3.1.6 Leakage

Specification

3.1.6.1 If the total reactor coolant leakage rate exceeds 10 gpm, the reactor shall be shutdown within 24 hours of detection.

3.1.6.2 If unidentified reactor coolant leakage (exceeding normal evaporative losses) exceeds 1 gpm or if any reactor coolant leakage is evaluated as unsafe, the reactor shall be shutdown within 24 hours of detection.

3.1.6.3.a If it is determined that any reactor coolant leakage exists through a non-isolable fault in a reactor coolant system strength boundary (such as the reactor vessel, piping, valve body, etc., except steam generator tubes), the reactor shall be shutdown and a cooldown to the cold shutdown condition shall be initiated within 24 hours of detection.

3.1.6.3.b If the leakage through the tubes of any one steam generator equals or exceeds 150 gallons per day (0.104 gpm), a reactor shutdown shall be initiated within 4 hours and the reactor shall be in the cold shutdown condition within the next 30 hours.

3.1.6.4 Deleted

3.1.6.5 Action to evaluate the safety implication of reactor coolant leakage shall be initiated within 4 hours of detection. The nature, as well as the magnitude of the leak, shall be considered in this evaluation. The safety evaluation shall assure that the exposure of offsite personnel to radiation is within the guidelines of 10CFR20.

3.1.6.6 If reactor shutdown is required per Specification 3.1.6.1, 3.1.6.2, or 3.1.6.3 the reactor shall not be restarted until the leak is repaired or until the problem is otherwise corrected.

3.1.6.7 When the reactor is at power operation, three reactor coolant leak detection systems of different operating principles shall be in operation. One of these systems is sensitive to radioactivity and consists of a radioactive gas detector and an air particulate activity detector. Both of these instruments may be out-of-service simultaneously for a period of no more than 72 hours provided two other means are available to detect leakage and reactor building air samples are taken and analyzed in the laboratory at least once per shift; otherwise, be in at least Hot Standby within the next 6 hours and in Cold Shutdown within the following 30 hours.

3.1.6.8 Loss of reactor coolant through reactor coolant pump seals and system valves to connecting systems which

A tube inspection (pursuant to Specification 4.18.5.a.9) shall be performed on each selected tube. If any selected tube does not permit the passage of the eddy current probe for a tube inspection, this shall be recorded and an adjacent tube shall be selected and subjected to a tube inspection.

3. Tubes in the following groups may be excluded from the first random sample if all tubes in a group in both steam generators are inspected. The inspection may be concentrated on those portions of the tubes where imperfections were previously found. No credit will be taken for these tubes in meeting minimum sample size requirements. Where only a portion of the tube is inspected, the remainder of the tube will be subjected to the random inspection.

   (1) Group A-1: Tubes within one, two or three rows of the open inspection lane.

   (2) Group A-2: Unplugged tubes with sleeves installed.

   (3) Group A-3: Tubes in the wedge-shaped group on either side of the lane region (Group A-1) as defined by Figure 4.18.1.

4. Indications left in service as a result of application of the upper tubesheet voltage-based repair criteria shall be inspected by bobbin and rotating coil probes during all subsequent refueling outages.

b. Implementation of the steam generator upper tubesheet voltage-based repair criteria requires a 100% bobbin coil inspection of the upper tubesheet. If a 100% bobbin coil examination of the upper tubesheet is performed, the results of this examination may be excluded from the first random sample.

c. The second and third sample inspections during each inservice inspection as required by Table 4.18-2 may be less than a full tube inspection by concentrating the inspection on those areas of the tube sheet array and on those portions of the tubes where tubes with imperfections were previously found.

The results of each sample inspection shall be classified into one of the following three categories:

Category	Inspection Results
C-1	Less than 5% of the total tubes inspected are degraded tubes and none of the inspected tubes are defective.
C-2	One or more tubes, but not more than 1% of the total tubes inspected, are defective, or between 5% and 10% of the total tubes inspected are degraded tubes.
C-3	More than 10% of the total tubes inspected are degraded tubes or more than 1% of the inspected tubes are defective.

the first sample inspection specified in Table 4.18-2. If the degradation mechanism which caused the leak is limited to a specific portion of the tube length, the inspection per this paragraph may be limited to the affected portion of the tube length. If the results of this inspection fall into the C-3 category, all of the tubes in the same group in the other steam generator will also be similarly inspected.)

2. A seismic occurrence greater than the Operating Basis Earthquake,

3. A loss-of-coolant accident requiring actuation of the engineered safeguards, or

4. A main steam line or feedwater line break.

4.18.5 Acceptance Criteria

a. As used in this specification:

1. Tubing or Tube means that portion of the tube or sleeve which forms the primary system to secondary system pressure boundary.

2. Imperfection means an exception to the dimensions, finish or contour of a tube from that required by fabrication drawings or specifications. Eddy current testing indications below 20% of the nominal tube wall thickness, if detectable, may be considered as imperfections.

3. Degradation means a service-induced cracking, wastage, wear or general corrosion occurring on either the inside or outside of a tube.

4. Degraded Tube means a tube containing imperfections ≤ 20% of the nominal wall thickness caused by degradation, except where all degradation has been spanned by the installation of a sleeve.

5. % Degradation means the percentage of the tube wall thickness affected or removed by degradation.

6. Defect means an imperfection of such severity that it exceeds the plugging limit except where the imperfection has been spanned by the installation of a sleeve. A tube containing a defect in its pressure boundary is defective.

7. Plugging Limit means the imperfection depth at or beyond which the tube shall be restored to serviceability by the installation of a sleeve or removed from service because it may become unserviceable prior to the next inspection; it is equal to 40% of the nominal tube wall thickness. This definition does not apply to the upper tubesheet volumetric indications for which the voltage-based repair criteria are being applied. Refer to specification 4.18.5.a.10 for the repair limit applicable to these indications.

8. Unserviceable describes the condition of a tube if it leaks or contains a defect large enough to affect its structural integrity in the event of an Operating Basis Earthquake, a loss-of-coolant accident, or a steam line or feedwater line break as specified in Specification 4.18.4.c.

9. Tube Inspection means an inspection of the steam generator tube from the point of entry completely to the point of exit.

10. Tubesheet Limit is used for the disposition of an alloy 600 OTSG tube for continued service that is experiencing predominately volumetric ODIGA located from 2.75 inches from the secondary face of the upper tubesheet to but not including the roll transition. The plugging limit within this portion of the tubesheet is based on maintaining steam generator tube serviceability as described below:

    a. Steam generator tubes, whose degradation is attributed to volumetric ODIGA within the upper tubesheet with a bobbin voltage ≤ 1.18 volts, minus an allowance for growth over the next operating cycle, will be allowed to stay in service. Tubes with indications that exceed this limit will be repaired or plugged.

    b. The determination that an indication is volumetric ODIGA will be based on rotating coil examination. If the indication can be characterized as crack-like (either as axial or circumferential) the steam generator tube shall be repaired or plugged.

b. The steam generator shall be determined operable after completing the corresponding actions (plug or sleeve all tubes exceeding the plugging limit and all tubes containing through-wall cracks) required by Table 4.18-2.

4.18.6 Reports

Following each inservice inspection of steam generator tubes, the complete results of the inspection shall be reported to the NRC. This report, to be submitted within 45 days of inspection completion, shall include:

a. Number and extent of tubes inspected;

b. Location and percent of wall-thickness penetration for each indication of an imperfection; and

c. Identification of tubes plugged and tubes sleeved.

This report shall be in addition to a Special Report (per Specification 6.12.5.d) required for the results of steam generator tube inspections which fall into Category C-3 as denoted in Table 4.18-2. The Commission shall be notified of the results of steam generator tube inspections which fall into Category C-3 prior to resumption of plant operation. The written Special Report shall provide a description of investigations conducted to determine cause of the tube degradation and corrective measures taken to prevent recurrence.

For implementation of the upper tubesheet voltage-based repair criteria, notify the Commission prior to returning the steam generator to service if any of the following conditions arise:

a. Leakage through an upper tubesheet volumetric ODIGA indication is detected during in-situ leak testing, or

b. Upper tubesheet indications previously left in service, on average, show signs of growth beyond that seen in the previous cycle, based on the results of the bobbin voltage data analysis from the current and previous inspections.

Bases

The surveillance requirements for inspection of the steam generator tubes ensure that the structural integrity of this portion of the RCS will be maintained. The program for inservice inspection of steam generator tubes is based on a modification of Regulatory Guide 1.83, Revision 1. Inservice inspection of steam generator tubing is essential in order to maintain surveillance of the conditions of the tubes in the event that there is evidence of mechanical damage or progressive degradation due to design, manufacturing errors, or inservice conditions that lead to corrosion. Inservice inspection of steam generator tubing also provides a means of characterizing the nature and cause of any tube degradation so that corrective measures can be taken.

The voltage-based repair limit of SR 4.18 implements the criteria derived from BAW-10226P, "Alternate Repair Criteria for Volumetric Outer Diameter Intergranular Attack in the Tubesheets of Once Through Steam Generators." The voltage-based repair limits are not applicable to other forms of once through steam generator (OTSG) tube degradation nor are they applicable to outer diameter intergranular attack (ODIGA) that occurs at other locations within the OTSGs. Additionally, the repair criteria apply only to indications where the degradation mechanism is dominantly volumetric. Upper tubesheet indications, for the purpose of this specification, are defined as indications within the upper tubesheet located 2.75 inches from the secondary face to but not including the roll transition.

BAW-10226P evaluated the potential for tube burst and accident induced leakage as a result of applying the voltage-based repair criteria to volumetric ODIGA within the tubesheet. Because of the constraint of the OTSG tube radial displacement within the tubesheet, burst pressure below that of an unflawed tube is precluded.

To assure acceptable accident induced leakage, worst case combined accident loads were applied to 29 samples with volumetric ODIGA with bobbin indications ranging from 0.04 to 1.62 volts. None of these flaws showed signs of leakage as a result of these loads. An additional four laboratory specimens created by electrodischarge machining were also testing. None of these additional samples leaked under worst case combined accident loads. Therefore, it was concluded that volumetric ODIGA flaws with eddy current indication up to 1.62 volts will not leak under accident conditions, and that this is an acceptable threshold value to use to assume zero accident leakage.

The voltage threshold value must be adjusted, as appropriate, to account for eddy current measurement uncertainties associated with the chosen eddy current technique. In addition, an appropriate allowance must be made for growth of the indications in order to ensure that the indication amplitude does not exceed the threshold value prior to the next planned inspection. This adjustment can be expressed by the following equation:

$$V_{RL} = V_{Threshold} - V_{NDE} - V_{Growth}$$

where

V_{RL} = Repair limit (volts)

$V_{Threshold}$ = Threshold voltage (1.62 volts)

V_{NDE} = Eddy current measurement uncertainty

V_{Growth} = Growth over one fuel cycle (volts)

The eddy current uncertainty is discussed in BAW-10226P and is equal to 0.44 volts. By performing eddy current inspections consistent with the guidance found in Appendix A to BAW-10226P this uncertainty value will be bounding for ANO-1. Therefore the ANO-1 repair limit is:

$$V_{RL} = 1.62 - 0.44 \text{ volts} - V_{Growth}$$

$$V_{RL} = 1.18 \text{ volts} - V_{Growth}$$

From growth rate studies performed on ANO-1 eddy current data collected from 1993 through 1996 the upper tubesheet volumetric ODIGA indications have shown an average growth rate of zero volts. To account for potential growth in the future, growth rate studies will be conducted each outage. The growth rate studies will compare the eddy current bobbin voltage values for the same indications from the previous inspection to that of the current inspection. Both the average growth and the 95% upper tolerance values will be calculated. For conservatism the 95% upper tolerance growth rate limit will be used in the establishment of the voltage-based repair limit.

To further enhance the leakage data base and to demonstrate the conservatism of the voltage-based repair limit, four of the larger accessible tubesheet volumetric ODIGA indications with a bobbin voltage measurement of > 1.0 volts will be in-situ leak tested each outage the voltage-based repair criteria is applied.

MARKUP OF CURRENT ANO-1 TECHNICAL SPECIFICATIONS

(FOR INFO ONLY)

3.1.6 Leakage

Specification

3.1.6.1 If the total reactor coolant leakage rate exceeds 10 gpm, the reactor shall be shutdown within 24 hours of detection.

3.1.6.2 If unidentified reactor coolant leakage (exceeding normal evaporative losses) exceeds 1 gpm or if any reactor coolant leakage is evaluated as unsafe, the reactor shall be shutdown within 24 hours of detection.

3.1.6.3.a If it is determined that any reactor coolant leakage exists through a non-isolable fault in a reactor coolant system strength boundary (such as the reactor vessel, piping, valve body, etc., except steam generator tubes), the reactor shall be shutdown and a cooldown to the cold shutdown condition shall be initiated within 24 hours of detection.

3.1.6.3.b If the leakage through the tubes of any one steam generator equals or exceeds 150~~5^0~~ gallons per day (0.104~~347~~ gpm)~~*~~, a reactor shutdown shall be initiated within 4 hours and the reactor shall be in the cold shutdown condition within the next 30 hours.

~~* This limit has been reduced to 144 gallons per day (0.1 gpm) for the remainder of cycle 14.~~

3.1.6.4 Deleted

3.1.6.5 Action to evaluate the safety implication of reactor coolant leakage shall be initiated within 4 hours of detection. The nature, as well as the magnitude of the leak, shall be considered in this evaluation. The safety evaluation shall assure that the exposure of offsite personnel to radiation is within the guidelines of 10CFR20.

3.1.6.6 If reactor shutdown is required per Specification 3.1.6.1, 3.1.6.2, or 3.1.6.3 the reactor shall not be restarted until the leak is repaired or until the problem is otherwise corrected.

3.1.6.7 When the reactor is at power operation, three reactor coolant leak detection systems of different operating principles shall be in operation. One of these systems is sensitive to radioactivity and consists of a radioactive gas detector and an air particulate activity detector. Both of these instruments may be out-of-service simultaneously for a period of no more than 72 hours provided two other means are available to detect leakage and reactor building air samples are taken and analyzed in the laboratory at least once per shift; otherwise, be in at least Hot Standby within the next 6 hours and in Cold Shutdown within the following 30 hours.

3.1.6.8 Loss of reactor coolant through reactor coolant pump seals and system valves to connecting systems which

A tube inspection (pursuant to Specification 4.18.5.a.9) shall be performed on each selected tube. If any selected tube does not permit the passage of the eddy current probe for a tube inspection, this shall be recorded and an adjacent tube shall be selected and subjected to a tube inspection.

3. Tubes in the following groups may be excluded from the first random sample if all tubes in a group in both steam generators are inspected. The inspection may be concentrated on those portions of the tubes where imperfections were previously found. No credit will be taken for these tubes in meeting minimum sample size requirements. Where only a portion of the tube is inspected, the remainder of the tube will be subjected to the random inspection.

   (1) Group A-1: Tubes within one, two or three rows of the open inspection lane.

   (2) Group A-2: Unplugged tubes with sleeves installed.

   (3) Group A-3: Tubes in the wedge-shaped group on either side of the lane region (Group A-1) as defined by Figure 4.18.1.

4. Indications left in service as a result of application of the upper tubesheet voltage-based repair criteria shall be inspected by bobbin and rotating coil probes during all subsequent refueling outages.

b. Implementation of the steam generator upper tubesheet voltage-based repair criteria requires a 100% bobbin coil inspection of the upper tubesheet. If a 100% bobbin coil examination of the upper tubesheet is performed, the results of this examination may be excluded from the first random sample.

c~~b~~. The second and third sample inspections during each inservice inspection as required by Table 4.18-2 may be less than a full tube inspection by concentrating the inspection on those areas of the tube sheet array and on those portions of the tubes where tubes with imperfections were previously found.

The results of each sample inspection shall be classified into one of the following three categories:

Category	Inspection Results
C-1	Less than 5% of the total tubes inspected are degraded tubes and none of the inspected tubes are defective.
C-2	One or more tubes, but not more than 1% of the total tubes inspected, are defective, or between 5% and 10% of the total tubes inspected are degraded tubes.
C-3	More than 10% of the total tubes inspected are degraded tubes or more than 1% of the inspected tubes are defective.

the first sample inspection specified in Table 4.18-2. If the degradation mechanism which caused the leak is limited to a specific portion of the tube length, the inspection per this paragraph may be limited to the affected portion of the tube length. If the results of this inspection fall into the C-3 category, all of the tubes in the same group in the other steam generator will also be similarly inspected.)

2. A seismic occurrence greater than the Operating Basis Earthquake,

3. A loss-of-coolant accident requiring actuation of the engineered safeguards, or

4. A main steam line or feedwater line break.

4.18.5 Acceptance Criteria

a. As used in this specification:

1. Tubing or Tube means that portion of the tube or sleeve which forms the primary system to secondary system pressure boundary.

2. Imperfection means an exception to the dimensions, finish or contour of a tube from that required by fabrication drawings or specifications. Eddy current testing indications below 20% of the nominal tube wall thickness, if detectable, may be considered as imperfections.

3. Degradation means a service-induced cracking, wastage, wear or general corrosion occurring on either the inside or outside of a tube.

4. Degraded Tube means a tube containing imperfections ≤ 20% of the nominal wall thickness caused by degradation, except where all degradation has been spanned by the installation of a sleeve.

5. % Degradation means the percentage of the tube wall thickness affected or removed by degradation.

6. Defect means an imperfection of such severity that it exceeds the plugging limit except where the imperfection has been spanned by the installation of a sleeve. A tube containing a defect in its pressure boundary is defective.

7. Plugging Limit means the imperfection depth at or beyond which the tube shall be restored to serviceability by the installation of a sleeve or removed from service because it may become unserviceable prior to the next inspection; it is equal to 40% of the nominal tube wall thickness. This definition does not apply to the upper tubesheet volumetric indications for which the voltage-based repair criteria are being applied. Refer to specification 4.18.5.a.10 for the repair limit applicable to these indications.

8. Unserviceable describes the condition of a tube if it leaks or contains a defect large enough to affect its structural integrity in the event of an Operating Basis Earthquake, a loss-of-coolant accident, or a steam line or feedwater line break as specified in Specification 4.18.4.c.

9. Tube Inspection means an inspection of the steam generator tube from the point of entry completely to the point of exit.

10. Tubesheet Limit is used for the disposition of an alloy 600 OTSG tube for continued service that is experiencing predominately volumetric ODIGA located from 2.75 inches from the secondary face of the upper tubesheet to but not including the roll transition. The plugging limit within this portion of the tubesheet is based on maintaining steam generator tube serviceability as described below:

    a. Steam generator tubes, whose degradation is attributed to volumetric ODIGA within the upper tubesheet with a bobbin voltage ≤ 1.18 volts, minus an allowance for growth over the next operating cycle, will be allowed to stay in service. Tubes with indications that exceed this limit will be repaired or plugged.

    b. The determination that an indication is volumetric ODIGA will be based on rotating coil examination. If the indication can be characterized as crack-like (either as axial or circumferential) the steam generator tube shall be repaired or plugged.

b. The steam generator shall be determined operable after completing the corresponding actions (plug or sleeve all tubes exceeding the plugging limit and all tubes containing through-wall cracks) required by Table 4.18-2. ~~with the following exception:~~

~~Tubes with intergranular attack indications within the upper tube sheet with the potential of through-wall depths greater than the plugging limit may remain in service for the remainder of cycle 14.~~

4.18.6 Reports

Following each inservice inspection of steam generator tubes, the complete results of the inspection shall be reported to the NRC. This report, to be submitted within 45 days of inspection completion, shall include:

a. Number and extent of tubes inspected;

b. Location and percent of wall-thickness penetration for each indication of an imperfection; and

c. Identification of tubes plugged and tubes sleeved.

This report shall be in addition to a Special Report (per Specification 6.12.5.d) required for the results of steam generator tube inspections which fall into Category C-3 as denoted in Table 4.18-2. The Commission shall be notified of the results of steam generator tube inspections which fall into Category C-3 prior to resumption of plant operation. The written Special Report shall provide a description of investigations conducted to determine cause of the tube degradation and corrective measures taken to prevent recurrence.

For implementation of the upper tubesheet voltage-based repair criteria, notify the Commission prior to returning the steam generator to service if any of the following conditions arise:

a. Leakage through an upper tubesheet volumetric ODIGA indication is detected during in-situ leak testing, or

b. Upper tubesheet indications previously left in service, on average, show signs of growth beyond that seen in the previous cycle, based on the results of the bobbin voltage data analysis from the current and previous inspections.

Bases

The surveillance requirements for inspection of the steam generator tubes ensure that the structural integrity of this portion of the RCS will be maintained. The program for inservice inspection of steam generator tubes is based on a modification of Regulatory Guide 1.83, Revision 1. Inservice inspection of steam generator tubing is essential in order to maintain surveillance of the conditions of the tubes in the event that there is evidence of mechanical damage or progressive degradation due to design, manufacturing errors, or inservice conditions that lead to corrosion. Inservice inspection of steam generator tubing also provides a means of characterizing the nature and cause of any tube degradation so that corrective measures can be taken.

The voltage-based repair limit of SR 4.18 implements the criteria derived from BAW-10226P, "Alternate Repair Criteria for Volumetric Outer Diameter Intergranular Attack in the Tubesheets of Once Through Steam Generators." The voltage-based repair limits are not applicable to other forms of once through steam generator (OTSG) tube degradation nor are they applicable to outer diameter intergranular attack (ODIGA) that occurs at other locations within the OTSGs. Additionally, the repair criteria apply only to indications where the degradation mechanism is dominantly volumetric. Upper tubesheet indications, for the purpose of this specification, are defined as indications within the upper tubesheet located 2.75 inches from the secondary face to but not including the roll transition.

BAW-10226P evaluated the potential for tube burst and accident induced leakage as a result of applying the voltage-based repair criteria to volumetric ODIGA within the tubesheet. Because of the constraint of the OTSG tube radial displacement within the tubesheet, burst pressures below that of an unflawed tube is precluded.

To assure acceptable accident induced leakage, worst case combined accident loads were applied to 29 samples with volumetric ODIGA with bobbin indications ranging from 0.04 to 1.62 volts. None of these flaws showed signs of leakage as a result of these loads. An additional four laboratory specimens created by electrodischarge machining were also testing. None of these additional samples leaked under worst case combined accident loads. Therefore, it was concluded that volumetric ODIGA flaws with eddy current indication up to 1.62 volts will not leak under accident conditions, and that this is an acceptable threshold value to use to assume zero accident leakage.

The voltage threshold value must be adjusted, as appropriate, to account for eddy current measurement uncertainties associated with the chosen eddy current technique. In addition, an appropriate allowance must be made for growth of the indications in order to ensure that the indication amplitude does not exceed the threshold value prior to the next planned inspection. This adjustment can be expressed by the following equation:

$$V_{RL} = V_{Threshold} - V_{NDE} - V_{Growth}$$

where

V_{RL} = Repair limit (volts)

$V_{Threshold}$ = Threshold voltage (1.62 volts)

V_{NDE} = Eddy current measurement uncertainty

V_{Growth} = Growth over one fuel cycle (volts)

The eddy current uncertainty is discussed in BAW-10226P and is equal to 0.44 volts. By performing eddy current inspections consistent with the guidance found in Appendix A to BAW-10226P this uncertainty value will be bounding for ANO-1. Therefore the ANO-1 repair limit is:

$$V_{RL} = 1.62 - 0.44 \text{ volts} - V_{Growth}$$

$$V_{RL} = 1.18 \text{ volts} - V_{Growth}$$

From growth rate studies performed on ANO-1 eddy current data collected from 1993 through 1996 the upper tubesheet volumetric ODIGA indications have shown an average growth rate of zero volts. To account for potential growth in the future, growth rate studies will be conducted each outage. The growth rate studies will compare the eddy current bobbin voltage values for the same indications from the previous inspection to that of the current inspection. Both the average growth and the 95% upper tolerance values will be calculated. For conservatism the 95% upper tolerance growth rate limit will be used in the establishment of the voltage-based repair limit.

To further enhance the leakage data base and to demonstrate the conservatism of the voltage-based repair limit, four of the larger accessible tubesheet volumetric ODIGA indications with a bobbin voltage measurement of > 1.0 volts will be in-situ leak tested each outage the voltage-based repair criteria is applied.