U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REGULATORY RESEARCH

December 1998
Division 1
Draft DG-1074

DRAFT REGULATORY GUIDE

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DRAFT REGULATORY GUIDE DG-1074

STEAM GENERATOR TUBE INTEGRITY

This regulatory guide is being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. It has not received complete staff review and does not represent an official NRC staff position.

Public comments are being solicited on the draft guide (including any implementation schedule) and its associated regulatory analysis or value/impact statement. Comments should be accompanied by appropriate supporting data. Written comments may be submitted to the Rules and Directives Branch, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001. Copies of comments received may be examined at the NRC Public Document Room, 2120 L Street NW., Washington, DC. Comments will be most helpful if received by **June 30, 1999.**

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A. INTRODUCTION

The steam generator (SG) tubes in pressurized water reactors have a number of important safety functions. These tubes are an integral part of the reactor coolant pressure boundary (RCPB) and, as such, are relied upon to maintain the primary system's pressure and inventory. As part of the RCPB, the SG tubes are unique in that they are also relied upon as a heat transfer surface between the primary and secondary systems such that residual heat can be removed from the primary system; the SG tubes are also relied upon to isolate the radioactive fission products in the primary coolant from the secondary system. In addition, the SG tubes are relied upon to maintain their integrity, as necessary, to be consistent with the containment objectives of preventing uncontrolled fission product release under conditions resulting from core damage severe accidents.

In this regulatory guide, tube integrity means that the tubes are capable of performing their intended safety functions consistent with the licensing basis, including applicable regulatory requirements.

Concerns relating to the integrity of the tubing stem from the fact that the SG tubing is subject to a variety of corrosion and mechanically induced **degradation mechanisms**[1] that are widespread throughout the industry. These degradation mechanisms can impair tube integrity if they are not managed effectively.

Title 10 of the Code of Federal Regulations establishes the fundamental regulatory requirements with respect to the integrity of the SG tubing. Specifically, several General Design Criteria (GDC) in Appendix A,[2] "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," are applicable to the integrity of the steam generator tubes.

GDC-1, "Quality Standards and Records," states in part that structures, systems, and components important to safety must be designed, fabricated, and tested to quality standards commensurate with the importance of the safety functions to be performed.

GDC-2, "Design Basis for Protection Against Natural Phenomena," states in part that structures, systems, and components important to safety must be designed to withstand the effects of natural phenomena without loss of capability to perform their safety functions.

GDC-4, "Environmental and Dynamic Effects Design Basis," states in part that structures, systems, and components important to safety are to be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. These structures, systems, and components must be protected against dynamic effects that may result from equipment failures and from conditions and effects outside the nuclear unit. However, dynamic effects associated with postulated pipe ruptures in nuclear power units

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[1]Words in bold-faced type are defined in "Definitions" in Section B.

[2]For PWR facilities licensed prior to the promulgation of Appendix A to 10 CFR Part 50, similar requirements may appear in the plant licensing basis.

may be excluded from the design basis when analyses that have been reviewed and approved by the NRC demonstrate that the probability of piping rupture is extremely low under conditions consistent with the design basis for the piping.

GDC-14, "Reactor Coolant Pressure Boundary," states that the RCPB shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.

GDC-30, "Quality of Reactor Coolant Pressure Boundary," states that components that are part of the RCPB must be designed, fabricated, erected, and tested to the highest quality standards practical. Means are to be provided for detecting and, to the extent practical, identifying the location of the source of the reactor coolant leakage.

GDC-32, "Inspection of Reactor Coolant Pressure Boundary," states that components that are part of the RCPB are to be designed to permit periodic inspection and testing of important areas and features to assess their structural and leaktight integrity.

Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 establishes the quality assurance requirements for the design, construction, and operation of safety-related components. The pertinent requirements of this appendix apply to all activities affecting the safety-related functions of these components; these include, in part, inspection, testing, operation, and maintenance. Criteria IX, XI, and XVI of Appendix B are particularly noteworthy with respect to the integrity of the steam generator tubing. Criterion IX, "Control of Special Processes," requires that measures be established to ensure that special processes, including welding, heat treating, and nondestructive testing, are controlled and accomplished by qualified personnel using qualified procedures in accordance with applicable codes, standards, specifications, criteria, and other special requirements. Criterion XI, "Test Control," requires in part that a test program be established to assure that all testing required to demonstrate that structures, systems, and components will perform satisfactorily in service is identified and performed in accordance with written test procedures which incorporate the requirements and acceptance limits contained in applicable design documents. Criterion XVI, "Corrective Action," requires, in part, that measures be established to assure that conditions adverse to quality are promptly identified and corrected.

This regulatory guide describes a method acceptable to the NRC staff for monitoring and maintaining the integrity of the SG tubes at operating pressurized water reactors (PWRs). It also provides guidance on evaluating the radiological consequences of design basis accidents involving leaking SG tubing in order to demonstrate that guidelines in 10 CFR Part 100, "Reactor Site Criteria," regarding offsite doses and GDC 19 regarding control room operator doses, can be met. This guide applies only to PWRs.

Regulatory guides are issued to describe to the public methods acceptable to the NRC staff for implementing specific parts of the NRC's regulations, to explain techniques used by the staff in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with regulatory guides is not required. Regulatory guides are issued in draft form for public comment to involve the public in developing the regulatory positions. Draft regulatory guides have not received complete staff review; they therefore do not represent official NRC staff positions.

The information collections contained in this draft regulatory guide are covered by the requirements of 10 CFR Part 50, which were approved by the Office of Management and Budget, approval number 3150-0011. The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number.

B. DISCUSSION

As part of the plant licensing basis, applicants for a PWR operating license analyze the consequences of postulated design basis accidents that assume degradation of the SG tubes such that primary coolant leaks to the secondary coolant side of the steam generators. Examples of such accidents are a steam generator tube rupture (SGTR), a main steam line break (MSLB), a locked rotor, and a control rod ejection. Analyses of these accidents consider the primary-to-secondary leakage that may occur during these postulated events when demonstrating that radiological consequences do not exceed the 10 CFR Part 100 guidelines, or some fraction thereof, for offsite doses, nor GDC-19 for control room operator doses. NUREG-0800, the Standard Review Plan (SRP) (Ref. 1), would be used by the staff to evaluate these accidents. This regulatory guide also provides acceptable alternative guidelines concerning the assessment of the radiological consequences of SGTR and MSLB accidents.

Consistent with the GDC, 10 CFR 50.55a(c) specifies that components that are part of the reactor coolant pressure boundary must be designed and constructed to meet the requirements for Class 1 components in Section III of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Ref. 2). To ensure the continued integrity of the tubing at operating PWR facilities, 50.55a further requires that throughout the service life of a PWR facility, Class 1 components meet the requirements in Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components" of the ASME Code (Ref. 2). This requirement includes the inspection and **tube repair criteria** of Section XI of the ASME Code. However, an exception is provided for design and access provisions and preservice examination requirements in Section XI. In addition, 10 CFR 50.55a(b)(2)(iii) states that if the technical specification surveillance requirements for steam generators differ from those in Article IWB-2000 of Section XI of the ASME Code, the inservice inspection program is governed by the technical specifications.

A plant's technical specifications, which are typified by the standard technical specifications in References 3, 4, and 5, require that licensees perform periodic inservice inspections of the SG tubing and repair or remove from service (by installing plugs in the tube ends) all tubes exceeding the tube repair limit. In addition, operational leakage limits are included in the technical specifications to ensure that, should tube leakage develop, the licensee will take prompt action to avoid rupture of the leaking tubes. These requirements are intended to ensure that **burst** margins are maintained consistent with Appendices A and B to 10 CFR Part 50 and that the potential for leakage is maintained consistent with what has been analyzed as part of the plant licensing basis.

Revision 1 of NRC Regulatory Guide 1.83, "Inservice Inspection of Pressurized Water Reactor Steam Generator Tubes" (Ref. 6), provides guidance concerning SG inspection scope and frequency and nondestructive examination (NDE) methodology. Regulatory Guide 1.83 is referenced in the SRP and is intended to provide a basis for reviewing inservice inspection criteria in the technical specifications. However, this guidance will be superseded by the final version of this regulatory guide.

NRC Regulatory Guide 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes" (Ref. 7), provides guidelines for determining the tube repair criteria and operational leakage limits that are specified in the technical specifications. These guidelines are superseded by this regulatory guide.

SUMMARY OF APPROACH

This regulatory guide provides an acceptable programmatic framework for monitoring and maintaining the integrity of the SG tubes consistent with Appendices A and B to 10 CFR Part 50 and the plant licensing basis. This framework includes **performance criteria** that, if satisfied, provide reasonable assurance that tube integrity is being maintained consistent with the licensing basis. In addition, this framework provides for monitoring and maintaining the tubes to ensure that the performance criteria are met at all times between scheduled inspections of the tubes.

Figure 1 provides a flow chart illustration of the overall program strategy embodied in this regulatory guide, including each of the major program elements.

Procedures for implementing these program elements are to be developed by the utilities. This regulatory guide provides broad guidelines concerning the key considerations, parameters, and constraints that should be addressed as part of the development of these program elements to ensure that tube integrity performance can be effectively monitored and controlled. These guidelines are intended to provide licensees with the flexibility to adjust the specifics of the program elements within the constraints of these guidelines to reflect new information, new NDE technology, new degradation mechanisms or **defect types**, changes in flaw growth rates, and other changing circumstances. Licensees must develop and implement **steam generator defect specific management (SGDSM)** strategies to fully achieve this flexibility. SGDSM strategies involve an integrated set of program elements, paralleling those in this regulatory guide, that address specific defect types.

As shown in Figure 1, the first program element consists of tube inspections using NDE methods in accordance with Regulatory Position 1 of this regulatory guide. These inspections are intended to provide information concerning the defect types present in the SGs and to identify tubes containing defects and the size of these defects. This information is used as part of other program elements, discussed below, to assess tube integrity performance relative to the performance criteria, to determine which tubes fail to satisfy the applicable tube repair criteria (and which must, therefore, be repaired or removed from service by plugging), and to assess needed improvements in measures being taken to mitigate **active degradation mechanisms and defect types.**

Guidelines for determining the appropriate frequency of inspection and level of tube sampling are provided in Regulatory Position 1. Guidelines for NDE data acquisition and analysis are given in Regulatory Position 1.2. **NDE techniques** and **NDE personnel** should be **qualified for detection** in accordance with the guidelines of Regulatory Position 1.2.1. Using NDE techniques and NDE personnel that are qualified for detection constitute a minimum acceptable approach that, in conjunction with implementation of the other programmatic elements of this regulatory guide, ensures that the tube integrity performance criteria will be met until the next scheduled inspection. If available, NDE techniques and NDE personnel that are also **validated for detection** and **validated for sizing** should be used. Validation involves quantifying the defect detection and sizing performance of NDE techniques and personnel. This information, if available, affords the licensee additional flexibility within the framework of this regulatory guide for ensuring that the performance criteria will be met until the next scheduled inspection.

The tube inspections are followed by assessments of tube integrity performance relative to performance criteria. Performance criteria acceptable to the NRC staff are given in Regulatory Position 2 of this regulatory guide. These performance criteria address three areas of tube integrity performance: structural integrity, operational leakage integrity, and accident-induced leakage integrity. These performance criteria are expressed in terms of parameters that are directly measurable or that may be calculated on the basis of direct measurements. The criteria correspond to conditions under which public health and safety is assured.

Performance criteria for tube structural integrity that are acceptable to the NRC, as identified in Regulatory Position 2.1.1, involve deterministic safety factors against burst that are consistent with the original design and licensing basis; namely, factors of safety consistent with the stress limits of Section III of the ASME Code (Ref. 2). Alternatively, licensees may submit a proposed change to the licensing basis to permit use of probabilistically based performance criteria for tube structural integrity, as identified in Regulatory Position 2.1.2, which are consistent with GDC-14. Proposed changes should be risk-informed and give appropriate consideration to defense in depth (i.e., the containment function of steam generator tubes). Guidance for submitting risk-informed proposed changes to the licensing basis is provided in Regulatory Guide 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis" (Reference 8).

Performance criteria acceptable to the NRC for accident leakage integrity are identified in Regulatory Position 2.3. These involve **accident leakage rates** consistent with those assumed in the licensing basis accident analyses for purposes of demonstrating that the accident consequences are in accordance with 10 CFR Part 100, or some fraction thereof, and GDC-19. For most plants, the leakage rates assumed in these analyses are based on operational leakage limits in the technical specifications. Licensees may submit a proposed change to the licensing basis updating the accident analyses to accommodate revisions to the performance criteria for accident leakage. The staff encourages licensees to follow risk-informed approaches when submitting such proposals following the guidance in Reference 8. Such proposals should be supported by an assessment of the radiological consequences in accordance with Regulatory Position 9.

Tube integrity performance is subject to two different types of assessments, as indicated in Figure 1: a **condition monitoring** assessment in accordance with Regulatory Position 3 of this regulatory guide and an **operational assessment** in accordance with Regulatory Position 4. The condition monitoring assessment is "backward looking" in that its purpose is to confirm that tube integrity has been maintained since the previous inspection. Condition monitoring involves an assessment of the "as found" condition of the tubing relative to the tube integrity performance criteria. The "as found" condition refers to the condition of the tubes during an SG inspection outage, prior to any plugging or repair of tubes. The condition monitoring assessment may utilize information from the tube inspections or from alternative examination methods to assess the condition of the tubing. Failure of one or more tubes to satisfy the performance criteria may be indicative of programmatic deficiencies in the licensee's program for monitoring SG tube integrity. Licensees should assess the causal factors associated with this type of finding and implement appropriate corrective actions. The condition monitoring assessment and implementation of resulting corrective actions, if necessary, should be completed prior to plant restart.

The operational assessment differs from the condition monitoring assessment in that it is "forward looking" rather than "backward looking." Its purpose is to demonstrate reasonable assurance that the tube integrity performance criteria will be met throughout the period prior to the next scheduled tube inspection. Operational assessment involves projecting the condition of the tubing at the time of the next scheduled inspection outage relative to the tube integrity performance criteria. This projection is based on the inspection results, the tube repair criteria to be implemented for each defect type, and the time interval prior to the next scheduled tube inspection. Corrective actions should be taken, as necessary, such that it can be demonstrated by operational assessment that the performance criteria will be met until the next scheduled inservice inspection. Corrective actions may include inspecting the steam generators at more frequent intervals or reducing the tube repair criteria. A preliminary operational assessment and implementation of corrective actions, as necessary, should be completed prior to plant restart, demonstrating that the performance goals will continue to be met for at least 90 days following plant restart. The final operational assessment and additional corrective actions, as necessary, should be completed within 90 days of plant restart, demonstrating that the performance criteria will continue to be met prior to the next scheduled inspection.

Plugging and repair of **defective tubes** is performed in accordance with Regulatory Position 5, prior to plant restart, based on the results of the tube inspections and operational assessment (or preliminary operational assessment). Plugging and repair of defective tubes is intended to ensure that tubes remaining in service will meet the tube integrity performance criteria until the next scheduled tube inspection.

Regulatory Position 5.1 provides guidelines for determining the appropriate repair limits for each defect type. An acceptable repair limit that is applicable to all defect types is the 40% through wall, depth-based criterion, subject to demonstrating by operational assessment that the performance criteria will be met until the next scheduled tube inspection. Licensees may submit proposed changes to the technical specifications to permit implementation of alternative repair criteria (ARC) for specific defect types as part of an SGDSM strategy. Such proposals should be risk-informed and give appropriate consideration to defense in depth (i.e., the containment function of steam generator tubes). SGDSM is an integrated approach aimed at ensuring that the performance criteria are met until the next scheduled inspection. SGDSM consists of a specific inservice inspection program (with specified frequency and level of sampling, specified qualified or validated NDE techniques) consistent with Regulatory Position 1 and specific condition monitoring and operational assessment methodologies consistent with Regulatory Positions 3 and 4. Regulatory Position 5.2 provides guidelines for developing appropriate plugging and repair methodologies, including the associated hardware (e.g., plugs and sleeves). Guidelines for submitting a proposed licensing basis change (including technical specification change) that is risk-informed are provided in Reference 8.

Regulatory Position 6 provides guidelines for implementing corrective actions, depending on the results of condition monitoring and operational assessment, as necessary to ensure the performance criteria will be met until the next scheduled tube inspection.

Preventive measures are implemented in accordance with Regulatory Position 7 and involve measures to mitigate active degradation mechanisms and to minimize the potential for new degradation mechanisms. Regulatory Position 7.1 addresses secondary water chemistry control. Regulatory Position 7.2 addresses measures to control loose parts and foreign objects within the steam generators, and Regulatory Position 7.3 addresses other measures for mitigating active degradation mechanisms.

Operational primary-to-secondary leakage monitoring is performed in accordance with Regulatory Position 8. These guidelines are intended to ensure that leakage is effectively monitored and that appropriate and timely action will be taken before a leaking tube exceeds the tube integrity performance criteria, including tubes undergoing rapidly increasing leak rates. Regulatory Position 8.1 addresses development of monitoring programs. Regulatory Position 8.2 addresses development of limiting condition for operation (LCO) limits in the technical specifications for allowable operational leakage. Regulatory Position 8.3 addresses the development of procedural limits for operational limits to ensure the performance criteria are met.

Guidelines for evaluating the radiological consequences of SG tube leakage during postulated accidents relative to 10 CFR Part 100 guidelines for offsite doses, or some part thereof, and GDC-19 criteria for control room operator doses are addressed in Regulatory Position 9.

Guidelines for submitting reports to the NRC concerning the results of inservice inspection and condition monitoring are addressed in Regulatory Position 10.

DEFINITIONS

Accident leakage rate is the primary-to-secondary leakage rate occurring during postulated accidents other than a steam generator tube rupture. This includes the primary-to-secondary leakage rate existing immediately before the accident plus additional primary-to-secondary leakage induced during the accident.

Active degradation mechanisms and **active defect types** are new indications associated with these mechanisms and defect types that have been identified during inservice inspection or that were previously identified indications associated with these defect types that have exhibited growth since the previous inspection of the subject tubes.

Alternative repair criteria (ARC) are tube repair criteria that may be implemented for a specific defect type as part of an SGDSM program in lieu of the generally applicable depth-based criterion (which is 40% of the initial tube wall thickness at most plants).

Buffer zone is a zone extending radially from the critical region (see definition) for a specific defect type. A buffer zone includes a sufficient number of tubes and portions thereof to permit confirmation by inspection that the critical region does in fact bound the region where the subject defect type is active.

Burst is gross structural failure of the tube wall. Analytically this corresponds to a condition in which a critical parameter for unstable crack propagation, e.g., limit load, is exceeded. Experimentally, it corresponds to unstable crack propagation limited only by testing considerations, e.g., loss of bladder or depletion of the pressure reservoir.

Condition monitoring is an assessment of the "as found" condition of the tubing with respect to the performance criteria. The "as found" condition refers to the condition of the tubing during an SG inspection outage, as determined from the inservice inspection results or by other means, prior to the plugging or repair of tubes.

Critical region is a region of the tube bundle that can be demonstrated to bound the region where a specific defect type is active.

Defective tube (or tube that is **defective**) is a tube that exhibits an indication exceeding the applicable tube repair criteria.

Defect size is the actual physical dimensions of the defect. Frequently, defect size is expressed in terms of a single parameter (e.g., depth, length) when the applicable tube repair criterion is expressed in terms of only that parameter (as measured by NDE).

Defect size measurement (or **measured defect size**) is the defect size as measured during an NDE tube inspection.

Defect type is a degradation mechanism and an associated set of general circumstances that affect the determination of appropriate NDE techniques for flaw detection and sizing, flaw growth rates, and calculational models for determining structural and leakage performance. General circumstances include the tube size, tube material, defect orientation, whether the defect initiates from the tube primary side or secondary side, and the location of the defect within the tube (e.g., in straight freespan, in u-bend, at tube support plate, at expansion transition). A degradation mechanism may include several defect types.

Defined region for a specific defect type is a region of the tube bundle consisting of a critical region (see definition) for that defect type and a surrounding buffer zone (see definition).

Degradation mechanism is the general defect morphology and its associated causes, e.g., wear-induced thinning of the tube wall caused by adjacent support structures, high cycle fatigue cracking caused by flow-induced vibration of the tube, intergranular stress corrosion cracking caused by stress, material susceptibility, and environment.

Degraded tube is a tube containing an indication less than the applicable plugging limit measured by an NDE technique and NDE personnel validated for sizing for the subject defect type.

Error is the difference between measured defect depth or length and actual defect depth or length.

Indication is the NDE signal response to a defect or condition that is present in the tube. An indication may or may not be measurable relative to the applicable tube repair criteria.

Indication size or **indication measurement** is the measurement of the defect size or the voltage amplitude of the NDE signal response to a defect.

NDE personnel are personnel involved with data analysis.

NDE technique includes specific data acquisition equipment and instrumentation, data acquisition procedures, and data analysis methods and procedures. NDE technique, in this context, includes the summation of techniques directed at each degradation mechanism. For example, the use of bobbin probes for performing an initial screening inspection followed by a rotating pancake coil (RPC) inspection to confirm and characterize possible indications found by the bobbin would constitute a single NDE technique for detection purposes.

Operational assessment is an assessment to ensure that the tubes will continue to satisfy the performance criteria until the next scheduled inspection.

Performance criteria are criteria approved by the NRC that, if satisfied, provide reasonable assurance that tube integrity is being maintained consistent with the licensing basis.

Plugging limit is the tube repair limit.

Potential defect types are defect types that may affect the steam generator tubes at a given plant during the steam generator lifetime based on consideration of plant and steam generator design, materials, operational practice (e.g., temperature, secondary water chemistry control performance), accumulated service time, and degradation experience at the plant and other plants of similar design, materials, and operational practice, as appropriate.

Qualified for detection means that NDE techniques and personnel have undergone performance demonstration for a given defect type and been shown capable of reliably detecting flaws associated with the defect type before these flaws are of sufficient size to cause the performance criteria to be exceeded.

Rupture is perforation of the tube wall such that the primary-to-secondary leak rate exceeds the normal charging pump capacity of the primary coolant system.

Steam generator defect-specific management (SGDSM) is an integrated strategy applicable to a given defect type for ensuring that the performance criteria will be satisfied. SGDSM strategies include a specific program for conducting inservice inspection (including specified NDE technique and frequency and level of sampling) and specific methodologies for conducting condition monitoring and operational assessments. SGDSM strategies may also include alternative repair criteria.

Structural limit is the calculated maximum allowable flaw size or indication size consistent with the safety factor performance criteria in Regulatory Position 2.1.1.

Tube repair criterion is the NDE measured flaw depth or length, or indication voltage amplitude, at or beyond which the subject tube must be repaired or removed from service by plugging.

Validated for detection means that NDE techniques and personnel have undergone supplemental performance demonstration for a given defect type as necessary to quantify defect detection performance (e.g., probability of detection (POD) of a given defect) expected under field conditions.

Validated for sizing means that NDE techniques and personnel have undergone supplemental performance demonstration for a given defect type as necessary to quantify the potential error or variability of indication size measurements (e.g., measured defect depth, measured defect length, measured voltage response to defect) expected under field conditions.

Variability refers to the repeatability of indication size measurements for a given defect.

C. REGULATORY POSITION

These guidelines provide an acceptable framework for the development of a program to monitor and maintain the integrity of the SG tubes. This program should be documented in plant procedures, should be auditable, and must conform to Appendix B of 10 CFR Part 50. Reporting should be in accordance with Regulatory Position 10 of this regulatory guide.

1. SG TUBE INSPECTION

The objective of SG tube inspection is to provide sufficient information concerning the defect types present in the SGs, the tubes that contain defects, and the size of these defects such that when implemented in conjunction with the other programmatic elements of this regulatory guide, there is reasonable assurance that the tube integrity performance criteria in Regulatory Position 2 are being maintained throughout the time period between SG tube inspections. Specifically, the information from SG tube inspections is used in conjunction with the other program elements of this regulatory guide to assess tube integrity performance relative to the performance criteria, to determine which tubes fail to satisfy the applicable tube repair criteria (and which must, therefore, be repaired or removed from service by plugging), and to assess needed improvements in measures being taken to mitigate active degradation mechanisms and defect types.

1.1 Inspection Scope and Frequency

1.1.1 Preservice Inspection

The preservice inspection should be performed after the field hydrostatic test for new plants and after tube installation for replacement steam generators, but prior to either initial power operation or plant startup after SG replacement. This inspection should be conducted on 100% of the tubes over their full length using a general purpose NDE technique (e.g., eddy current bobbin probe). The data acquisition and analysis should be performed in accordance with written procedures in accordance with Regulatory Position 1.2. The general purpose NDE technique and data analysis personnel should be qualified for detection in accordance with Regulatory Position 1.2.1 for volumetric defect types such as wall thinning.

Additional inspections should be conducted with specialized and more sensitive NDE techniques (e.g., eddy current rotating pancake coil) to establish a definitive baseline record against which inservice changes may be compared. These inspections should include a sample of expansion transition locations, small radius u-bends, and locations exhibiting abnormal conditions (e.g., dents, tube geometry abnormalities) or unusual signal responses during the general purpose examination.

1.1.2 Frequency of Inservice Inspections

Inservice inspection of each steam generator should be performed at the first refueling outage (a duration not less than 6 effective full power months (EFPM) and not more than 24 EFPM). Subsequent inservice inspections of each steam generator should be performed at a frequency such that operational assessment in accordance with Regulatory Position 4 demonstrates that tube integrity performance criteria in Regulatory Position 2 will continue to be met until the next scheduled inspection of that steam generator. No steam generator should operate more than two fuel cycles between inservice inspections. Inservice inspections (unscheduled) should also be performed during plant shutdown subsequent to any of the following conditions:

1. Primary-to-secondary leakage leading to plant shutdown for repair of the leaking tubes, applicable only to leaks involving tube, plug, or sleeve flaws or sleeve-to-tube welds

2. Seismic occurrence greater than the Operating Basis Earthquake

3. Loss-of-coolant accident requiring actuation of the engineered safeguards

4. Main steam line or feedwater line break

1.1.3 Initial Inspection Sample for Inservice Inspections

The initial tube sample for inservice inspection, scheduled and unscheduled, should include a minimum 20% sample of the total number of steam generator tubes that remain in service (i.e., tubes that have not been plugged). This 20% sample may be a random sample or a systematic, sequential, uniformly distributed sample. This sample should be divided equally among all SGs being inspected during a given plant outage. The initial inspection sample should be over the full length of the tube (hot leg tube end to cold leg tube end, including installed sleeve repairs).

The initial inspection sample should be conducted with NDE techniques and personnel that are appropriate and in accordance with Regulatory Position 1.2 to address all defect types that may affect the SGs over their lifetime (i.e., **potential defect types**). Potential defect types should be assessed prior to each inservice inspection. This assessment should include consideration of plant and steam generator design, materials, and operational practice (e.g., temperature, secondary water chemistry control performance). This assessment should also include consideration of the accumulated service time and degradation experience at the subject plant and at other plants of similar design, materials, and operational practice, as appropriate.

The initial inspection sample in a SG should be supplemented to include tubes previously found to be degraded but left in service without repair. The inspection should include 100% of such tubes or, alternatively, the operational assessment should demonstrate, in accordance with Regulatory Position 4, that the tube integrity performance criteria in Regulatory Position 2 will continue to be met until the next scheduled inspection of that steam generator. These supplemental inspections may be limited to a partial length of the tube containing the previously observed **indication** provided the subject defect type can be shown to be limited to that partial length. These supplemental inspections should use appropriate NDE techniques and personnel for each of the subject defect types as discussed in Regulatory Position 1.2.

In general, the above guidance for initial sampling also applies for unscheduled inspections caused by primary-to-secondary leakage for the steam generator affected by the leak. However, if the defect type associated with the leak has been established to be confined to a **critical region**, the initial inspection sample may be limited to an associated **defined region** encompassing the critical region in the affected steam generator.

Indications found during the initial sample should be evaluated as necessary to establish the active defect types present in the steam generators. The appearance of one or more new indications or growth in pre-existing indications indicate active defect types.

1.1.4 Expanded Inspection Sample

For each active defect type identified during the initial sampling of a given steam generator, an expanded inspection sample should be performed in that steam generator and an initial sample inspection in accordance with Regulatory Position 1.1.3 should be performed in any steam generators not already scheduled for inspection. For unscheduled inspections caused by primary-to-secondary leakage, an expanded inspection sample in the affected steam generator and initial sample inspection of the other steam generators is performed only if nonleaking indications involving the subject defect type are found during the initial sample in the affected steam generator.

The expanded sample should apply to the entire tube bundle of the affected steam generator unless the defect type can be demonstrated to be confined to a **critical region**, in which case the expanded inspections for the subject defect type may be confined to a **defined region** consisting of the critical regions and a surrounding **buffer zone**. Technical justification to support identification of a critical region should be maintained as part of the inspection record. Technical justification should either (1) address the uniqueness of essential contributing factors (for the subject defect type) to the critical area or (2) demonstrate that the indications found during initial sampling are of sufficient number and spatial distribution to provide a strong empirical basis for the critical region.

The expanded sample should consist of 100% of the tubes within the tube bundle or defined region, whichever is applicable, or alternatively, should be as necessary to demonstrate by operational assessment in accordance with Regulatory Position 4 that the tube integrity performance criteria in Regulatory Position 2 will continue to be met until the next scheduled inspection of that steam generator.

The expanded inspection sample for each active defect type should be performed with appropriate NDE techniques and personnel for that defect type as discussed in Regulatory Position 1.2. When more sensitive and more accurate NDE techniques are employed compared to previous inspections, additional inspections conducted with the previous techniques may be used as a benchmark for determining flaw growth between inspections and the rate of new indications during the previous cycle.

1.2 NDE Data Acquisition and Analysis

Licensees should ensure that each organization (e.g., utility or vendor) that conducts SG NDE inspections has a written procedure for conducting NDE data acquisition and analysis. These procedures must be in accordance with Appendix B to 10 CFR Part 50. The objective of these procedures is to ensure the capability to reliably detect and, if practical, size tubing defects. In the context of this regulatory guide, this objective has been satisfactorily achieved when implementation of these procedures in conjunction with the other programmatic elements of this regulatory guide ensures that the tube integrity performance criteria will be met until the next scheduled SG inservice inspection. The following guidelines should be followed to ensure that this objective is met.

(1) The procedures should ensure that NDE techniques and personnel used to address each potential defect type are "qualified for detection" in accordance with Regulatory Position 1.2.1 with respect to that defect type. NDE technique refers to specific data acquisition equipment and instrumentation, data acquisition procedures, and data analysis methods and procedures. In this context, "NDE technique" includes the summation of techniques directed at each degradation mechanism. For example, the use of bobbin probes for performing an initial screening inspection followed by a rotating pancake coil (RPC) inspection to confirm and characterize possible indications found by the bobbin would constitute a single NDE technique for detection purposes. NDE personnel are personnel involved with data analysis.

(2) The procedures should ensure that NDE techniques and personnel used to address each potential defect type are "validated for detection" and "validated for sizing" in accordance with Regulatory Position 1.2.2 for that defect type, assuming the availability of such techniques and personnel. For defect types for which validated techniques and personnel are not available, nonvalidated NDE techniques and personnel may be used provided they are qualified for detection in accordance with Regulatory Position 1.2.1. A comparative evaluation should be performed for available nonvalidated techniques and the best of these techniques in terms of detection performance for the subject defect type should be employed.

(3) The procedures should ensure that the above qualifications and validations are applicable to the specific plant to which they are being applied. This means that the plant-specific circumstances (e.g., magnitude of dent, deposit, and geometric discontinuity signals; electrical noise, tube and calibration standard noise; and overall signal-to-noise ratio) associated with each defect type have been representatively included in the qualification and validation performance demonstration data set.

(4) The procedure should provide (directly or by reference) a technique specification for each NDE technique to be employed to address each degradation mechanism. The technique specification should identify the data acquisition equipment and instrumentation, data acquisition and analysis procedures, and values of all essential variables. The technique specification should be consistent with what has been qualified and validated in accordance with Regulatory Positions 1.2.1 and 1.2.2. In addition, the technique specification should be consistent with the data acquisition equipment and instrumentation, data acquisition and analysis procedures, and values of all essential variables implicit in SGDSM strategies being implemented in accordance with Regulatory Position 5.1 for specific defect types.

(5) The procedures should ensure that NDE data analysis personnel are performing their duties within the limits of applicability, i.e., the specific NDE techniques and the application of these techniques for which the personnel have been qualified and validated. Application refers to the specific defect types to which the subject NDE technique is being applied.

(6) The procedures should include site-specific data analysis guidelines to ensure that the most appropriate data analysis practices are used for each defect type and to ensure that the data are analyzed in a consistent and reliable manner. These procedures should include site-specific training and performance demonstration of the data analysts to be implemented prior to each inspection to ensure their knowledge of the site-specific guidelines and their application to defect types and accompanying circumstances (e.g., denting, deposits) expected at the site. These procedures should include procedures for an independent two-party data analysis, including procedures for discrepancy resolution, to minimize the potential for missing or incorrectly characterizing and sizing an indication. The procedures should include process controls as necessary to ensure the quality of the inspection. Examples of needed process controls include a process to document changes in the procedures and their proper dissemination and data quality requirements (including acceptable noise levels).

1.2.1 Qualification for Detection

Qualified for detection means that NDE techniques and personnel have been shown capable of reliably detecting flaws associated with a given defect type before these flaws are of sufficient size to cause the performance criteria to be exceeded. Implementation of NDE techniques and personnel that meet this criterion is a minimum acceptable approach that, in conjunction with implementation of the other programmatic elements of this regulatory guide, ensures that the tube integrity performance criteria will be met until the next scheduled inspection.

This qualification should be conducted in accordance with written procedures described or referenced in the data acquisition and analysis procedures maintained by the organization (utility or vendor) conducting the inspection. These procedures should address training and written examination requirements for data analysis personnel. In addition, these procedures should address performance demonstration requirements for NDE techniques and data analysis personnel.

A qualification record should be maintained for each NDE technique to be employed during the inservice inspection for each intended application (i.e., for each defect type to be addressed by that technique) by the organization that conducted the qualification. The qualification record should include:

- A description of the performance demonstration test specimen data set and the results of the performance demonstration.

- The limits of a technique's applicability to specific defect types and associated extraneous test variables (e.g., denting signals, electrical noise, tube noise, calibration standard noise, deposit noise), signal to noise ratios, and tube geometry and material. These limits should be consistent the conditions covered by the performance demonstration test specimen data set.

- A technique specification defining all essential variables to which the qualification is applicable.

A qualification record should be maintained for each of the NDE personnel to be employed during the inservice inspection by the employer of these personnel. The qualification record should include:

- Record of training, including training hours, dates attended, and training institution.

- Dates and pass/fail results of the written examination and of the performance demonstration test for each defect type tested.

NDE techniques and NDE personnel that have been qualified in accordance with Appendices G and H of the EPRI PWR Steam Generator Examination Guidelines (Ref. 9), for a given flaw type may be deemed qualified for detection with respect to that flaw type as defined in this section of the regulatory guide.

1.2.1 <u>Validation for Detection/Sizing</u>

Validated for detection means that NDE techniques and NDE personnel have undergone supplemental performance demonstration for a given defect type as necessary to quantify defect detection performance (e.g., probability of detection (POD) of a given defect) expected under field conditions. Validated for sizing means that NDE techniques and personnel have undergone supplemental performance demonstration for a given defect type as necessary to quantify the potential **error** or **variability** of **indication size** measurements (e.g., measured defect depth, measured defect length, measured voltage response to defect) expected under field conditions. Error is the difference between the measured defect depth or length and the actual defect depth or length. Variability refers to the repeatability of indication size measurements for a given defect. It is the error of an indication size measurement that is of interest when the applicable tube repair criterion is in terms of measured flaw size or when structural and leakage models used for condition monitoring and operational assessment express burst pressure and accident leakage as a function of actual flaw size. It is the variability of the indication size measurement that is of interest when the tube repair criterion is in terms of indication voltage amplitude or when structural and leakage models used for condition monitoring and operational assessment express burst pressure and accident leakage as a function of indication size measurement (e.g., voltage amplitude of defect signal, measured flaw depth).

Validation involves quantifying detection and sizing performance, not demonstrating that this performance satisfies a specific numerical criteria. The availability of this performance information (particularly indication size measurement performance) enables direct consideration of the NDE inspection results as part of condition monitoring and operational assessment (see Regulatory Positions 3 and 4) to ensure that the performance criteria will be met until the next scheduled inspection. Information on indication size measurement performance enables use of the NDE inspection results to discriminate between which degraded tubes are **defective** and which are not, in lieu of assuming all tubes with indications are defective (see Regulatory Position 5). This information is also needed when developing new **alternate repair criteria** (see Regulatory Position 5.1). Although this information is not necessary from the standpoint of ensuring that the performance criteria will be maintained, it affords the licensee much more flexibility in terms of how it ensures that this objective is met. Potential benefits from using validated NDE techniques and NDE personnel include reducing the number of tubes that must be plugged or repaired and facilitating justification for operating a full operating cycle between inservice inspections.

Supplemental performance demonstration for NDE techniques and NDE personnel should be performed in accordance with written procedures maintained by the organization (utility or vendor) conducting the inspection. This demonstration for both the technique and the data analysis personnel should be performed on a common set of test specimens so as to allow defect detection and **defect size measurement** performance to be evaluated against the actual presence of defects and actual **defect size** and should be consistent with the following guidelines:

(1) Separate sets of test samples (i.e., separate data sets) should be employed for each potential defect type. The data sets should include extraneous signals (e.g., denting signals, deposit signals, electrical noise, tube noise, calibration standard noise, signal to noise ratio) representative of those experienced in the field for a given flaw type.

(2) Data acquisition with the subject NDE technique should be conducted for the entire data set. Data analysis by individual analysts should be conducted for a portion of the total data set such that the analysts are not tested on identical data sets. This performance demonstration test for data acquisition and analysis should be blind.

(3) The total and partial data sets for each defect type should contain a statistically valid sample of flawed and unflawed grading units large enough to permit POD performance, probability of false call performance, and indication size measurement performance to be evaluated at an appropriate confidence level for the range of defect sizes of interest (i.e., defect sizes ranging from less than one-half of the tube repair criteria to sizes that would not meet the structural performance criteria). The appropriate confidence level should be that necessary to permit the overall results of the operational assessment to be evaluated at 95% confidence (see Regulatory Position 4).

(4) Each data set for a given defect type should consist of service-degraded tube specimens (i.e., tube specimens removed from operating steam generators) to the extent practical. Data acquisition with the subject NDE technique should take place prior to tube removal. Service-degraded tube specimens may be supplemented as necessary by tube specimens containing defects fabricated using mechanical or chemical methods provided it is firmly established in written documentation to be maintained as part of the supplemental performance demonstration record that signal responses are fully consistent with those in the field for the same defect type and geometry. In particular, fabricated defects should exhibit signal responses of similar voltage amplitude, complexity, and signal-to-noise ratio as defects in the field with the same defect type and geometry. For example, electric discharge machining notches should not be used to represent stress corrosion cracks since electric discharge machining notches exhibit a higher voltage, higher signal-to-noise ratio, and more simple signal patterns than cracks.

(5) The defect detection, false call, and defect size measurement performance of NDE technique and NDE personnel for each grading unit should be evaluated against the actual presence of the defect and actual defect size. When indication size measurement variability is of interest, both technique variability and personnel variability should be determined.

(6) Records of the supplemental performance demonstration should be maintained by the organization (e.g., vendor, utility) conducting the demonstration. These records should include the information listed in Regulatory Position 1.2.1. In addition, these records should include the POD, probability of false call, and indication size measurement error or variability results as necessary to support the information needed to conduct condition monitoring and operational assessment.

2. PERFORMANCE CRITERIA FOR SG TUBE INTEGRITY

These performance criteria are the benchmarks against which the tubes should be monitored and maintained in accordance with this regulatory guide. Satisfaction of these criteria ensures tube integrity; namely, that the SG tubes are capable of performing their safety functions consistent with the licensing basis. These performance criteria address three areas of tube integrity performance: structural integrity, operational leakage integrity, and accident-induced leakage integrity.

2.1 Structural Performance Criteria

2.1.1 Deterministic Structural Performance Criteria

All tubes should retain margins of safety against burst consistent with the safety factor margins implicit in the stress limit criteria of Section III of the ASME Code (Ref. 2), as referenced in 10 CFR 50.55a, for all service level loadings. Satisfaction of these criteria means that all tubes have been determined to retain a margin of 3.0 against gross failure or burst under normal plant operating conditions, including startup, operation in the power range, hot standby, and cooldown, and all anticipated transients that are included in the plant design specification. In addition, all tubes have been determined to retain a margin of safety against gross failure or burst consistent with the margin of safety determined by the stress limits in NB-3225 of Section III of the ASME Code under postulated accidents concurrent with a safe shutdown earthquake.

2.1.2 Probabilistic Structural Performance Criteria

Probabilistic criteria may be used as an alternative to the use of deterministic criteria based on ASME Code margins as part of an SGDSM program for specific defect types. However, the use of such criteria for a specific defect type constitutes a change to the licensing basis, since it involves a change to the margins of safety to be maintained against burst. Thus any proposed use of such criteria for a specific defect type must be submitted for NRC review and approval. The staff encourages such proposals to be risk-informed following the guidance provided in Regulatory Guide 1.174 (Ref. 8).

Proposed probabilistic criteria should not exceed the following:

1. The frequency of SG tube bursts that occur as spontaneous, initiating events under normal operating conditions should not exceed 2.5×10^{-3} per reactor-year.

2. The conditional probability of burst of one or more tubes under postulated accident conditions should not exceed 2.5×10^{-2}.

The above criteria apply to the total tube burst frequency per plant and the total conditional probability of burst associated with all defect types affecting each steam generator. Frequency and conditional probability criteria applicable to any one defect type should not exceed 40% of the above values.

2.2 Operational Leakage Performance Criteria

Operational primary-to-secondary leak rate should not exceed the limiting condition for operation (LCO) limits for primary-to-secondary leakage rate for any SG.

2.3 Accident Leakage Criteria

Calculated potential primary-to-secondary leak rate during postulated design basis accidents other than a steam generator tube rupture (SGTR) should not exceed the LCO leakage rate limits (in terms of both total leakage for all SGs and leakage from an individual SG).

Alternative accident leakage performance criteria may be applied to the component of calculated accident leakage associated with implementation of SGDSM programs described or referenced in the technical specifications. The balance of the calculated leakage rate (i.e., calculated leakage rate for defect types not addressed by SGDSM programs described or referenced in the technical specifications) should not exceed the LCO leakage limits. The use of alternative accident leakage criteria when implementing the SGDSM programs must be submitted as a proposed licensing basis change. The staff encourages licensees to follow risk-informed approaches when submitting such proposals following the guidance provided in Reference 8. Risk-informed proposals should address accident leakage associated with implementation of all SGDSM programs to which the alternative leakage criteria will be applied. As a maximum, the alternative criteria should not exceed the accident leakage rate assumed in the licensing basis accident analyses, minus the LCO limits for operational leakage. To accommodate the proposed leakage criteria, licensees may submit updated licensing basis accident analyses as part of the proposed licensing basis change as necessary to accommodate the proposed accident leakage criteria. Such a proposal should include a radiological assessment in accordance with Regulatory Position 9 to demonstrate that the consequences of design basis accidents meet the guideline limits in 10 CFR Part 100 for offsite doses, or some fraction thereof as appropriate to the accident, and GDC-19 criteria for control room operator doses. Following NRC acceptance and approval, the description of the new accident and its consequences must be incorporated into the licensee's updated final safety analysis report (FSAR). For SGDSM programs associated with certain defect types, risk considerations may prove more limiting than dose considerations for purposes of establishing alternative accident leakage criteria. Thus, more restrictive accident leakage criteria may be necessary for the component of accident leakage associated with implementation of certain SGDSM programs.

For plants with technical specifications incorporating the flex methodology described in Regulatory Position 9, the performance criteria should not exceed the value given in the flex plot (see example plots in Figures 2-4) as a function of RCS dose equivalent ^{131}I. Performance criteria based on flex are only applicable to defect types and associated SGDSM programs that were submitted as part of the proposed change to incorporate flex into the technical specifications. To extend the applicability of flex to other defect types and associated SGDSM programs, licensees must submit a new proposed change to the licensing basis. Again, for SGDSM programs associated with certain defect types, risk considerations may prove more limiting than dose considerations for purposes of establishing alternative accident leakage criteria. Thus, more restrictive accident leakage criteria may be necessary for the component of accident leakage associated with implementation of certain SGDSM programs.

3. CONDITION MONITORING ASSESSMENT

Condition monitoring involves monitoring and assessing the as found condition of the tubing relative to the tube integrity performance criteria. The as found condition refers to the condition of the tubes during an SG inspection outage, prior to any plugging or repair of tubes. Failure of one or more tubes to satisfy the performance criteria may be indicative of programmatic deficiencies in the licensee's program for monitoring and maintaining SG tube integrity. Failure of one or more tubes to satisfy the performance criteria should be reported to the NRC in accordance with 10 CFR 50.72 and corrective actions should be implemented in accordance with Regulatory Position 6 prior to plant restart.

For an unscheduled inspection that is due to primary-to-secondary leakage, the condition monitoring assessment need only address the defect type that caused the leak provided the interval between scheduled inspections is not lengthened. (However, it will be necessary to estimate the contribution of accident leakage from the other active defect types, as determined from the most recent operational assessment for these defect types, to demonstrate that performance criteria for accident leak rate is met.)

Specific considerations relative to monitoring tube structural integrity, operational leakage integrity, and accident leakage integrity are presented in Regulatory Positions 3.1, 3.2, and 3.3, respectively. Additional details concerning specific topics in these sections are addressed in Regulatory Position 3.4. The condition monitoring assessment is subject to the reporting criteria in Regulatory Positions 10.1 and 10.2.

3.1 Structural Integrity

3.1.1 Assessment Vis-a-Vis Deterministic Performance Criteria

Tube structural integrity may be monitored against the deterministic structural performance criteria of Regulatory Position 2.1.1 by analysis, based on the results of inservice NDE inspection, or by alternative means (e.g., in situ pressure testing) for each defect type. Tube structural integrity may be demonstrated by analysis for a given defect type if the NDE technique and NDE personnel are validated for sizing with respect to that defect type in accordance with Regulatory Position 1.2.2. The analysis approach involves demonstrating that the most limiting defects associated with each defect type, as determined from inservice inspection, do not exceed the appropriate **structural limit** for each defect type. Structural limit refers to the calculated maximum allowable defect size consistent with the safety factor performance criteria in Regulatory Position 2.1.1. The analysis should account for all significant uncertainties so that an indication measured by inservice NDE inspection to be at the structural limit satisfies the performance criteria with a probability of 0.95 evaluated at 50% confidence. Conservative bounding models and assumptions should be employed to account for uncertainties not directly treated in the assessment.

Potential significant sources of uncertainty include error or variability of NDE indication size measurement, material properties, and structural models. Considerations for assessing NDE indication size measurement error or variability are addressed in Regulatory

Position 4.3.5. Structural models (i.e., models relating burst pressure to actual defect size or to measured indication size) may be empirical or analytical (i.e., idealized models based on engineering mechanics). Empirical models should be in accordance with Regulatory Position 3.4.2 and should quantify significant model uncertainties such as burst pressure data scatter and the parameter uncertainty of the empirical fit. Analytical models generally do not explicitly quantify uncertainties in the model estimates and, thus, should be developed to produce bounding estimates. The conservatism of analytical models should be confirmed by test.

For certain defect types, analytical approaches to demonstrating tube integrity may be inappropriate or inefficient because of an inability to size certain flaw dimensions, large error or variability associated with indication size measurements, or large uncertainties of the structural models. These difficulties may necessitate bounding approaches to ensure a conservative analysis, but they may lead to unrealistic (overly conservative) results. Other approaches, such as in situ pressure testing, may provide a more realistic assessment and may be used as an alternative to, or as a supplement to, the above analytical approach for a given defect type to demonstrate structural integrity in accordance with the performance criteria of Regulatory Position 2.1.1. Guidance for in situ pressure testing to demonstrate the performance criteria are met is provided in Regulatory Position 3.4.3.

3.1.2 <u>Assessment Vis-a-Vis Probabilistic Performance Criteria</u>

Considerations for monitoring tube structural integrity against the probabilistic performance criteria of Regulatory Position 2.1.2 should include the following for a given defect type.

- Probabilistic approach should only be used when inservice inspection techniques and personnel are validated for detection and sizing in accordance with Regulatory Position1.2.2.

- The as-found frequency distribution of indications as a function of indication size should be established. The as-found distribution should be adjusted to consider the percentage of tube locations sampled to address the subject defect type. The uncertainty of the as-found frequency distribution is characterized by consideration of indication size measurement error or variability in accordance with Regulatory Position 4.3.5.

- Empirical models for burst pressure as a function of flaw size or indication size should be established. These models for burst pressure or failure load should account for data scatter and model parameter uncertainties and should also satisfy criteria in Regulatory Position 3.4.2.

- The probability of burst calculation should account for uncertainties in indication size measurement error or variability, material properties, and in the burst pressure model with rigorous statistical analyses. Statistical sampling methods such as Monte Carlo may be used.

- The frequency of burst and conditional probability of burst estimates should be expected (mean) value estimates.

3.2 Operational Leakage Integrity

Operational leakage integrity should be monitored during plant operation in accordance with Regulatory Position 8.1.

3.3 Accident Leakage Integrity

The potential primary-to-secondary leakage rate for the most limiting postulated design basis accident other than SGTR should be assessed, based on the as-found condition of the SG tubing, to confirm that the performance criteria for accident-induced leakage (Regulatory Position 2.3) were met immediately prior to the outage. The potential leak rate may be determined by analysis, based on the results of inservice NDE inspection, or by alternative measures (e.g., in situ pressure testing). The potential leak rate may be determined by analysis for a given defect type provided the NDE technique and NDE personnel have been validated for sizing in accordance with Regulatory Position 1.2.2. The potential accident-induced total leak rate should be an upper 95% quantile estimate (one-sided) evaluated at 50% confidence, based on quantitative consideration of uncertainties affecting the estimate. Conservative bounding models and assumptions should be employed to account for uncertainties not directly treated in the assessment.

Key elements of a condition monitoring accident leakage assessment by analysis should include the following for each defect type.

- The as-found frequency distribution of indications for each active defect type is established as a function of indication size. The distribution should be adjusted statistically to consider the percentage of tubes sampled to address the subject defect type.

- Models relating the magnitude of leakage rate as a function of actual flaw size or NDE indication size measurement for each flaw mechanism are established.

- The leakage calculation for each flaw and for total SG leakage rate is performed deterministically or probabilistically (e.g., with statistical sampling methods such as Monte Carlo), accounting for all significant uncertainties. Potential sources of uncertainty include NDE indication size measurement error or variability, material properties, and leakage models. Considerations for assessing NDE indication size measurement error or variability are addressed in Regulatory Position 4.3.5. Leakage models may be empirical or analytical (i.e., idealized models based on engineering mechanics). Empirical models should be in accordance with Regulatory Position 3.4.2 and should quantify significant model uncertainties such as data scatter and the parameter uncertainty of the empirical fit. Analytical models generally do not explicitly quantify uncertainties in the model estimates and, thus, should be developed to produce bounding estimates. The conservatism of analytical models should be confirmed by test.

In situ pressure testing in accordance with the guidelines in Regulatory Position 3.4.3 may be used as part of, or as an alternative to, condition monitoring by analysis for a given defect type. Estimates of total leak rate from the results of the in situ tests should assume no functional relationship between leakage rate and the NDE indication size measurement, unless there are sufficient data and a rigorous statistical basis for doing so in accordance with Regulatory Position 3.4.2. These estimates should be adjusted to reflect indications involving the subject defect type that were not subjected to the pressure tests. In addition, these estimates should reflect the percentage of tube locations sampled by NDE to address the subject defect type. Assuming a sufficient number of tubes leak during testing, the total leak rate estimate should be a bounding estimate with a probability of 0.95 evaluated at 50% confidence. Alternatively, a bounding estimate should be performed based on the available data. Total leak rate may be assumed to equal zero if no leaking tubes are observed during in situ pressure testing, assuming a sufficient number of tubes have been tested in accordance with Regulatory Position 3.4.3.2.

3.4 Special Considerations for Condition Monitoring Assessment

3.4.1 Loadings

The following types of loadings should be considered.

1. Loadings associated with normal plant operation, including startup, operation in the power range, hot standby, cool down, as well as all anticipated transients (e.g., loss of electrical load, loss of offsite power) that are included in the design specifications for the plant.

2. Loadings and tube deformations imposed on the tube bundle during the most limiting postulated design basis accidents. Dynamic loading considerations should be included in the evaluation. All major hydrodynamic and flow-induced forces should be considered.

The combination of loading conditions for the postulated accident conditions should be evaluated in accordance with the licensing basis and should include, but not necessarily be limited to, consideration of the following sources.

- Pressure differentials associated with loss of secondary system pressure
- Impulse loads caused by rarefaction waves during blow-down
- Loads caused by fluid friction from mass fluid accelerations
- Loads caused by centrifugal force on u-bends caused by high velocity fluid motion
- Loads caused by dynamic structural response of the steam generator components and supports
- Seismic loads
- Flow-induced vibration during blow-down from main steam line break (MSLB)

3.4.2 Empirical Models

3.4.2.1 Statistical Modeling. Empirical models may be used to establish the relationship between a tube integrity parameter (e.g., burst pressure or accident leakage rate) and defect size or NDE indication size. Development of empirical models should conform to principles of good statistical practice for purposes of establishing mean correlations and for quantifying the uncertainties associated with the mean correlation.

Empirical correlations should reflect a statistically significant set of data such that uncertainties associated with the correlation can be quantified. Ideally, the data should be relatively uniform over the range of flaw sizes of interest. If the data set are relatively sparse over a portion of the flaw size range compared to another portion, standard statistical tests should be performed to ensure that the model parameters are not being unduly influenced by individual data in the sparsely populated portion of the flaw size range.

Empirical correlations should be a reasonable fit of the data as evidenced by "goodness of fit" and residual analysis. Empirical models for burst pressure and leakage rate should explicitly account for data scatter and for model parameter (e.g., slope and intercept) uncertainties. Such models should involve a statistically significant correlation with defect or indication size (e.g., a linear regression fit of the data can be shown valid at the $P = 0.05$ level). If such "significance of correlation" cannot be rigorously demonstrated for leakage rate models, the regression fit of the leak rate data as a function of defect or indication size should be assumed to be a constant value. Empirical models for probability of leakage (POL), if used, should explicitly account for parameter uncertainty. For POL models, a number of functional forms may exhibit similar goodness-of-fit attributes; however, they may lead to significantly different results for a given flaw size. Thus, the functional form of the fit should be selected with care to ensure a conservative leakage assessment.

3.4.2.2 Test Specimens. Test specimens should consist of pulled tube specimens, as practical, when the tube integrity parameter (e.g., burst strength, accident leakage rate) is being correlated with actual defect size (e.g., defect depth, defect length). However, laboratory specimens (i.e., specimens with defects induced in the laboratory by mechanical or chemical means simulating the defect type of interest) may be used in lieu of or to supplement pulled tube specimens when the laboratory defect can be expected to yield representative or conservative values of the tube integrity parameter for a given defect size.

Tube specimens from the field should be included as part of the data base when the tube integrity parameter is being correlated with an NDE indication size measurement (e.g., measured depth, measured voltage amplitude). Field specimens may consist of pulled tube specimens or installed tubing that is tested in situ; at least two field specimens from a given plant should be included as part of the data base before the correlation may be applied for that unit. In addition, two additional field specimens should be included in the data base for each plant after at least two but not more than three operating cycles have elapsed since the initial specimens were removed from the steam generators. Installed tubing tested in situ may be substituted for the two additional pulled tube specimens. Field specimens may be supplemented by laboratory specimens provided it can be demonstrated through standard statistical methods that the two data sets are producing consistent results, in terms of both the nominal correlation and the indicated uncertainties associated with the correlation.

3.4.2.3 Testing Issues. Laboratory test systems, including the test apparatus, instrumentation, and procedures, for measuring burst pressure and leak rate must satisfy the requirements of Appendix B to 10 CFR Part 50. These systems should accommodate and permit measurement of as high a leak rate as may be practical, including leak rates that may be in the upper tail of the leak rate distribution for a given defect size (e.g., length, voltage). The test systems should be evaluated for their accuracy, capabilities, and limitations as part of the test system qualification. The maximum and minimum measurable leak rates and the accuracy of the measured leak rates should be determined as a function of applied pressure. The maximum test pressure should be established, as well as available pressurization rates and the ability to hold reasonably constant pressure as a function of time. Attention should be paid to functional limitations that might impair the nominal measuring ranges, such as when the order of magnitude of the flow resistance of piping connections becomes comparable to that of the leaking section of the tube. It is useful to know the applied pressure at the defect site as a function of leak rate when large leakage occurs. For example, the development or enlargement of through wall cracks during pressure testing can lead to large leak rates that prevent further pressurization. The pressure at the defect location could then be significantly less than the pressure at the supply location.

The actions necessary to produce a prototypic or conservative stress state at the flawed location, in terms of the stress components that have a dominant effect on burst at that location, should be considered in the application of a test system for a specific defect type. The fact that primary membrane plus bending stress from sources other than the pressure differential across the tube (see Regulatory Position 3.4.1, "Loadings") may be present under the most limiting postulated accident plus SSE conditions should also be considered. This may be dealt with by including these loads as part of the test or by increasing the test pressure as necessary to produce a conservative test.

Leakage rate data should be collected at temperature for the differential pressure loadings associated with the limiting postulated accident. Leakage tests at temperature should include pressure control to ensure single phase flow inside the tube prior to exiting through the defect. The test pressure should be adjusted relative to the accident pressure value to account for pressure measurement uncertainty. When it is not practical to perform hot temperature leak tests, room temperature leak rate testing may be performed as an alternative. However, the test pressure should be adjusted further as necessary to account for material property differences at temperature. In addition, thermal-hydraulic adjustments to the leakage data should be performed to reflect at temperature conditions.

Leakage tests, when it is not possible to reach and maintain the desired test pressure because of leakage through the defect in excess of the test system capabilities, should not be treated as invalid tests. To do so would systematically exclude high leakage data from the data base, leading to a nonconservative bias in the empirical model. Additional testing and analysis of the test specimen should be performed as necessary to extrapolate the expected leakage rate at the desired test pressure. One approach is to place a bladder over the leaking flaw and then pressurize the specimen to the desired test pressure. A further adjustment to the test pressure may be necessary to account for strengthening of the test specimen provided by the bladder. (Strengthening effects of from 5 to 10% have been estimated in one industry report.) The bladder should then be removed and the specimen loaded to the maximum valid pressure for which a valid leak rate measurement can be attained. This leak rate measurement should be used to extrapolate the leakage rate at the desired test pressure using an appropriate hydraulic model.

Burst testing may be performed at room temperature. Burst data and correlations should be adjusted as necessary to reflect material property values at temperature. Burst data and correlations should also be adjusted as necessary to account for the strengthening effect provided by bladders when such bladders are used.

Additional guidance pertaining to the conduct of in situ burst and leakage testing is addressed in Regulatory Position 3.4.3.

3.4.2.4 <u>Data Management Issues</u>. Each empirical model should be supported by a data management system that ensures data records are maintained, that all relevant data have been considered in the development of the model, and that models are periodically updated as additional relevant data become available. When an empirical model for a specific defect type is based on pulled tube or laboratory flaw data, the relevant data include all such data obtained for each plant and for the range of defect sizes for which the empirical model will be applied. Available in situ pressure test results need not be included as part of the data base. However, such data should be evaluated to ensure that they are statistically consistent with the data from the pulled tube or laboratory flaw data.

Valid reasons for excluding relevant data are limited to the following:

1. Data are associated with an invalid test. Note that this criterion does not apply when tests are systematically invalid for the most extreme data. For example, failure to attain the desired test pressure because of excessive specimen leakage is a "systematically" invalid test rather than a "randomly" invalid test. This is because test system limitations prevent leakage measurements for specimens exhibiting relatively high leak rates. Exclusion of such data would tend to skew the correlation.

2. Data are associated with atypical morphology based on morphology criteria that are defined rigorously and applied to all data, and these criteria can be unambiguously applied by an independent observer provided (1) the model can be conservatively applied to flaws exhibiting the atypical morphology or (2) a separate model is developed to address flaws with the atypical morphology and NDE can reliably discriminate flaws exhibiting the atypical morphology. This criterion should not be applied when the supporting data base depends in part on in situ pressure test results.

3. The exclusion of data results in conservatism associated with application of the affected correlation in terms of the calculated structural limit, probability of burst, and total accident-induced leak rate.

Statistical tests alone do not provide an adequate basis for determining a burst or leakage test to be invalid or for deleting data from the data base.

3.4.3 <u>In Situ Pressure Tests</u>

The following guidelines for performing in situ pressure tests apply when the test results are to be used as an integral part of the condition monitoring or operational assessment.

3.4.3.1 <u>Methodology</u>. Regulatory Position 3.4.2.3 provides general guidance concerning the conduct of leakage and burst testing. This section supplements the guidance in Regulatory Position 3.4.2.3 as it applies to in situ pressure tests. in situ pressure testing refers to hydrostatic pressure tests performed on installed tubing in the field. The purpose of these tests is to demonstrate that the subject tubes satisfy the structural and accident-induced leak rate performance criteria in Regulatory Position 2. In situ pressure testing, including the test apparatus, instrumentation, and procedures are subject to the requirements of Appendix B to 10 CFR Part 50.

A structural assessment should be performed and maintained, or cited by reference, as part of the test record for each application (i.e., defect type) demonstrating that the test is capable of producing a stress state at the flawed section of tubing that is equivalent to, or a conservative bound of, the actual stress state during normal operation and postulated accident conditions multiplied by the appropriate factor of safety in accordance with Regulatory Position 2.1.1. When the actual limiting stress state includes bending stress (e.g., from loss-of-coolant accidents (LOCA) or a safe shutdown earthquake (SSE), the corresponding test pressure should be adjusted as appropriate to reflect these stresses. The tests may be conducted at room temperature; however, the test pressures should be adjusted to account for tube material properties at the appropriate hot conditions. In addition, leak rate data should be adjusted as appropriate to reflect the actual temperature during postulated accidents. The design of the test apparatus and test pressures must also consider, as necessary, any fixity between the tubes and tube support plates caused by the buildup of corrosion products to ensure that the appropriate stress state is produced by the test.

Leak rate testing should be conducted at a pressure differential simulating the most limiting postulated accident, subject to test pressure adjustments discussed above and in Regulatory Position 3.4.2.3. If it is not possible to achieve the desired pressure level because of leakage through the flaw in excess of the makeup capacity of the test system, additional testing and analysis should be conducted in accordance with Regulatory Position 3.4.2.3 to determine the expected leak rate at the desired pressure level. Subsequent to leak rate testing, each subject tube should be tested at a pressure corresponding to the most limiting deterministic structural criterion to demonstrate adequate structural margin, subject to test pressure adjustments discussed above in Regulatory Position 3.4.2.3.

3.4.3.2 Tube Selection. The sample size and selection of tubes for in situ pressure testing should ensure that the most limiting tubes from a structural and accident-induced leakage integrity standpoint are included in the sample. Tube selection should be based on consideration of the inservice NDE inspection results in terms of the indication size measurements. The size of the sample should be determined on the basis of the NDE sizing performance as demonstrated during the NDE validation so that there is reasonable assurance that the most limiting tubes are included in the sample. When NDE sizing performance has not been validated, the initial sample size should be at least 10 tubes, assuming there are at least 10 tubes identified as being affected by this mechanism. A second sample consisting of the second ten potentially most limiting tubes (assuming there are at least an additional 10 affected tubes involving this mechanism) should also be tested to confirm that the most limiting tubes from a burst and leakage standpoint were included in the first sample. If not confirmed by the second sample, a third sample, and if necessary subsequent samples, should be tested until there is reasonable assurance that the most limiting tubes have been tested.

4. OPERATIONAL ASSESSMENT

An operational assessment should be performed to demonstrate that the performance criteria of Regulatory Position 2 will continue to be met until the next scheduled steam generator inservice inspection. The length of the operating cycle prior to the next scheduled inspection and the tube repair criteria should be adjusted as necessary to meet this objective. Additional corrective actions in accordance with Regulatory Position 6 should also be performed as necessary to meet this objective. The operational assessment and implementation of the resulting corrective actions should be completed within 90 days following plant restart from an inspection outage. However, it will generally be necessary to perform at least a preliminary assessment prior to performing tube plugging or repairs to ensure that the tube repair criteria being implemented are sufficient to support operation for the planned operating interval preceding the next scheduled steam generator inspection.

For an unscheduled inspection that is due to primary-to-secondary leakage, the operational assessment need only address the defect type that caused the leak provided the scheduled interval between inspections remains unchanged and provided the leakage was not caused by a factor that would affect prior operational assessments performed for the other defect types.

Specific considerations for performing an operational assessment of tube structural integrity and accident leakage integrity are provided in Regulatory Positions 4.1 and 4.2, respectively. The performance criteria in Regulatory Position 2.2 for operational leakage integrity does not apply to the operational assessment of this section. Additional details concerning specific topics in these sections are addressed in Regulatory Position 4.3.

4.1 Structural Integrity

4.1.1 Assessment Vis-a-Vis Deterministic Performance Criteria

Reasonable assurance that tube structural integrity will continue to be adequately maintained is established by demonstrating that the projected condition of the most limiting tubes immediately prior to the next scheduled inspection satisfies the deterministic criteria of Regulatory Position 2.1.1 for each defect type. Conceptually, this involves demonstrating that the projected limiting defect sizes or indication sizes do not exceed the appropriate "structural limit" for each degradation mechanism. Equivalently, this can involve demonstrating that the projected limiting defects for each defect type will exhibit burst-strength capacities consistent with the criteria of Regulatory Position 2.1.1. The assessment methodology should account for all significant uncertainties so that, should the most limiting projected defect or indication size be at the calculated structural limit immediately prior to the next scheduled inspection, the defect or indication satisfies the performance criteria with a probability of 0.95 evaluated at 95% confidence. The assessment methodology may be performed deterministically or probabilistically (e.g., with statistical sampling methods such as Monte Carlo). Conservative bounding models and assumptions should be employed to account for uncertainties not directly treated in the assessment.

Potential sources of uncertainty include significant uncertainties associated with the projected limiting defect or indication size, material properties, and structural model. General considerations for projecting the most limiting flaw sizes associated with each defect type, including the uncertainty associated with these projections, include the following.

- The frequency distribution of indications left in service as a function of indication size
- The frequency distribution of indications (as a function of indication size) found during the most recent past inspection of tubes that were not repaired or plugged at that time and that are not being inspected during the current inspection
- The frequency distribution of defect or indication growth rates determined in accordance with Regulatory Position 4.3.3 as a function of indication size

- The rate and size distribution function of new indications as a function of time between inspections in accordance with Regulatory Position 4.3.4

- The probability distribution of NDE sizing error or variability determined in accordance with Regulatory Position 4.3.5

- The level of sampling performed during the current inspection and date of last inspection for uninspected tubes.

Note that the above considerations for projecting the limiting defect or indication size are based on the premise that NDE technique and personnel are validated for sizing in accordance with Regulatory Position 1.2.2 for the subject defect type. If this is not the case, alternative or conservative bounding approaches must be taken as discussed later in this Regulatory Position.

Specific details for projecting the maximum defect or indication size are to be developed by licensees. The evaluation of the performance of the predictive methodology in projecting the maximum defect or indication size should be based on the results of future inservice inspections and appropriate adjustments made to the methodology as necessary to ensure this objective is met.

Structural models (i.e., models relating burst pressure to defect or indication size may be empirical or analytical (i.e., idealized models based on engineering mechanics). Empirical models should be in accordance with Regulatory Position 3.4.2 and should quantify significant model uncertainties such as burst pressure data scatter and the parameter uncertainty of the empirical fit. Analytical models generally do not explicitly quantify uncertainties in the model estimates and, thus, should be developed to produce bounding estimates. The conservatism of analytical models should be confirmed by test.

For certain degradation mechanisms, operational assessment methodologies may be inefficient because of an inability to size certain flaw dimensions, large error or variability associated with defect or indication size measurements, or large uncertainties of the structural models. These difficulties may necessitate bounding approaches to ensure a conservative analysis. Appropriate bench marking of the assessment against the results of in situ pressure tests performed during condition monitoring may provide a means for mitigating excessive conservatism. However, the development of NDE techniques with good probability of detection and sizing performance and more precise structural models is key to ensuring a realistic operational assessment and avoiding unnecessary corrective actions (including operational restrictions).

4.1.2 <u>Assessment Vis-a-Vis Probabilistic Performance Criteria</u>

Considerations for performing the operational assessment against the probabilistic performance criteria of Regulatory Position 2.1.2 for structural integrity should include the following for a given defect type.

- The probabilistic approach should only be used when inservice inspection techniques and personnel are validated for detection and sizing in accordance with Regulatory Position1.2.2.

- The calculation of the frequency distribution of defects or indications should be by the size projected to exist immediately prior to the next scheduled inspection based on the considerations identified in Regulatory Position 4.1.1. The specific details for projecting the distribution of defect or indication sizes are to be developed by licensees. The performance of the predictive methodology that projects a distribution that results in a conservative estimate of conditional probability of burst should be evaluated based on the results of future inservice inspections and appropriate adjustments made to the methodology as necessary to ensure this objective is met.

- The empirical burst pressure should be established as a function of defect or indication size. These empirical models should account for data scatter and model parameter uncertainties and are subject to the special considerations in Regulatory Position 3.4.

- The projected distribution of defect or indication sizes, the calculated frequency of burst, and the calculated conditional probability of burst during postulated accidents should include a rigorous statistical treatment of all significant sources of uncertainty affecting the calculation, including growth rate, indication size measurement, and burst-pressure model. Statistical sampling methods such as Monte Carlo may be used.

- The frequency and conditional probability of burst should be evaluated at the one-sided, upper 95% confidence level.

4.2 Accident Leakage Integrity

The potential SG primary-to-secondary leakage rate during the most limiting postulated accident (other than SGTR) should be assessed relative to the performance criteria for accident leakage integrity in Regulatory Position 2.3, based on the frequency distribution of defects or indications as a function of defect or indication size projected to occur immediately prior to the next scheduled SG inspection outage. The calculated potential accident leakage rate should be an upper 95% quantile estimate (one-sided) evaluated at 95% confidence, based on quantitative consideration of uncertainties affecting the estimate. Conservative bounding models or assumptions should be employed to account for uncertainties not directly treated in the assessment.

General considerations for projecting the frequency distribution of defects or indications as a function of defect or indication size, including the associated uncertainties, are the same as those identified in Regulatory Position 4.1.1 for projecting the most limiting defect or indica-
tion size. Considerations for establishing the magnitude of leakage for each defect type as a function of flaw or indication size are the same as those identified in Regulatory Position 3.3.

For certain defect types, operational assessment methodologies may be in efficient because of an inability to size certain defect dimensions, large error or variability in the NDE defect or indication sizing measurements, or large uncertainties of the leakage models. These difficulties may necessitate bounding approaches to ensure a conservative analysis. Appropriate bench marking of the assessment against the results of in situ pressure tests performed during condition monitoring may provide a means for mitigating excessive conservatism. However, the development of NDE techniques with good POD and sizing performance and more precise structural models is key to ensuring a realistic operational assessment and avoiding unnecessary corrective actions (including operational restrictions).

4.3 Special Considerations for Operational Assessment

4.3.1 Loadings

See Regulatory Position 3.4.1.

4.3.2 Empirical Models

See Regulatory Position 3.4.2.

4.3.3 Defect Growth Rates

Defect growth rates over the next inspection interval must be estimated for each defect type for purposes of projecting defect or indication sizes or size distributions expected to exist prior to the next scheduled inspection. These projections are used as part of operational assessments performed in accordance with Regulatory Position 4. The growth rate estimates can be based on inservice inspection results or on laboratory data and models. If the growth rate estimates are based on laboratory data and models, it should be shown that the test conditions for the laboratory tests are prototypical for the locations of interest or bound (i.e., are more aggressive) and for the conditions at the location of interest and that the models are conservative or bounding. The conditions that should be considered include primary and secondary water chemistry, crevice chemistry, residual and applied stresses, tube alloy microstructure, and operating temperature. The models may describe the crack growth rates in terms of probability distributions provided that the model accounts for the upper tail of the measured or observed crack growth rates. If inservice inspection results are used, these growth rate estimates should be based on the inservice inspection results from the most recent inspection and the previous one or two inspections. The inservice inspection results for a given defect type may be used where the NDE techniques and personnel used to obtain these results were validated for sizing in accordance with Regulatory Position 1.2.2. If the NDE technique and personnel do not satisfy this provision, indications found during a given inspection will generally be "new indications," since indications found in previous inspections will have been plugged or repaired in accordance with Regulatory Position 5 Under these circumstances, the projected flaw size distribution prior to the next scheduled inspection will be determined primarily on the basis of the observed "rate and size of new indications" (see Regulatory Position 4.3.4) rather than on the basis of observed growth rates.

Flaw growth rates should be evaluated on the basis of the change in indication size between inspections when there is a detectable indication during both inspections (growth implications of new indications are addressed in Regulatory Position 4.3.4). These growth rates should be adjusted as necessary to reflect any increase or decrease in the length of the time interval between scheduled inservice inspections. For a given indication found during the latest inspection, the previous inspection results for the subject location should be evaluated, consistent with the NDE data analysis guidelines for the defect type being evaluated. If the data analysis guidelines employed during the previous inspection differ from those employed during the latest inspection, the previous data should be evaluated to the latest data analysis guidelines. In addition, the previous data should be adjusted to compensate for differences in data acquisition procedures (including probes and equipment) to the extent there is a technical basis for doing so. When this is not possible, the locations of the indications (or a large sample of these locations) should be reinspected using the previous data acquisition procedures so that results can be compared directly to the previous inspection results. It is desirable that the same analyst be used to evaluate the data from the latest and previous inspections for a given location for purposes of assessing incremental flaw growth.

It is acceptable to supplement plant-specific growth data with applicable data from other units when plant-specific data is scarce for a given degradation mechanism. The data applied from other units should be consistent with or conservative with respect to available plant-specific data regarding average and bounding growth rates. Other considerations concerning the applicability of data from other plants include, for primary-side-initiated stress corrosion cracking, similarities in Inconel microstructure, primary water chemistry, relevant design features (e.g., residual stress levels associated with tube expansions and u-bends, sleeve design), level of denting, and operating temperature. Other considerations for secondary-side- initiated corrosion include similarities in secondary water chemistry, crevice chemistry, thermal and hydraulic environment, Inconel microstructure, level of denting, and relevant design features.

It is acceptable to use a statistical model fit of the observed growth rate distribution to support operational assessments provided that the statistical model accounts for the upper tail of the observed distribution.

When statistical sampling techniques are applied to the growth rate distribution, negative growth rate samples should be treated as zero growth rate.

Probability distributions of growth rates constructed directly from comparative inspection results will tend to be contaminated by NDE indication size measurement error or variability, which will tend to extend the tails of the distribution in both directions. It is conservative to ignore this contamination when the measurement error or variability is random. Alternatively, appropriate statistical methods may be employed to separate out the contribution of measurement error or variability. However, the deconvolved distribution attributable to measurement error or variability should be evaluated to ensure that it is consistent and fully accounted for in what is being assumed for NDE measurement error in Regulatory Position 4.3.5.

4.3.4 Rate and Size of New Indications

The frequency distribution of indications as a function of indication size projected to exist prior to the next scheduled inspection consists of two groups of indications. The first group consists of defects found by inservice inspection that are being permitted to remain in service prior to plant restart and that may grow. Thus, the projected frequency distribution of indications associated with this first group can be determined from the known distribution of indications left in service and the known distribution of indication growth rates. The second group of projected indications consists of defects that have not been detected by inservice inspection prior to plant restart. These indications have not been detected because either (1) defects are present but have not been detected by inservice inspection or (2) defects do not initiate until after plant restart. Failure of inservice inspection to detect defects that are present can be due to either (1) the subject tube has not been inspected at the flaw location or (2) the tube has been inspected, but the defect has not been detected because of NDE technique or personnel limitations. Methodologies should be developed for each defect type for projecting the frequency distribution of indications associated with the second group of indications (i.e., indications not detected during the current inspection). Predictions using these methodologies should be assessed versus the actual distribution of new indications found at the next inspection. These methodologies should be revised as necessary, based on the results of the comparative assessment.

The projected rate (i.e., number per inspection interval) and size distribution of new indications may be determined, in part, on the basis of the inservice inspection results. This is contingent, in the case of size distribution, on the NDE technique being validated for sizing with respect to the subject defect type. The projected rate of new indications should account for the anticipated rate of increase in the rate of new indications over time, based on plant-specific and applicable industry experience. The previously observed size distribution of new indications may be fitted with a statistical model that conservatively accounts for the upper tail of the distribution so that the distribution may be scaled to reflect the expected number of new indications.

When the NDE technique and NDE personnel are not validated for sizing, alternative approaches may be taken to project the most limiting sizes of new indications for purposes of supporting a conservative or bounding operational assessment. For example, burst test results of in situ pressure tests performed as part of condition monitoring may be used to estimate defect sizes equivalent to the observed burst pressures or to conservatively bound the defect sizes based on the maximum test pressures achieved where no burst was observed. The projected bounding values of defect size should be adjusted as appropriate to reflect the projected increase in rate of new indications (which would tend to stretch the upper tail of the size distribution to higher values) and to account for increases or decreases in the length of the time interval between scheduled inservice inspections.

4.3.5 NDE Indication Sizing Error or Variability

The probability distribution of NDE indication size measurement error or variability may be determined from the performance demonstration data for NDE techniques and NDE personnel obtained during the validation process in accordance with Regulatory Position 1.2.1. Consideration should be given to whether the indication sizing performance quantified during the validation process can be improved through the practice of reviewing field data with independent analysts. Whether this can, in fact, lead to a reduction in measurement uncertainty would need to be demonstrated for each application (i.e., for each set of defect types, NDE technique, data analysis procedures, and procedures relating to how the independent analyses are performed and discrepancies resolved).

5. TUBE PLUGGING AND REPAIRS

All tubes found to be defective during preservice or inservice inspection should be removed from service by plugging or repaired prior to plant startup. Tubes are defective when they contain indications that fail to satisfy the applicable tube repair criteria for the subject defect type. All indications should be considered defective, unless these indications have been sized with NDE techniques and NDE personnel that have been validated for sizing. Guidelines for the development of tube repair criteria are given in Regulatory Position 5.1 below. Guidelines concerning the development of plugging and repair methodologies are given in Regulatory Position 5.2.

5.1 Tube Repair Criteria

The purpose of tube repair limits, in conjunction with the other programmatic elements of this regulatory guide, is to provide reasonable assurance that tubes accepted for continued service without plugging or repair will exhibit adequate tube structural and leakage integrity, consistent with the performance criteria of Regulatory Position 2, with appropriate allowance for NDE indication size measurement error or variability and for defect growth prior to the next scheduled inspection.

The tube repair criterion for each defect type should be 40% of the nominal tube wall thickness, subject to demonstrating by operational assessment in accordance with Regulatory Position 4 that the performance criteria in Regulatory Position 2 will continue to be met prior to the next scheduled inspection of that steam generator. This 40% criterion is applicable to the maximum measured depth of the subject indication.

Licensees may submit proposed changes to the technical specifications to permit implementation of alternative repair criteria (ARC) for specific defect types as part of an SGDSM strategy. Proposed changes should be risk-informed and give appropriate consideration to defense in depth (i.e., the containment function of steam generator tubes). SGDSM is an integrated approach aimed at ensuring that the performance criteria are met until the next scheduled inspection. SGDSM consists of a specific inservice inspection program (with specified frequency and level of sampling, specified qualified or validated NDE techniques) consistent with Regulatory Position 1 and specific condition monitoring and operational assessment methodologies consistent with Regulatory Positions 3 and 4. The ARC associated with an SGDSM strategy may not be a fixed value, but may involve a computational method to be implemented as part of the operational assessment for determining an acceptable ARC value that is consistent with ensuring that the performance criteria for tube integrity are met until the next scheduled inspection. Guidelines for submitting a proposed licensing basis change (including technical specification change) that is risk-informed are provided in Reference 8.

5.2 <u>Tube Plugging and Repair Methods</u>

Plugging and repair methods must be developed, qualified, and implemented in accordance with the applicable provisions of the ASME Code (Ref. 2) and Appendices A and B to 10 CFR Part 50. These methods should be designed to ensure tube structural and leakage integrity and should be qualified by both analytical and experimental programs. Repair methods may include leak limiting repair methods; however, any potential leakage from these repairs during operational transients or postulated accidents should be included as part of the operational assessment of Regulatory Position 4. Plugs and repaired portions of tubing should be inspectable with appropriate NDE techniques and personnel as described in Regulatory Position 1.2.

6. CORRECTIVE ACTIONS

Failure of condition monitoring to confirm that the performance criteria have been satisfied should lead to the following actions prior to plant restart from the inspection outage.

- Assessment of causal factors such as
    - New or unexpected degradation mechanism or defect type
    - Insufficient sample sizes for tube inspection
    - Unexpectedly high crack growth rates

- Performance of NDE techniques or NDE personnel is less than expected
- Deficiencies in predictive methodology for condition maintenance assessment (e.g., inadequate treatment of uncertainties).

- Implementation of corrective actions such as

  - Shortened inspection interval
  - Water chemistry enhancements
  - Chemical cleaning
  - Reduction of hot leg temperature
  - Design modifications
  - Larger tube inspection samples
  - Improved inspection techniques (to enhance probability of detection and sizing performance)
  - Enhanced training of NDE personnel
  - More restrictive tube repair criteria
  - Enhanced monitoring of operational leakage
  - Reduced coolant iodine activity limits
  - Enhancements to predictive methodology for operational assessment

Note that the adequacy of these corrective actions to ensure that the performance criteria will be maintained prior to the next scheduled inspection should be confirmed as part of the operational assessment in Regulatory Position 4. A reduction in the length of operating time between inspections should be made if it cannot be shown with a high degree of confidence that other corrective actions are sufficient to ensure that the performance criteria will be met for the period extending to the next scheduled inspection.

Irrespective of whether the condition monitoring assessment confirms that the tubes meet the performance criteria of Regulatory Position 2, actions should be taken as necessary so that the operational assessment confirms that the performance criteria will be satisfied throughout the operating cycle until the next scheduled inspection.

7. PREVENTIVE MEASURES

Preventive measures should be developed and implemented to minimize the potential for tube degradation and to mitigate active degradation mechanisms and defect types in accordance with the guidelines below. The effectiveness of these preventive measures, as indicated by inservice inspection results and other pertinent indicators, should be assessed as part of the periodic operational and condition monitoring assessments discussed in Regulatory Positions 3 and 4, respectively.

7.1 Secondary Water Chemistry Program

Licensees should have a program for monitoring and control of secondary water chemistry to inhibit secondary side corrosion-induced degradation. This program should include

- Identification of all critical variables

- Identification of a sampling schedule for the critical variables and control points for these variables

- Identification of the procedures used to measure the values of the critical variables

- Identification of process sampling points, which should include monitoring the discharge of the condensate pumps for evidence of condenser in-leakage

- Procedures for the recording and management of data

- Procedures for defining corrective actions for all off-control point chemistry conditions

- A procedure identifying the authority responsible for the interpretation of the data, and the sequence and timing of administrative actions required to initiate corrective action.

Development of the specifics of this program is the responsibility of the licensee. However, licensees should consider the recommendations in Reference 10 when developing or updating their programs.

7.2 Loose Parts and Foreign Objects

Licensees should have a program for monitoring and control of loose parts and foreign objects to inhibit fretting and wear degradation of the tubing as follows.

7.2.1 Secondary Side Visual Inspections

The program should include secondary side visual inspections. The program should define when such inspections are to be performed, the scope of inspection, and the inspection procedures and methodology to be utilized. Loose parts or foreign objects that are found should be removed from the SGs, unless it is shown by evaluation (to be maintained as part of the inspection record) that these objects pose no potential for damaging the SG tubing or any other part of the secondary system. Tubes found to have visible damage should be inspected nondestructively and plugged or repaired if the tube repair criteria in Regulatory Position 5 are not satisfied.

7.2.2 Control of Loose Parts and Foreign Objects

The program should include procedures that are effective in precluding the introduction of loose parts or foreign objects into either the primary or secondary side of the SG whenever it is opened (e.g., for inspections, maintenance, repairs, modifications). Such procedures should include (1) detailed accountability procedures for all tools and equipment used during an operation, (2) appropriate controls on foreign objects such as eyeglasses and film badges, (3) cleanliness requirements, and (4) accountability procedures for components and parts removed from the internals of major components (e.g., reassembly of cut and removed components).

7.3 Measures To Mitigate Active Degradation Mechanisms

Licensees should consider developing and implementing, at their discretion, additional measures to mitigate active degradation mechanisms and defect types. Examples of such measures include providing for improved condenser integrity, minimizing air in-leakage into the secondary system, eliminating copper-bearing alloys from the feed train, chemical cleaning, boric acid treatments, and operating with a reduced hot leg temperature.

8. OPERATIONAL PRIMARY-TO-SECONDARY LEAKAGE MONITORING AND LIMITS

8.1 Leakage Monitoring

Primary-to-secondary operational leakage monitoring is an important defense-in-depth measure that can assist plant operators in monitoring tube integrity during operation. Leakage monitoring also gives operators information needed to safely respond to situations in which tube integrity becomes impaired and significant tube leakage, rupture, or burst occurs.

The objectives of leakage monitoring are (1) to provide clear, accurate, and timely information on operational leakage to allow timely remedial actions to be taken to prevent tube rupture and burst and (2) to provide clear, accurate, and timely information to facilitate the mitigation of any tube rupture or burst event.

Although leak-before-break cannot be totally relied upon for steam generator tubes, primary-to-secondary leakage monitoring can afford early detection and response to rapidly increasing leakage, thereby serving as an effective means for minimizing the incidence of SG tube rupture and burst. This can be achieved by having near real-time leakage information available to control room operators. Use of such monitoring capability, along with appropriate alarm set points and corresponding action levels, can help operators respond appropriately to a developing situation in a timely manner.

The monitoring program should account for plant design, steam generator tube degradation, and previous leakage experience. Degradation and leakage experience should not be limited to a specific plant. A primary measure of program effectiveness is the ability of operators to appropriately deal with the full range of primary-to-secondary tube leakage. The program should ensure that operators have the information and guidance needed to safely and appropriately respond to situations ranging from stable leakage at very low levels to rapidly increasing leakage leading to or resulting from tube failure. The program elements considered by the NRC staff to contribute to meeting the stated leakage monitoring objectives are discussed below. These elements have been shown to be important by the corrective actions taken following tube leakage or rupture events.

8.1.1 Monitoring Strategy

Each monitoring method has limitations, and therefore, no single means of detecting primary-to-secondary leakage nor single monitored pathway or radionuclide should be relied upon. A monitoring strategy should use an array of methods to detect and measure leakage, and indications should be available to control room operators. Continuous control room display of key radiation monitor trends (e.g., blowdown, condenser exhaust, Nitrogen-16 monitor of leakage rates and change in leak rate over time) gives operators real-time information that can be used to safely respond to the full range of primary-to-secondary leakage.

Although no single monitor should be expected to fulfill all monitoring roles, some monitoring methods have demonstrated particular value in certain situations. Use of N-16 monitors installed on or near steam lines has become increasingly common in the industry as a supplemental means of monitoring leakage. These monitors exhibit short time response to changes in leak rate and are very useful to operators, provided their limitations are understood. Indications from these monitors can greatly aid operator ability to diagnose and combat a quickly escalating primary-to-secondary leakage situation. However, the short half-life for N-16 presents some problems in the ability of the detector to measure leak rate. Changes in power level and characteristics of the leak itself (location and type of leak) will affect the N-16 concentration reaching the detector.

Licensees should evaluate the monitoring methods available based on factors such as those in guidance provided by EPRI Report TR-104788, "PWR Primary-to-Secondary Leak Guidelines" (Ref. 11). Detection capability and measurement uncertainties are discussed in the guidance, as well as the characteristics of certain monitoring methods. This is useful to licensees in determining the adequacy of specific parts of their monitoring system and the effectiveness of the combination of methods used.

The monitoring program should also include provisions for detection of primary-to-secondary leakage during low power or plant shutdown conditions. Licensees should ensure that means are available to detect tube leakage whenever primary pressure is greater than secondary system pressure. This includes hot shutdown conditions and plant startup situations, when normal means of detecting leakage might be limited or unavailable. For instance, the radionuclide mix is altered following a period of plant shutdown so that condenser offgas monitor indications may be questionable during startup since they are calibrated for a specific radionuclide mix based on power operation. Also, N-16 monitoring is not considered reliable at low power since lower levels of N-16 are available to trigger detector response during a tube leak.

Shutdown or low power monitoring methods do not need to be relied upon to track low levels of leakage over extended periods as might be required for power operation. Plants spend a relatively small fraction of time in low power or hot shutdown. However, it is prudent to have techniques and procedures available to detect a rapidly developing leak under these circumstances. In the event a tube failure develops, operators should have reasonable time to respond to the situation before the plant reaches full power operation, when the consequences of a tube failure would be magnified.

Monitoring instrumentation alarms and operator action levels should be selected to ensure that operators can respond to leakage in a timely fashion, prior to rupture or burst of the tubing.

8.1.2 Operational Guidance

Clear guidelines should be available to direct operator response to leakage in order to minimize the chance for operator errors during a developing leak event. The EPRI guidelines (Ref. 11) recommend operating actions in response to a range of primary-to-secondary leakage, methods of calculating leak rates from various secondary system sample points, and various strategies to track leakage once detected. The action levels given in the EPRI guidelines provide a framework that licensees can use to formulate preplanned operator actions based on specified leakage indications.

Licensees should be careful, however, not to return too quickly to a more routine monitoring regime following an increase in leakage. The guidelines give a definition of stable leak rate (≤10% increase in an hour), but confirmation of indications of slowing leak rate is not discussed. A firm basis, in terms of change in leak rate over time, upon which to determine the stability of the leak is difficult to formulate. Therefore, prudence dictates that operators should use more than a single indication as the basis for concluding that leak rates have stabilized. A similar approach, of confirming leak rates prior to declaring a leakage condition, is applied to Action Level 2 (i.e., leak rate requiring plant shutdown) in the EPRI guidelines (Ref. 11).

8.1.3 Operator Training

As much as practicable, training scenarios should include various types of leakage progressions based on actual leakage events. The characteristics of specific plant monitoring instrumentation should be considered when providing operator indications for training purposes.

The EPRI guidelines offer some assistance to licensees in formulating appropriate simulator scenarios. However, licensees should ensure that information gained throughout the industry by operation with primary-to-secondary leakage or from tube rupture events is used in training programs. Operator training should accurately reflect the expected indications and plant responses for the particular plant during a progressing tube leak that may develop into tube rupture or burst. Various plant conditions and failures of various key indicators should be considered when devising training scenarios.

8.1.4 Program Updates and Self-assessment

Means should be established for the leakage monitoring program to take advantage of new data. Information from actual leakage events can be used to check the adequacy of the monitoring program or enhance its effectiveness.

The foregoing leakage monitoring program components can afford a sufficient level of defense in depth against primary-to-secondary leakage. However, data from actual leakage events throughout the industry can serve as a valuable tool to help licensees verify that an appropriate balance exists among the program components. For example, licensees have incorporated leakage data from previous events to adjust alert and alarm set points of radiation monitors, improve chemistry sampling procedures, and supplement primary-to-secondary training scenarios.

Licensees should also have measures in place to allow careful evaluation of leakage monitoring program performance following any primary-to-secondary leakage event at their plant. Suitable adjustments in the monitoring program can then be made, based on the results of such an evaluation.

8.2 Technical Specification LCO Leakage Limits

The technical specifications should include an LCO limit with respect to the allowable primary-to-secondary leakage rate through any one SG, beyond which prompt and controlled shutdown must be initiated. An acceptable LCO limit is 150 gallons per day. Alternatively, this limit should be established so that an axial crack which is leaking at a rate equal to the limit under normal operating conditions would be expected to satisfy the performance criteria for structural integrity in Regulatory Position 2.1.1. Predictive models, including the treatment of uncertainties, for assessing structural integrity performance relative to the structural performance criteria should be in accordance with Regulatory Position 3.1.1.

Sources of uncertainty that should be considered include burst pressure and leak rate as a function of crack length and material properties.

The technical specifications should include, if necessary, an LCO limit with respect to the allowable total primary-to-secondary leak rate through all SGs, beyond which prompt and controlled shutdown must be initiated. (Such a limit is not necessary if its value would exceed the maximum total leakage rate that is permitted by the LCO leakage limit for individual steam generators.) This limit should be established such that total leakage in all steam generators equal to this limit under normal operating conditions would be expected to satisfy the performance criteria for accident leakage integrity in Regulatory Position 2.3. Predictive models, including the treatment of uncertainties, should be in accordance with this Regulatory Position 8.2.

8.3 Procedural Limits on Operational Leakage

Procedural limits for allowable leak rate and the allowable rate of increase in leak rate should be established to ensure that the performance criteria for operational leakage are not exceeded. These limits, when used in conjunction with a leak rate monitoring program in accordance with Regulatory Position 8.1, are intended to ensure that appropriate and timely action will be taken to ensure that leaking tubes, including tubes undergoing rapidly increasing leak rates, satisfy the performance criteria for operational leakage in Regulatory Position 2.2. The Action Level 1 and 2 criteria and recommended actions in the EPRI primary-to-secondary leak guidelines (Reference 11) provide an acceptable approach with the exception that the >150 gallons per day criterion in these action levels may need to be revised consistent with the above objectives.

9. RADIOLOGICAL ASSESSMENT

A radiological assessment in accordance with the guidance of this Regulatory Position is necessary to support any change to the performance criteria in Regulatory Position 2.3 for accident leakage.

The operational leakage and accident leakage performance criteria in Regulatory Position 2.3 are intended, in part, to ensure that the plant is maintained in a condition consistent with what has been analyzed as part of the licensing basis. Consequences of postulated design basis accidents must be shown to satisfy two conditions. First, the offsite consequences of accidents must not result in doses that would exceed the guideline doses of 10 CFR Part 100, or fraction thereof, as defined in Table 1. Second, the accident must not result in releases that would cause the dose to control room operators to exceed the guidelines of GDC-19 of Appendix A to 10 CFR Part 50.

A steam generator tube rupture (SGTR) event is one of a number of the design basis accidents that are analyzed as part of a plant's licensing basis. In the analysis of a SGTR event, a bounding primary-to-secondary leakage rate equal to the operational leakage rate limits in the technical specifications plus the leakage rate associated with a double-ended rupture of a single tube is assumed. For other design basis accidents such as main steam line break (MSLB), the tubes are assumed to retain their structural integrity (i.e., they are assumed not to rupture). However, in all cases these analyses typically assume that the tubes will exhibit primary-to-secondary leakage that is at the operational leakage limit allowed by technical specifications.

Limiting operational leakage to within the leakage limits in the technical specifications does not ensure that the total primary-to-secondary leakage will not exceed the operational limits during postulated accidents such as an MSLB. Under certain accident conditions, additional primary-to-secondary leakage beyond that of the operational limits may be induced when tubes with deep or entirely through-wall defects are present in the SGs. For example, a deep, part-through wall crack may propagate entirely through-wall under the increased pressure differential associated with a design basis MSLB, leading to leakage of the affected tube during the accident. As another example, an entirely through-wall crack that is leaking at a rate equal to the technical specification operational leakage rate limits may develop an increased crack opening area under the increased pressure differential associated with an MSLB, leading to leakage during the event in excess of the operational leakage limits. The presence of such defects may occur inadvertently as a consequence of tubes not having been inspected during the most recent inspection, defects escaping detection during inspection, or of high defect growth rates. In addition, the presence of such defects may occur as a matter of policy by implementing alternative tube repair criteria. Alternative repair criteria may permit up to entirely through-wall defects to remain in service provided (1) the tubes retain acceptable structural margins against burst, (2) leakage from the tubes during normal operation is not in excess of the technical specification operational leakage limits, and (3) the calculated potential accident leakage rate does not exceed that which was assumed in the accident analyses.

The consequences of design basis accidents such as MSLB, SGTR, rod ejection, and locked rotor are, in part, functions of the dose equivalent ^{131}I in the primary coolant and the accident primary-to-secondary leakage rates. Limits are included in the plant technical specifications for operational leakage and for dose equivalent ^{131}I in primary coolant to ensure the plant is operated within its analyzed condition. For most PWRs, the SGTR accident is usually the limiting design basis event that establishes technical specification limits for the maximum instantaneous and the 48-hour values of dose equivalent ^{131}I in primary coolant and the operational leakage limit. The typical analysis of this accident and other accidents, such as the locked rotor, rod ejection, and MSLB, assumes that primary-to-secondary leakage is at the operational leakage limit of 1 gallon per minute, and that the reactor coolant activity levels of dose equivalent ^{131}I are at the technical specification values for maximum instantaneous, and the 48-hour levels are 60 μCi/g and 1 μCi/g for the pre-existing and accident-initiated spike cases, respectively.

Tubes must be plugged or sleeved when they are found by inspection to contain defects with a measured size that exceeds the applicable tube repair criteria. Either action, plugging or sleeving, results in a reduction in the heat removal capability of the SGs. If a sufficient number of tubes are plugged or sleeved, the unit will be derated. Consequently, licensees have an incentive to maintain as many tubes in service as possible for as long as possible. The use of alternative tube repair criteria provides one strategy for allowing tubes with indications to remain in service, while maintaining structural and leakage integrity. However, the benefit that may be gained through implementation of alternative repair criteria is, in part, a function of the performance criteria against which accident leakage integrity of the tubing is evaluated. The higher the performance criteria associated with implementation of the alternative repair criteria, the more tubes that may be permitted to remain in service. Permitting such tubes to remain in service presents an opportunity for accident leakage to progress to a state that it exceeds the operational leakage limits assumed in the licensing basis for the previously referenced accidents. When this occurs, a new licensing basis analysis must be performed at the increased accident leakage rate. If reanalyses of these design basis accidents at these increased accident leak rates show that the offsite and control room operator doses would exceed the dose criteria of Part 100 (or some fraction thereof) or GDC-19, the licensee must take certain actions to reduce the potential consequences of accident. Either the accident leakage or the maximum instantaneous or the 48-hour values of dose equivalent I-131 in primary coolant can be reduced. However, since the actions being taken are focused on allowing accident leakage to increase, the preferred action taken by licensees is to decrease the allowable activity levels of either or both maximum instantaneous or 48-hour values of dose equivalent I-131 in reactor coolant, as appropriate.

The typical evaluation of design basis accidents, other than an SGTR, involving primary- to-secondary accident leakage assumes that the accident leakage rate is equal to the operational leakage limits in the technical specifications. Thus, the appropriate performance criteria for these units for accident leakage are values equal to the operational leakage limits. Increasing these performance criteria to allow for accident-induced leakage beyond the operational leakage rate limits in the technical specifications may provide licensees with added operational flexibility. Licensees may submit a proposed change to the licensing basis updating the dose analysis to accommodate such an increase in the accident leakage performance criteria. This may necessitate including a proposed change to the LCO limits for dose equivalent I-131 in the primary coolant. The staff encourages licensees to follow risk-informed approaches when proposing such changes utilizing the guidance in Reference 8. The risk implications of implementing a higher accident leakage performance criteria are generally defect type and SGDSM-specific. Therefore, the risk-informed proposals should address each defect type and accompanying SGDSM approach to which the revised performance criteria will be applied.

For earlier-licensed plants, the licensing basis, as reviewed and approved by the NRC in its safety evaluation report (SER), does not include a radiological dose assessment of the consequences of a MSLB, SGTR, locked rotor, or control rod ejection accident. Instead, the reactors were given technical specifications for the maximum instantaneous activity level of dose equivalent I-131 and a 48-hour value of dose equivalent I-131 in reactor coolant along with a maximum activity level for dose equivalent I-131 in the secondary coolant and a maximum primary-to-secondary leak rate. For these plants, the SER stated that it was the NRC's position that the establishment of these technical specification limits would ensure that the doses resulting from accidents involving SGs would pose no risk to public health and safety. The staff has concluded that this position remains valid today for plants in this category provided calculated potential for accident leakage does not exceed values equal to the technical specification operational leakage limits during postulated accidents other than an SGTR. However, licensees must submit a proposed change to the licensing basis accident analyses to support increasing the accident leakage performance criteria above the operational leakage limits for these plants. Such a proposed change should be supported by a radiological assessment. Risk-informed proposals should address each defect type and accompanying SGDSM approach to which the revised performance criteria will be applied.

Following NRC acceptance and approval of a licensing basis change involving a new radiological dose assessment, the description of the new accident and its consequences must be incorporated into the licensee's updated Final Safety Analysis Report (FSAR).

9.1 Dose Calculation Methodology

Licensees may select one of two methodologies for performing a radiological assessment to support the use of increased performance criteria for accident leakage above values equal to the technical specification operational leakage limits. Both calculational methodologies are deterministic in nature. The first method is referred to as the default or SRP approach. This method utilizes the concepts presented in SRP Sections 15.1.5, Steam System Piping Failures Inside and Outside of Containment (PWR); 15.3.3-15.3.4, Reactor Coolant Pump Rotor Seizure and Reactor Coolant Pump Shaft Break; 15.4.8, Spectrum of Rod Ejection Accidents (PWR); and 15.6.3, Radiological Consequences of Steam Generator Tube Failure (PWR). These SRPs may be utilized for calculating the doses resulting from a MSLB, locked rotor, rod ejection, and an SGTR accident, respectively.

The second calculation method that may be used is referred to as the flex methodology. In this methodology a set of calculations are performed with both accident leakage and dose equivalent I-131 varying, rather than being fixed. The flex methodology incorporates the same accident dose methodology as presented for the default approach, but a number of different cases are evaluated for each application, which allows licensees to establish a plot of maximum allowable primary-to-secondary accident leak rate as a function of the maximum instantaneous and the 48-hour values of reactor coolant activity levels of dose equivalent I-131. These plots are based upon the limiting accident scenario. Based upon the projected accident leakage for the next operating cycle (as determined by operational assessment in accordance with Regulatory Position 4), licensees may choose to limit the maximum instantaneous reactor coolant activity level of dose equivalent I-131 and the 48-hour value of dose equivalent I-131 so that the accident leakage performance criterion can be met or licensees can limit leakage by choosing to sleeve or plug tubes. Further details on this methodology are provided below.

9.1.1 Default Methodology

This methodology can be utilized for the various design basis accidents that are detailed in SRP Sections 15.1.5, 15.3.3-15.3.4, 15.4.8, and 15.6.3. This methodology assumes that the reactor coolant activity level of dose equivalent I-131 is at the technical specification limit and the leak rate is equal to the proposed performance criterion value. The assumed accident leakage associated with this methodology is fixed and is usually intended to bound the accident leakage rate that may be calculated during operational assessments for future operating cycles. To date, the degradation mechanisms that have been identified in SGs are irreversible and no treatment has yet been identified which will prevent the mechanisms from continually propagating throughout the generator. Consequentially, licensees find that the number of degraded tubes in the steam generators increase with each operating cycle. The degradation reaches a point at which, in the event of an accident, the anticipated primary-to-secondary leakage (accident leakage) from these tubes exceeds the licensing basis primary-to-secondary leakage. Usually, this leakage is limited to 1 gpm from all SGs. To accommodate the increased accident leakage, the licensee submits to the NRC staff, for review and approval, a revised accident analysis that incorporates this new value for accident leakage. To implement this increase in accident leakage, the licensee frequently decreases the technical specification allowable activity level of dose equivalent I-131 in primary coolant. This is to demonstrate that the consequences of accidents do not result in doses that would exceed the guidelines of GDC-19 or 10 CFR Part 100 or some fraction thereof. After one or more operating cycles, the licensee may again find that it is necessary to modify the licensing basis for the facility because of an increase in projected accident leakage because of the continual degradation of the SG tubes. This process may continue until the SGs are replaced.

The dose criteria for each of the design basis accidents noted above are presented in Table 1. Based upon these criteria, one accident scenario usually will be limiting with respect to the calculation of doses. This scenario should be used in establishing the plant-specific technical specifications for operational leakage and maximum instantaneous and 48-hour values for dose equivalent I-131. This scenario will likely remain the most limiting case until either a new, more limiting scenario is identified or the conditions associated with the scenario change. When a new scenario is identified as being the limiting case, a submittal to the NRC identifies the new scenario and the accident associated with the scenario. This submittal should also provide an assessment of the consequences of the accident and propose any licensing basis changes that are required as a result of the new dose assessment (e.g., changes to the performance criteria for accident leakage integrity, technical specification coolant iodine activity levels). The staff encourages licensees to follow risk-informed approaches when proposing such changes. Risk-informed proposals should address each defect type and accompanying SGDSM approach to which the revised performance criteria will be applied. If a new scenario is identified that does not fall into one of the accident categories presented in Table 1, a new category must be proposed and with it the licensee should propose a limiting dose criteria for the accident.

The staff has identified a potential pitfall in the performance of these dose assessments. This involves calculating the curie content in primary and secondary coolant using one dose conversion factor while using a different dose conversion factor in the calculation of doses. Such an inconsistent application could result in either an underestimation or an overestimation of the dose consequences.

The activity level of dose equivalent I-131 is calculated using the following Equation:

$$\text{DE I-131} = \sum DCF_i C_i / DCF_{131}$$

where

DE I-131 = the dose equivalent concentration of I-131, Ci/g

DCF_i = the dose conversion factor for isotope I, rem/Ci

C_i = the concentration of isotope I in the primary coolant, μCi/g

DCF_{131} = the dose conversion factor for I-131, rem/Ci

The dose conversion factors that are to be used are based on the plant-specific technical specification definition of dose equivalent I-131. Typical dose conversion factors contained in technical specifications are derived from Regulatory Guides 1.4 and 1.109 and ICRP 30. Some licensees may use the dose conversion factors from one source in the calculation of the curie content of dose equivalent I-131 in reactor coolant but then use a different source in the calculation of doses. Based upon the predominant isotope, I-131, if the doses are calculated in this manner, the doses could be incorrectly calculated by as much as 50%. The calculation of curie content in primary and secondary coolant should be based upon the technical specification definition of dose equivalent I-131. In some cases, licensees may wish to change their technical specifications to incorporate the use of a particular dose conversion factor.

9.1.2 Flex Methodology

In lieu of using the default methodology, the licensee may elect to use the dose calculation option that the NRC staff has labeled flex. The intent of the flex methodology is to provide licensees with operational flexibility, yet ensure that the plant is operated within its analyzed licensing basis. The flex methodology is used to generate a plot of allowable primary-to-secondary accident leakage rates as a function of primary coolant activity level of dose equivalent I-131. This plot is generated based upon a series of calculations for a number of different accident scenarios in which the accident leak rates vary with primary coolant activity level of dose equivalent I-131. With such a plot, licensees are permitted to revise the accident leakage performance criteria for applicable defect types and accompanying SGDSM programs to a desired allowable leakage value provided the primary coolant activity level of dose equivalent I-131 is maintained below the corresponding value as determined from the plot. In the case of risk-informed proposals, applicable defect types and accompanying SGDSM programs are those for which accident leakage equal to the allowable leakage has been demonstrated not to lead to unacceptable risk and to maintain adequate defense in depth.

Risk assessment insights and considerations of maintaining defense in depth may result in upper bounds to the acceptable value for accident leakage, independent of the limitations imposed by the design basis accident calculations detailed in the SRP.

This flex methodology plot is based on the limiting accident scenario and conformance with the dose guidelines of Table 1. Whichever accident scenario results in the least amount of allowable leakage would be the scenario for which the plot would be established. The plot would consist of two parts. The first would be for the maximum instantaneous value of dose equivalent I-131 in primary coolant and the second would be for the 48-hour value of dose equivalent I-131 in primary coolant. The plot would be plant-specific and in the technical specifications. It is possible that one accident scenario may be limiting for the maximum instantaneous value of dose equivalent I-131 while a different scenario may be more limiting for the 48-hour value.

The benefit of the plot is that it allows utilities to revise their performance criteria for accident-induced leakage integrity, without the frequent submittal of additional licensing basis changes or changes to the technical specification limits for dose equivalent I-131 in the primary coolant, as necessary to accommodate increased levels of calculated accident-induced leakage occurring as a result of increased levels of degradation in the SG or as a result of implementation of SGDSM programs that may include implementation of alternate repair criteria. Any such revision to the performance criteria must be within what has been evaluated in terms of defect type and accompanying SGDSM program and magnitude of accident leakage. Any such revision to the accident leakage performance criteria would result in more restrictive limits on primary coolant activity levels as determined from the plot that would be part of the technical specifications. However, a resubmittal of the flex plot is required, along with NRC approval, if a new or a different limiting accident or scenario is identified. A resubmittal to the NRC is also required if the consequences of a previously analyzed accident changed or the assumptions, which were the basis for the plot, changed or if the licensee wishes to apply the flex methodology to accident leakage associated with defect types and accompanying SGDSM programs that are not addressed in the initial licensing basis change to incorporate flex into the technical specifications.

Under the default methodology, if operational assessment in accordance with Regulatory Position 4 reveals that the performance criteria for accident-induced leakage will be exceeded prior to the next scheduled SG inspection, the licensee either takes corrective action as necessary in accordance with Regulatory Position 6 such that the performance criteria is met or the licensee updates the radiological dose assessment to accommodate a higher performance criterion that meets or exceeds the accident leakage that may occur prior to the next scheduled inspection. In addition, the licensee may to have to decrease the technical specification limits for the maximum instantaneous and 48-hour values of dose equivalent I-131 in reactor coolant. Thus, NRC approval would be required prior to the licensee operating outside the accident leakage value assumed in the licensing basis accident analyses. With the flex program, the frequency at which NRC approval would be required in order to obtain approval for the increased accident leakage and the associated technical specifications changes would likely be reduced. NRC approvals would only be required if a new accident scenario is identified or if the licensee wished to apply the flex methodology to accident leakage associated with defect types and accompanying SGDSM approaches that are not addressed in the licensing basis change to incorporate flex into the technical specifications.

9.2 Flex Methodology Illustration

The following is an illustration of how the flex methodology might be applied to develop the plot.

> For purposes of illustration, it is assumed that risk and defense-in-depth considerations have resulted in a maximum allowable accident leakage value of 100 gpm, independent of the design basis accident analyses addressed by the flex methodology.
>
> The licensee will select a primary coolant activity level based upon the maximum allowable instantaneous value for dose equivalent I-131. In addition, accident leakage, consisting of the technical specification value of the normal operating primary-to- secondary operating leakage, plus additional accident leakage associated with implementation of SGDSM programs, will be assumed. Based on these values, for each of the potential accidents the licensee will calculate the doses for the control room operator, exclusion area boundary (EAB) and low population zone (LPZ). Using as an example the pre-existing spike case for a MSLB, the maximum allowable accident leakage rate at the assumed reactor coolant activity level for dose equivalent I-131 is determined by multiplying the assumed accident leakage rate times the ratio of the dose criteria for the accident case of interest to the maximum calculated dose at the location. A second primary coolant activity level value for dose equivalent I-131, smaller than the first, would be selected, the leakage assumed and a similar calculation performed. Again, the maximum allowable leakage value for the assumed coolant activity level value would be determined. This process would continue with a series of calculations performed for a number of coolant activity level values of dose equivalent I-131 until the allowable accident leakage exceeded 100 gpm. Then a plot would be made of maximum allowable primary-to-secondary accident leakage as a function of primary coolant activity level of dose equivalent I-131. Maximum allowable leakage is limited to 100 gpm. The primary coolant activity level of dose equivalent I-131 is limited to a maximum of 60 μCi/g, which is the current maximum allowed value in technical specifications.

The second step of the process would have the execution of a similar calculation but for the primary coolant activity level of dose equivalent I-131 at the 48-hour technical specification value for dose equivalent I-131. Again, taking the MSLB accident as a representative case, it would be assumed that a MSLB occurs co-incident with an accident-initiated spike. The maximum allowed coolant activity level value for the 48-hour value for dose equivalent I-131 and an assumed accident primary-to-secondary accident leak rate would be selected. Doses would be calculated at the EAB, LPZ, and control room operator locations based upon the spike following the accident. The maximum allowable primary-to-secondary accident leakage at the assumed primary coolant activity level for dose equivalent I-131 would be determined by multiplying the assumed accident leakage rate times the ratio of the dose criteria for the case of interest to the maximum calculated dose for the location. A second smaller primary coolant activity level value for dose equivalent I-131 would be selected, an accident leakage rate assumed and a similar calculation performed. Again, the maximum allowable leakage value for the assumed primary coolant activity level value would be determined. A series of calculations would be performed until, at a given primary coolant activity level, the allowable leakage exceeded 100 gpm. These data points would be utilized to generate the plot in the technical specifications for the maximum allowable primary-to-secondary accident leakage as a function of the 48-hour value of dose equivalent I-131. In no cases would the primary-to-secondary leakage rate be allowed to exceed 100 gpm. The primary coolant activity level of dose equivalent I-131 is limited to a maximum of 1 μCi/g, which is the maximum allowed by existing technical specifications.

Figures 2 through 4 provide examples of plots for three plants. These plots have been generated from actual amendment requests. These plots demonstrate that allowable leakage is plant-specific.

With the flex option, licensees would perform dose assessments for the locked rotor, rod ejection, MSLB, and SGTR events, as well as any other accident in which primary-to-secondary leakage impacts releases. The SRPs should be used in the performance of such assessments. The EAB, LPZ, and control room operator doses would be compared to the dose guidelines of Table 1. The SGTR assessments would be performed at the maximum allowed instantaneous value for dose equivalent I-131 and the maximum allowed 48-hour value of dose equivalent I-131. Such an evaluation would be performed to ensure that the most limiting scenario is obtained with respect to the determination of the maximum allowed technical specification values for dose equivalent I-131 operational leakage and accident leakage.

Use of the flex program incorporates most of the dose assessment methodology contained in SRPs 15.1.5, 15.3.3-15.3.4, 15.4.8, and 15.6.3. For the MSLB and the SGTR, the parameters that should be used in the flex option are shown in Table 2. As noted from a review of this table, adoption of the flex program requires some changes from the parameters and assumptions in SRPs 15.1.5 and 15.6.3. Such changes include limitation of the dose consequences based upon the accident rather than the case, as well as use an iodine spiking factor of 500 for the MSLB and 335 for the SGTR for the accident-initiated spike cases.

While the SRPs for the MSLB and SGTR accidents have the dose acceptance criteria as a function of whether the event is an accident initiated spike case or a pre-existing spike case, the staff has established for the flex program the dose acceptance criteria to be a function of the accident. In the SRP approach, for the accident-initiated spike case for either a SGTR or a MSLB, the acceptance criteria are 10% of Part 100 guidelines. For the pre-existing spike case for either the SGTR or the MSLB, the acceptance criteria are the full Part 100 guidelines. With the adoption of the flex program, the dose acceptance criteria are no longer a function of the case but rather a function of the accident. For the MSLB it will be the full Part 100 values for the pre-existing spike case and well within Part 100 for the accident-initiated spike case. For the SGTR it will be 10% of Part 100 values for either case. This change in dose criteria would only be for those implementing the flex program.

The spiking factors that are to be used for the accident-initiated spike cases for the flex program are 335 for a SGTR and 500 for a MSLB. The value of 335 was obtained from the staff's assessment of release rate data collected by Adams and Atwood in a paper entitled "The Iodine Spike Release Rate During A Steam Generator Tube Rupture" (Ref. 12). The value of 500 is the same release rate as that presented in SRP Sections 15.1.5 and 15.6.3. This value remains unchanged because there are no data on an iodine spike associated with a MSLB, and the models that have been proposed do not justify a different value. Since there presently is no basis for using another value, the value of 500 will continue to be used for a MSLB.

With the selection of the flex option and the determination of the accident-induced primary-to-secondary leakage rate, licensees will be able to determine, from the previously generated plot that has been incorporated into technical specifications, allowable reactor coolant activity levels of maximum instantaneous dose equivalent I-131 and the 48-hour value of dose equivalent I-131.

As noted previously, the plot in technical specifications is good so long as a new or different accident or a new release pathway need not be considered. When such situations arise and result in a new limiting scenario, an assessment must be submitted to the NRC for review and approval and a new plot for the technical specifications must be developed and submitted for NRC approval. The plot in the technical specifications is applicable only to accident leakage associated with defect types addressed in the licensing basis change to incorporate flex into the technical specifications. This figure will be used to select an appropriate accident leakage performance criteria for applicable defect types and accompanying SGDSM programs and for corresponding primary coolant activity limits.

9.3 Technical Specifications

The standard technical specifications (STS) and the improved STS (ISTS) contain specific values for the primary coolant maximum activity level of dose equivalent I-131, a 48-hour value of dose equivalent I-131, and a maximum primary-to-secondary leak rate during normal operations. For licensees who chose to use the default option for the calculation of doses, the existing STS and the ISTS are sufficient. Therefore, no change to their existing technical specifications would be necessary.

However, licensees who opt for the flex program must change their present technical specifications. A plant that incorporates the flex program will have a figure in its technical specifications that is a plot of allowable accident leakage as a function of the primary coolant activity level of dose equivalent I-131. Incorporation of this figure into the technical specifications will provide licensees the flexibility of operation to administratively limit themselves to either a lower accident leakage rate (i.e., a lower performance criteria for accident leakage) if the fuel is degraded such that primary coolant activity levels are high, or to permit higher accident leakage rates if the primary coolant activity level is low due to fuel integrity being very good. The technical specification will indicate the defect types and accompanying SGDSM programs for which the flex plot is acceptable.

With respect to the technical specifications, Table 3 presents the technical specifications required for the default case and for the flex program. The most limiting case for allowable leakage will also be the case that establishes the technical specification values.

10. REPORTS TO THE NRC

10.1 SG Tube Inservice Inspection

Licensees should submit the complete results of the SG tube inservice inspection and condition monitoring assessment within 12 months following completion of each inservice inspection. This report should include:

1. The number and extent (e.g., full length, hot leg only) of tubes subjected to inservice inspection and to any supplemental testing (e.g., in situ pressure testing) as part of the condition monitoring assessment.

2. The location and measured size of each indication found by inservice inspection and the type of NDE test probe used (e.g., eddy current bobbin coil, eddy current rotating pancake coil). The orientation of the indication (e.g., axial, circumferential) should be provided for linear-type indications such as cracks.

3. The results of any supplemental testing beyond inservice inspection performed as part of the condition monitoring assessment (e.g., in situ pressure testing).

4. Identification of tubes plugged or repaired.

10.2 Failure of the Condition Monitoring Assessment

Failure of the condition monitoring assessment to confirm that the performance criteria of Regulatory Position 2 have been met must be reported to the NRC in accordance with 10 CFR 50.72. In addition, a special report should be submitted prior to restart consisting of the information listed in Regulatory Positions 10.1.a, 10.1.b, and 10.1.d as it pertains to the specific defect types for which the performance criteria were not met.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants regarding the staff's plans for using this regulatory guide.

This draft guide has been released to encourage public participation in its development. Except in those cases in which a licensee or applicant proposes an acceptable alternative method for complying with specified portions of the NRC's regulations, the method to be described in the active guide reflecting public comments will be used in the evaluation of applications for new licenses or license renewals and for evaluating compliance with regulations applicable to steam generator degradation.

Table 1. Dose Criteria for Accidents Involving Primary-to-Secondary Leakage Pathways

	Default Methodology			
	Thyroid		Whole Body	
Accident	EAB/LPZ	Control Room	EAB/LPZ	Control Room
MSLB				
1. Pre-existing spike case	300	30	25	5
2. Accident-initiated spike case	30	30	2.5	5
SGTR				
1. Pre-existing spike case	300	30	25	5
2. Accident initiated spike case	30	30	2.5	5
Locked Rotor	30	30	2.5	5
Control Rod Ejection	75	30	6	5

	Flex Methodology			
	Thyroid		Whole Body	
Accident	EAB/LPZ	Control Room	EAB/LPZ	Control Room
MSLB	300*	30	25**	5
SGTR	30	30	2.5	5
Locked Rotor	30	30	2.5	5
Control Rod Ejection	75	30	6	5

* 75 rem for the accident-initiated spike case

** 6 rem for the accident-initiated spike case

Table 2. Sources of Parameters To Calculate Thyroid Doses for SGTR and MSLB Accidents

Parameter	Default/SRP	Deterministic/Flex
X/Q	Site-specific @95%	Site-specific @95%
Breathing Rate	Regulatory Guide 1.4 Value	Regulatory Guide 1.4 Value
Dose Conversion Factor (DCF)	Regulatory Guides 1.4 and 1.109, ICRP 30	ICRP 30
Reactor Coolant System Activity (RCS)	60 μCi/g pre-existing spike 1 μCi/g accident-initiated spike	Curve generated with a maximum of 60 μCi/g for the pre-existing spike and 1 μCi/g for the accident-initiated spike
Spiking Factor	500	500 MSLB/ 335 SGTR
Dose Limit (Thyroid)		
MSLB	300-rem pre-existing spike/30-rem accident-initiated spike	300-rem pre-existing spike/75-rem accident-initiated spike
SGTR	300-rem pre-existing spike/30-rem accident-initiated spike	30 rem all cases
Maximum Allowable Leakage	1 gpm or 150 gpd per SG times the number of SGs plus accident-induced leakage	Variable, function of limitations of 48-hour TS value for dose equivalent I-131 and the maximum instantaneous value for dose equivalent I-131 in the RCS and the limiting dose exposure pathway and the limiting accident scenario.

Table 3. **Technical Specifications for Dose Assessment**

Parameter	Default Case	Flex Case
Maximum Activity Level Dose Equivalent I-131, μCi/g	60	Variable
Maximum 48-hour Value for Dose Equivalent I-131, μCi/g	1	Variable
Normal Operating Leakage, Total	1 gpm or 150 gpd/SG	150 gpd/SG
Dose Conversion Factors for Defining Dose Equivalent I-131	Regulatory Guides 1.4 and 1.109, ICRP-30	ICRP-30
Allowable Leakage, Event Induced, gpm	NA	Variable, function of product of leakage and dose equivalent I-131 activity level, limiting accident and scenario and 100 gpm limit
RCS Sampling Frequency following a 15% power change in 1 hour	Once per 4 hours	Once per 4 hours

PROGRAM STRATEGY/ STEAM GENERATOR TUBE INTEGRITY

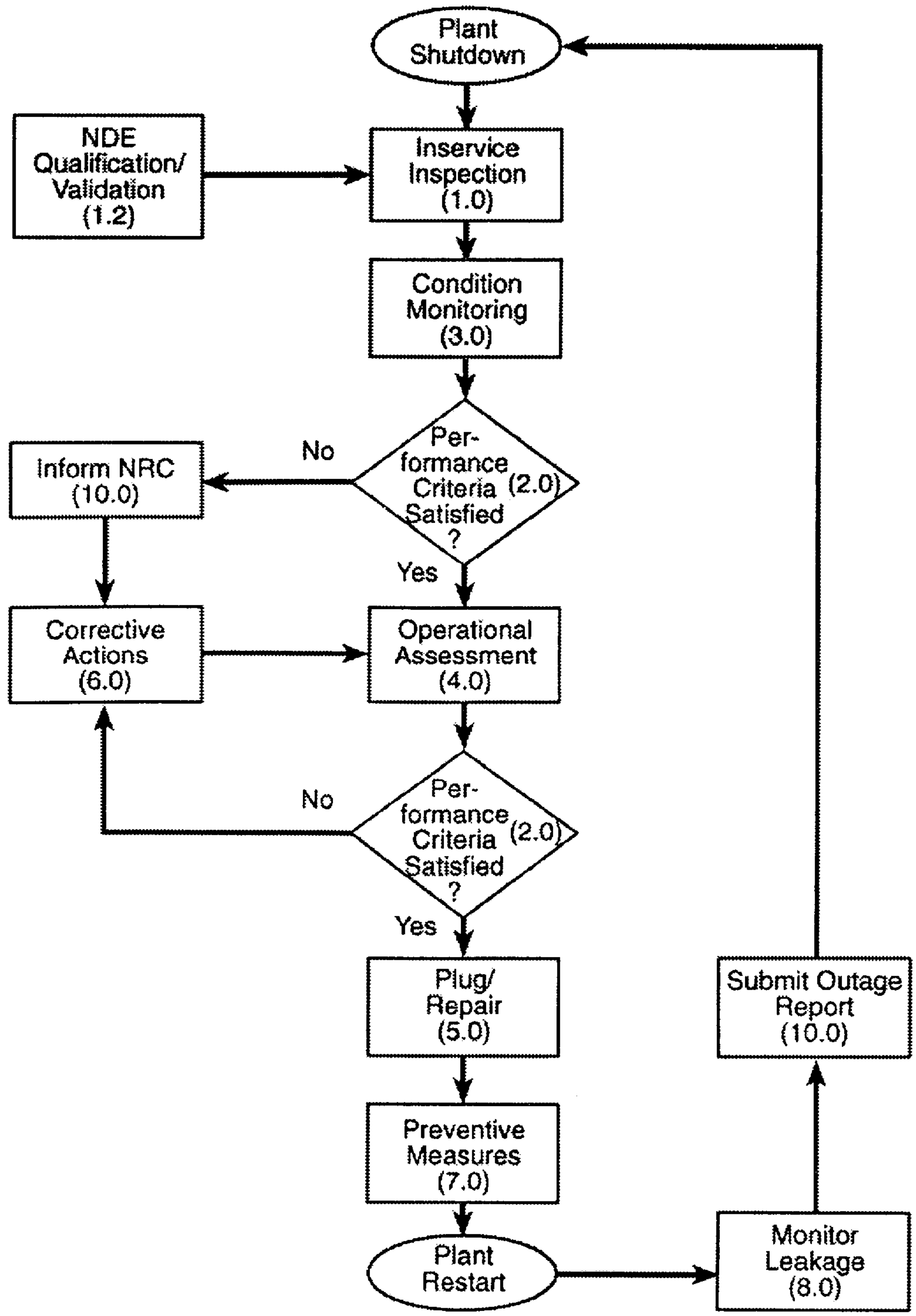

Figure 1

Plant A

TS Plot of Allowable Primary Coolant Activity Level of Dose Equivalent Iodine

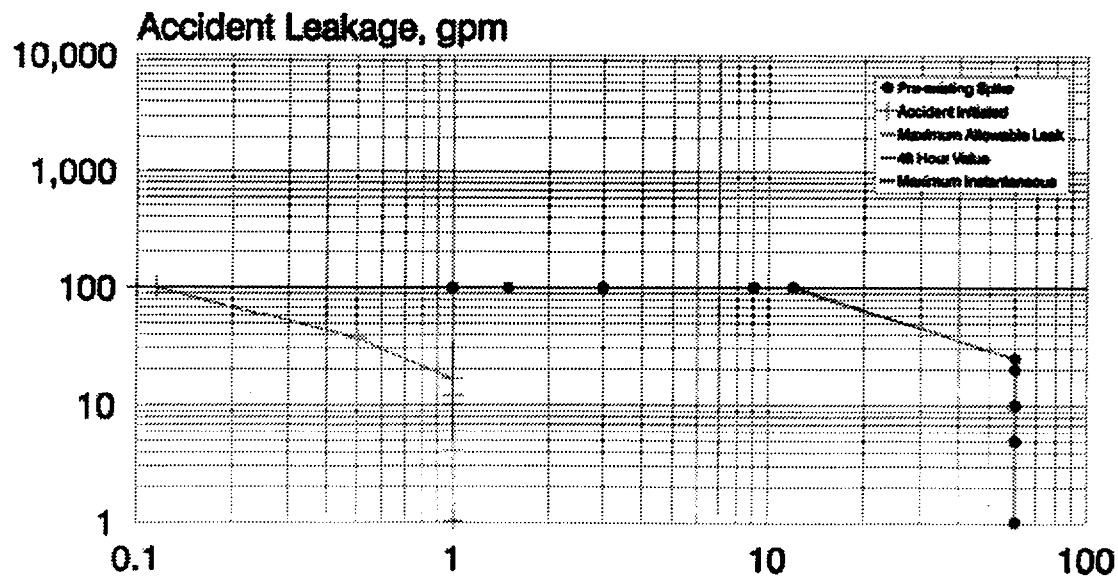

Figure 2

Plant B

TS Plot of Allowable Primary Coolant Activity Level of Dose Equivalent Iodine

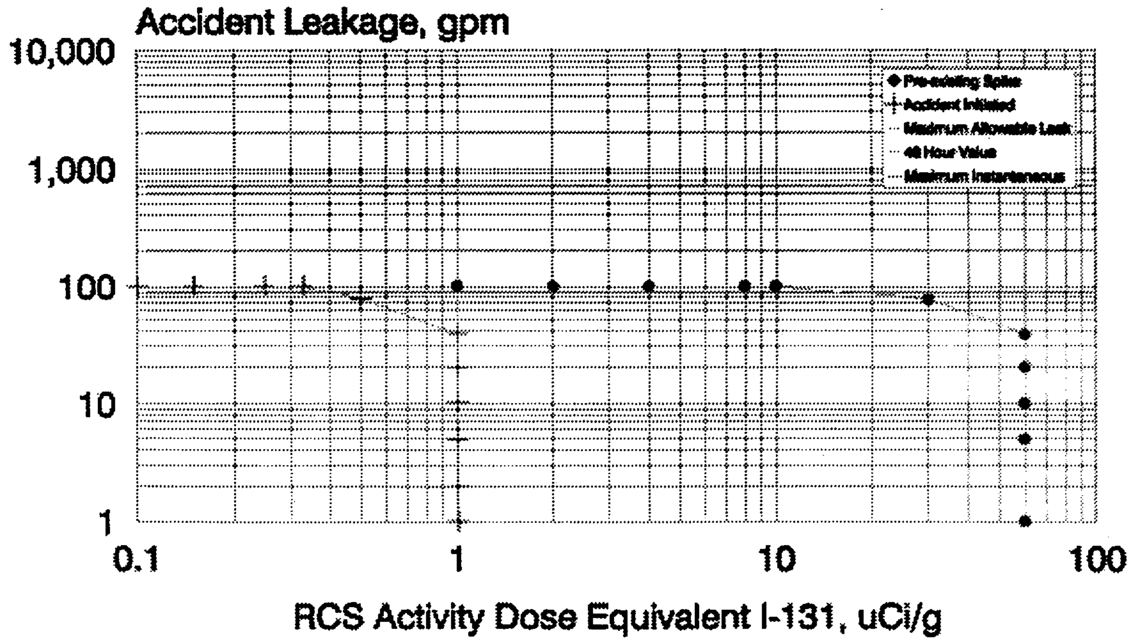

Figure 3

Plant C

TS Plot of Allowable Primary Coolant Activity Level of Dose Equivalent Iodine

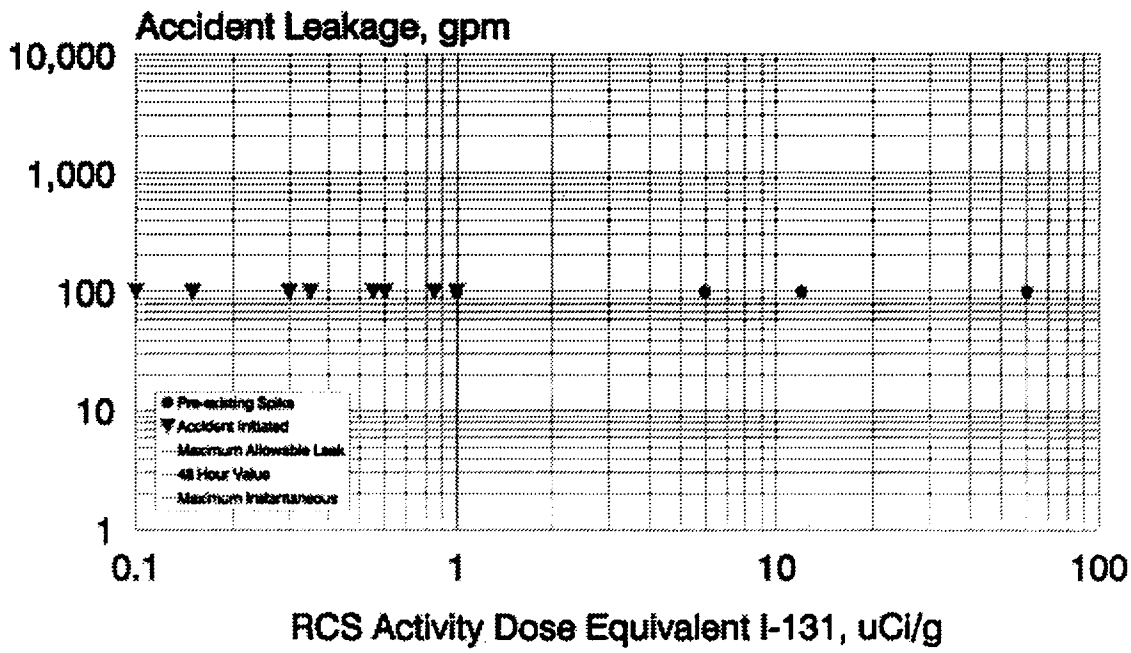

Figure 4

REFERENCES

1. "Standard Review Plan for the Review of Safety Analysis Reports or Nuclear Power Plants," LWR Edition, NUREG-0800, July 1981.

2. American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Sections III and XI, ASME. (Copies may be obtained from ASME, 345 East 47th Street, New York, NY 10017.)

3. "Standard Technical Specifications for Babcock and Wilcox Pressurized Water Reactors," NUREG-1430, Revision 1, April 1995.

4. "Standard Technical Specifications for Combustion Engineering Pressurized Water Reactors," NUREG-1432, Revision 1, April 1995.

5. "Standard Technical Specifications for Westinghouse Pressurized Water Reactors," NUREG-1431, Revision 1, April 1995.

6. USNRC, "Inservice Inspection of Pressurized Water Reactor Steam Generator Tubes," Regulatory Guide 1.83, Revision 1, July 1975.

7. USNRC, "Bases for Plugging Degraded PWR Steam Generator Tubes," Regulatory Guide 1.121, August 1976.

8. USNRC, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," Regulatory Guide 1.174, July 1998.

9. Electric Power Research Institute, "PWR Steam Generator Examination Guidelines," EPRI NP-6201, Revision 5, Appendices G and H, September 1997.

10. Electric Power Research Institute, "PWR Secondary Water Chemistry Guidelines," EPRI NP-102134, Revision 3, May 1993.

11. Electric Power Research Institute, "PWR Primary-to-Secondary Leak Guidelines," EPRI Report TR-104788, May 1995.

12. J.P. Adams and C.L. Atwood, "The Iodine Spike Release Rate During a Steam Generator Tube Rupture, *Nuclear Technology,* Volume 4, PP. 361-371, June 1991.

REGULATORY ANALYSIS

A separate regulatory analysis was not prepared for this regulatory guide. The regulatory analysis prepared to support revising the current regulatory framework addressing steam generator tube integrity provides the regulatory basis for this guide and related documents and examines the costs and benefits as implemented by this guide. A copy of "Regulatory Analysis: Regulatory Approach for Steam Generator Tube Integrity," May 1997, is available for inspection and copying for a fee at the NRC Public Document Room, 2120 L Street NW, Washington, DC.

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