Guidelines

For the purposes of BWR AST applications, the function of the SLC system is to:

> Inject within 24 hours of a LOCA a sufficient amount of sodium pentaborate solution into the reactor vessel to maintain suppression pool pH $\geq$ 7.0 for 30 days.

To demonstrate that the SLC system is capable of performing its AST function, the SLC system should meet the following guidelines:

1. The SLC system should be classified as ESF grade in accordance with 10 CFR 50.34(b) or as a safety-related system as defined in 10 CFR 50.2, and satisfy the regulatory requirements for such systems.

   There may be plants with an SLC system which is not classified as safety-related or as ESF grade. In such instances, the staff reviewer will determine whether the SLC system is comparable to a system classified as safety-related or ESF. A SLC system meeting items (a)-(e) below would result in its acceptance in support of a 10 CFR 50.67 request even if the system is not classified as safety-related or as ESF grade.

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   (d) The SLC system should be incorporated into the plant's Maintenance Rule program consistent with 10 CFR 50.65.

   (e) The SLC system should meet 10 CFR 50.49 and Appendix A (GDC 4) to 10 CFR 50.

2. The licensee should have plant procedures for injecting the sodium pentaborate using the SLC system. This information would be reviewed by the appropriate technical review branch, as requested by the lead SPSB reviewer.

   (a) A review of the procedures may be appropriate if a reliability approach is taken (4(a) below) due to timing considerations for the injection of chemicals.

   (b) The SLC activation steps are placed in a safety-related plant procedure.

(c) The steps be activated by parameters that are symptoms of imminent or actual core damage.

(d) The instrumentation relied upon to provide this indication meets the quality requirements for a Type E variable as defined in RG 1.97 Tables 1 and 2.

(e) Personnel receive initial and periodic refresher training in the procedure.

(f) Other plant procedures (e.g., ERGs/SAGs) that call for termination of SLC as a reactivity control measure are appropriately revised to enable SLC injection for pH control.

3. A sufficient concentration and quantity of sodium pentaborate should be available for injection into the reactor vessel to control pH in the suppression pool.

The source term analysis is tied to the plant's design basis accident, which is the large break LOCA, a break of a recirculation pipe. The licensee needs to demonstrate that within 24 hours there is adequate recirculation between the suppression pool and the reactor vessel through flow out the break to provide transport and mixing, consistent with the assumptions in the chemical analyses.

4. The SLC system should not be rendered incapable of performing its AST function due to a single failure of an active component. For this purpose the check value is considered an active device for AST since the check valve must open to inject sodium pentaborate for suppression pool pH control.

If the SLC system can not be considered redundant with respect to its active components, this lack of redundancy may be offset if the licensee can satisfy (a) or (b) or (c) below:

(a) Acceptable quality and reliability of the non-redundant active components and/or compensatory actions in the event of failure of the non-redundant active components.

Under this approach, the licensee should provide the following information in justifying the lack of redundancy of active components in the SLC system:

(1) The licensee should identify the non-redundant active components in the SLC system and provide their make, manufacturer, and model number. The staff reviewer will compare this information with performance data for the component from industry data bases and other sources.

(2) The licensee should provide the design-basis conditions for the component and the environmental and seismic conditions under which the component may be required to operate during a design-basis accident. Environmental conditions include design-basis pressure, temperature, relative humidity and radiation

fields. The staff reviewer will compare the environmental and seismic conditions associated with the design-basis accident to the conditions for which the component was designed to determine whether the component is capable of performing its intended function.

(3) The licensee should indicate whether the component was purchased in accordance with Appendix B to 10 CFR Part 50. If the component was not purchased in accordance with Appendix B, the licensee should provide information on the quality standards under which it was purchased. For the latter situation, information on the component would be reviewed by the appropriate technical review branch responsible for the component, as requested by the lead SPSB reviewer.

(4) The licensee should provide the performance history of the component both at the licensee's facility and in industry databases such as EPIX and NPRDS. The staff reviewer will use this information to evaluate the reliability of the component relative to other components used in safety-related applications.

(5) The licensee should provide a description of its inspection and testing program including standards, frequency, and acceptance criteria. The staff reviewer will use this information to evaluate the licensee's activities to monitor the component's performance at the facility. The information on the component would be reviewed by the appropriate technical review branch responsible for the component, as requested by the lead SPSB reviewer.

(6) The licensee should also indicate potential compensating actions that could be taken within an acceptable time period to address the failure of the component. An example of a compensating action might be the ability to jumper a switch in the control room to overcome its failure. The staff reviewer will consider the availability of compensating actions and the likelihood of successful injection of the sodium pentaborate where non-redundant active components fail to perform their intended functions.

(b) An alternative success path for injecting chemicals into the suppression pool.

If the licensee chooses to address the SLC system's susceptibility to single failure by selecting an alternative injection path, the alternative path must be capable of performing the AST function noted above and all components which make up the alternative path should meet the same quality characteristics required of the SLC system (described in Items 1(a)-1(e), 2 and 3 above). When the staff determines that an alternative path is acceptable, the staff's safety evaluation should address the manner in which the SLC system and the alternative path met Items 1(a)-1(e), 2 and 3 above.

If the use of an alternate path is part of the EOPs, then the license amendment needs to address the following items: (1) Does the alternate injection path

require actions in areas outside the control room? (2) How accessible will these areas be? (3) What additional personnel will be required?

(c) 10 CFR 50.67 and Appendix A, General Design Criterion (GDC) 19 doses are met even if pH is not controlled.

The licensee may demonstrate, through dose calculations, that 10 CFR 50.67 and GDC 19 doses are met even if pH is not controlled. The re-evolution of iodine in the particulate form from the water in the suppression pool to the elemental form for airborne iodine must be incorporated into the calculation. The calculation may take credit for the mitigating capabilities of other equipment, for example the standby gas treatment system (SGTS), if such equipment would be available. The staff will perform calculations to confirm the licensee's conclusions. If the acceptability of the facility's dose calculations was based on the utilization of certain ESF equipment, for example the SGTS, then the staff's safety evaluation should reflect this. Such a citation is necessary to assure that it is recognized and documented that there is a link between the particular ESF component's performance and the SLC system's susceptibility to single failure .

Appendix A - Single Failure Considerations

Most of the SLC system designs, see Figure 1, that the staff is aware of have a single injection line which penetrates the containment. Two check values, one inside containment and one outside containment, in this line provide containment isolation (close, which may be considered a “passive” function) and allow injection (open, which may be considered an “active” function). These valves can be considered single failure points in most plants, as failure to open would fail the safety function to inject sodium pentaborate.

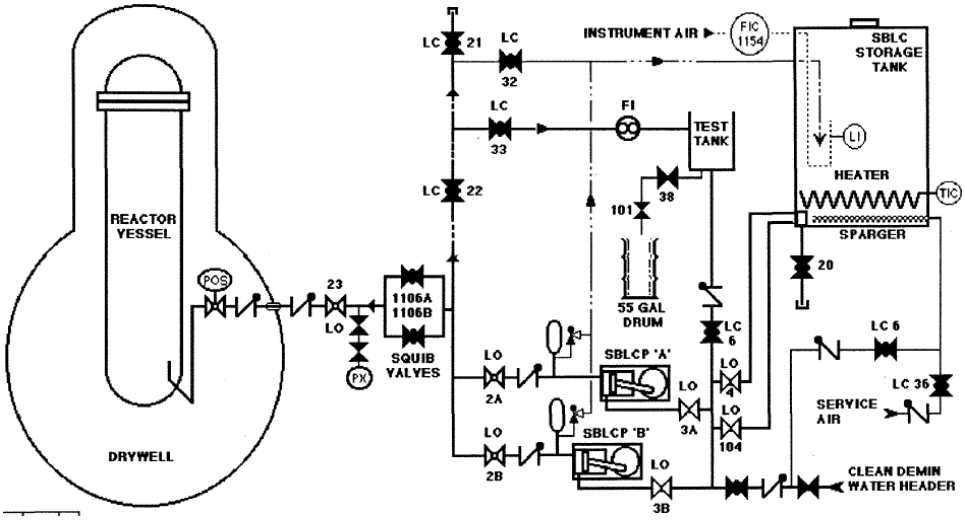

Figure 1 -Typical Standby Liquid Control System (BWR Mark I)

The classification of a check valve as “active” or “passive” for failure considerations is historically problematic. For example:

> (1) Single Failure Criterion: Under “Passive Failure in a Fluid System,” SECY-77-439 states: “*A passive failure in a fluid systems means a breach in the fluid pressure boundary or a mechanical failure which adversely affects a flow path. Examples include the failure of a simple check valve to move to its correct position when required* ...” and later in SECY-77-439, “... *the staff does consider the effects of certain passive failures (e.g., check valve failure* ... .” While SECY-77-439 describes an active failure in a fluid system as “*(1) the failure of a component which relies on mechanical movement for its operation to complete its intended function, or (2) an unintended movement of the component*,” which could describe the operation of a check valve, the list of examples is specifically limited to motor- or air-operated valves (no mention of check valves). The further statement that *“In some instances such failures can be induced by operator error*,” and the specific citation of check valves under “passive failure” has resulted in the consideration of only passive failure modes for check valves during design reviews. The original design reviews of the SLC system as an alternative shutdown system (for example, Perry, Grand Gulf, and Hope Creek) found no single active failure could fail

the injection function; thus, the check valves on the single injection line were considered to only have “passive” failure modes.

(2) Inservice Testing (IST): For IST, check valves are considered as having active failure modes.

(3) License Renewal: The check valve disc/pin/hinge (moving parts) are considered active, while the valve body is considered passive.

(4) In ANSI/ANS-58.9-1981, for example, passive failure (for a fluid system) is defined as “a failure of a component to maintain its structural integrity or the blockage of a process flow path. Blockage of a process flow path could occur, for example, due to separation of a valve disc from its stem.” Examples of the active failure (for a fluid system) definition include “the failure of a powered valve or check valve to move to its correct position, or the failure of a pump, fan, or diesel generator to start.”

The SLC system has always been covered in technical specifications, and these check valves have been periodically tested for both failure to close (containment isolation), and failure to open (pentaborate injection). This operating experience should be factored into a review to validate the high reliability of these valves, independent of the “active” or “passive” classification.