September 2006

Hydro Plant Risk Assessment Guide

Appendix E11: Emergency Closure Gate and Valve Condition Assessment

E11.1 GENERAL

Emergency closure gates and valves are key safety components in the power train at hydroelectric powerplants. Unexpected failure can have a significant economic impact due to the high cost of emergency repairs and lost revenues during an extended forced outage. Failure of emergency closure equipment can also affect life safety.

Determining the present condition of an emergency closure gate and valve is an essential step in analyzing the risk of failure. This appendix provides a process for arriving at an Emergency Closure Gate and Valve Condition Index which may be used to develop a business case addressing risk of failure, economic consequences, and other factors.

E11.2 SCOPE / APPLICATION

The condition assessment methodology outlined in this appendix applies to hydroelectric powerhouse emergency closure equipment. The condition assessment primarily focuses on the gates, valves, and associated operators (i.e., hoists, hydraulic cylinders, and valve operators). The appendix does not apply to closure systems that are not used for emergency purposes.

In recognition that many organizations have facility safety review programs, it is intended that the assessments described herein fully utilize information provided by such reviews to avoid duplication of work and to minimize outage time. This information may be available in the form of comprehensive facility reviews, special examinations, maintenance databases, and operational reports. If the assessment requires an additional physical inspection, then it should be coordinated with the organization's existing review program.

This appendix is not intended to define maintenance practices or describe in detail inspections, tests, or measurements. Utility-specific maintenance policies, procedures, and guidelines must be consulted for such information.

E11.3 CONDITION AND DATA QUALITY INDICATORS AND EMERGENCY CLOSURE SYSTEM CONDITION INDEX

This appendix describes the condition indicators generally regarded by hydro plant engineers as providing the initial basis for assessing the condition of the emergency closure system. The

following indicators are used to separately evaluate the condition of the gates or valves and their associated operator:

- Age
- Physical Condition – Gates/Valves
- Physical Condition – Operators
- Operations History
- Maintenance History

These condition indicators are initially evaluated using Tier 1 inspections, tests, and measurements, which are conducted by utility staff or contractors over the course of time and as a part of routine maintenance activities. Numerical scores are assigned to each condition indicator, which are then weighted and summed to determine the overall Emergency Closure System Condition Index.

An additional stand-alone indicator is used to reflect the quality of the information available for scoring the condition indicators. In some cases, data may be missing, out-of-date, or of questionable integrity. Any of these situations could affect the accuracy of the associated condition indicator scores as well as the validity of the overall Emergency Closure System Condition Index. Given the potential impact of poor or missing data, the Data Quality Indicator is used as a means of evaluating and recording confidence in the final Emergency Closure System Condition Index.

Additional information regarding gate, valve and associated operator condition may be necessary to improve the accuracy and reliability of the Emergency Closure System Condition Index. Therefore, in addition to the Tier 1 condition indicators, this appendix describes a "toolbox" of Tier 2 inspections, tests, and measurements that may be applied to the Emergency Closure System Condition Index, depending on the specific issue or problem being addressed. Tier 2 analyses are considered non-routine. However, if Tier 2 data is readily available, it may be used to supplement the Tier 1 assessment. Alternatively, Tier 2 tests may be deliberately performed to address Tier 1 findings. Results of the Tier 2 analysis may either increase or decrease the score of the Emergency Closure System Condition Index. The Data Quality Indicator score may also be revised during the Tier 2 assessment to reflect the availability of additional information or test data.

The Emergency Closure System Condition Index may indicate the need for immediate corrective actions and/or follow-up Tier 2 testing. The Emergency Closure System Condition Index is also suitable for use as an input to the risk-and-economic analysis model.

Note: A severely negative result of ANY inspection, test, or measurement may be adequate in itself to require immediate corrective action, regardless of the Emergency Closure System Condition Index score.

E1.4 INSPECTIONS, TESTS, AND MEASUREMENTS

Inspections, tests, and measurements should be conducted and analyzed by staff suitably trained and experienced in the equipment being inspected. The more basic tests may be conducted by

qualified personnel that are competent in these routine procedures. More complex inspections and measurements may require an expert.

Inspections, tests, and measurements should be conducted on a frequency that provides the accurate and current information needed by the assessment.

Details of the inspection, testing, and measurement methods and intervals are described in technical references specific to each electric utility.

E11.5 SCORING

Condition indicator scoring is somewhat subjective, relying on the experience and opinions of experts. Relative terms such as "Results Normal" and "Degradation" refer to results that are compared to industry-accepted levels; or to baseline or previous (acceptable) levels on this equipment; or to equipment of similar design, construction, or age operating in a similar environment.

E11.6 WEIGHTING FACTORS

Weighting factors used in the condition assessment methodology recognize that some condition indicators affect the Emergency Closure System Condition Index to a greater or lesser degree than other indicators. These weighting factors were arrived at by consensus among design and maintenance personnel with extensive experience.

E11.7 MITIGATING FACTORS

Every emergency closure system is unique and, therefore, the methodology described in this appendix cannot quantify all factors that affect individual condition. It is important that the Emergency Closure System Condition Index arrived at be scrutinized by experts. Mitigating factors specific to the utility may determine the final Emergency Closure System Condition Index and the final decision on replacement or rehabilitation of the system.

E11.8 DOCUMENTATION

Substantiating documentation is essential to support findings of the assessment, particularly where a Tier 1 condition indicator score is less than 3 (i.e., less than normal) or where a Tier 2 analysis results in subtractions to the Emergency Closure System Condition Index. Test reports, facility review reports, special examinations, photographs, O & M records, and other documentation should accompany the Emergency Closure System Condition Assessment Summary Form.

E11.9 CONDITION ASSESSMENT METHODOLOGY

The condition assessment methodology consists of analyzing each condition indicator individually to arrive at a condition indicator score. The scores are weighted and summed to determine the Condition Index.

Reasonable efforts should be made to perform Tier 1 inspections, tests, and measurements. However, when data is unavailable to properly score the Condition Indicator, it may be assumed that the score is "Good" or numerically equal to some mid-range number such as 2. This strategy must be used judiciously to prevent erroneous results and conclusions. In recognition of the potential impact of poor or missing data, a separate Data Quality Indicator is rated as a means of evaluating and recording confidence in the final Emergency Closure System Condition Index.

E11.10 TIER 1 – INSPECTIONS, TESTS, AND MEASUREMENTS

Tier 1 includes those inspections, tests, and measurements that are routinely accomplished as part of normal operation and maintenance, or are readily discernible by examination of existing data. Tier 1 results are quantified below as condition indicators that are weighted and summed to arrive at a Condition Index. A Tier 1 analysis may indicate abnormal conditions that can be resolved with standard corrective maintenance solutions. The Tier 1 results may also indicate the need for an additional investigation, categorized as a Tier 2 analysis.

E11.11 TIER 1 – EMERGENCY CLOSURE CONDITION INDICATORS

Condition Indicator 1 – Age of Gates, Valves, and Operators

Age is an important factor to consider when assessing the condition of an emergency closure system (gates, valves, and operator equipment). Rate the system on the oldest major component (gate, operator, controls). Use the year a component was last completely rehabilitated; otherwise, use the year it was put into service.

Results of the age analyses are applied to Table 1 to arrive at an appropriate Emergency Closure System Age Indicator Score.

Table 1 – Age of Gate, Valve, and Operator

Age of the Equipment	Emergency Closure System Age Indicator Score
< 20 years	3
≥ 20 and < 35 years	2
≥ 35 and < 60 years	1
≥ 60 years	0

Condition Indicator 2 – Physical Condition of Gates/Valves

This section is divided into two parts:

- Gates
- Valves

Select the ***primary*** device used for emergency closure purposes to base the evaluation on.

Gates

Typical types of closure gates included in this study are: Roller-mounted gates (Stoney, Caterpillar, Tractor, and Coaster), Wheel-mounted gates (fixed-wheeled gates), Ring Follower gates, Paradox gates, Ring-seal gates and Cylinder gates, i.e., any gate used for emergency closure purposes.

The known physical condition of the emergency closure gates is a major indicator of overall system reliability. This indicator is based on maintenance records and past inspection reports only. Items to note from records with regard to the gates are: Have the wheels/rollers been inspected? Do all of the wheels/rollers move freely? What's the condition of the wheels/rollers (corrosion, pitting)? Condition of bearings/bushings, overall structural soundness and condition of the gate (has the gate been inspected?), corrosion or damage to the gate, condition of coating, anode condition, condition of gate seals (nicks or abrasion on the seal or excessive leakage (50 gpm or more)), condition of sill plate and the embedded guide in the water passage (pitting, straightness, loosening).

Qualified personnel should make a subjective determination of scoring that encompasses as many factors as possible under this indicator. Results are analyzed and applied to Table 2 to arrive at an appropriate Gate Condition Indicator Score.

Table 2 – Gate Physical Condition	
Results	**Gate Condition Indicator Score**
Limited corrosion on gates, wheels, or rollers; wheels/rollers turn; coating is in good condition; anodes are in good condition; no cracked welds in structure or loose bolts/rivets; gate guides are in good condition; sill is in good condition; leakage past seals is minimal (< 25 gpm or < 1.6 liters/s).	3
Moderate corrosion on the gates, wheels, or rollers; most of the wheels/rollers turn; three-quarters of the anodes are left; no cracked welds in the structure or loose bolts/rivets; gate guides are in good condition; sill is in good condition; leakage past seals is minimal (< 25 gpm or < 1.6 liters/s).	2
Large areas of corrosion on the gates, wheels, or rollers; most of the wheels/rollers turn; one-half of the anodes are left; no cracked welds in the structure or loose bolts/rivets; gate guides are in good condition; sill is in good condition; leakage past seals is moderate (≥ 25 and < 50 gpm or ≥ 1.6 and < 3.2 liters/s).	1
Severe corrosion on the gates, wheels, or rollers; few of the wheels/rollers turn; coating is poor; one-quarter or less of the anodes are left; some cracked welds in the structure or loose or missing bolts/rivets; gate guides are in poor condition; sill is in poor condition; excessive leakage past the seals (≥ 50 gpm or ≥ 3.2 liters/s).	0

Valves

Types of valves generally used for emergency closure purposes are: Butterfly, Spherical, and Cone (plug) valves.

The known physical condition of the emergency closure valves is a major indicator of overall system reliability. For this assessment, the valve will be looked at specifically. This indicator is based on maintenance records and past inspection reports only. Items to note from records with regard to the valves are: Condition of the inside of the valve. Is cavitation present? Condition of the valve seals and sealing surfaces, condition of bearings/bushings, condition of greasing system, overall structural soundness and condition, corrosion, damage to valve, condition of valve bypass.

Qualified personnel should make a subjective determination of scoring that encompasses as many factors as possible under this indicator. Results are analyzed and applied to Table 3 to arrive at an appropriate Valve Condition Indicator Score.

Table 3 – Valve Physical Condition	
Results	**Valve Condition Indicator Score**
Limited corrosion on leaf/plug and water passage; coating is in good condition; seals and seats are in good condition and properly adjusted with no or minimal leakage, bearing/pivot point lubrication is in good condition; the bypass is in good condition; valve is regularly exercised.	3
Moderate corrosion on leaf/plug and water passage; coating is in adequate condition; seals and seats are in adequate condition with minimal leakage; bearing/pivot point lubrication is in good condition; the bypass is in good condition; valve is regularly exercised.	2
Large areas of corrosion on leaf/plug and water passage; coating is less than adequate; seals and seats have some damage with minor leakage; bearing/pivot point lubrication is in adequate condition; the bypass has moderate corrosion; valve is regularly exercised.	1
Severe corrosion on leaf/plug and water passage; coating is poor; seals and seats are damaged allowing excessive leakage; bearing/pivot point lubrication is not functioning properly; the bypass has excessive corrosion; there is severe chattering, vibration, or binding during operation; the valve is either rarely exercised or is excessively exercised (i.e., ≥ 50 cycles per year).	0

Condition Indicator 3 – Physical Condition of Operators

This section will be broken into two major categories:

- Gate Operators
- Intake Valve Operators

Gate Operators

Typical operators for emergency closure gates are generally either a hydraulic system or an electric-driven mechanical hoist.

- The hydraulic system consists of one or more hydraulic cylinders and all the other components typical to a hydraulic system.
- The electric-driven mechanical hoist is usually either a traveling hoist, such as a gantry crane, or a fixed hoist that is permanently installed for use with a particular gate. Both the traveling and fixed hoist may use wire rope or chain for lifting the gate.

As appropriate, use either the Hydraulic Hoist or Electric Hoist methodology to score the gate operator being evaluated.

Hydraulic Hoist

Items to examine or note from maintenance records with regard to the cylinders and hydraulic system include: seals (rod), stem packing, gate drift, corrosion on cylinder rod or case, condition of the hydraulic control panel (relief valves, check valves, four-way valve, lower/raise valve), gate location indicating devices, hydraulic system leaks, condition of the hydraulic pumping unit (HPU) and accumulators, condition of attachment mounts or beams, flexible hydraulic hoses, hydraulic couplings, general coating condition where applicable, condition of the hydraulic fluid, and replacement parts availability. Have the hydraulics been exercised on a regular basis?

Results are analyzed and applied to Table 4 to arrive at an appropriate Gate Operator (Hydraulic Hoist) Physical Condition Indicator Score.

Table 4 – Gate Operator (Hydraulic Hoist) Physical Condition

Results	Hydraulic Hoist Condition Indicator Score
Seals, stems, cylinders, hydraulic piping/valves/controls, and gate position indicators are updated or in good condition with replacement parts available; coating is in good condition; hydraulic oil is in good condition; hydraulic system has been tested and exercised regularly; no gate drift while suspended from the cylinder. No external oil leaks.	3
Seals, stems, cylinders, hydraulic piping/valves/controls, and gate position indicators are in good condition; protective coating is in adequate condition; hydraulic oil condition is adequate; hydraulic system has been tested and exercised regularly; no gate drift while suspended from the cylinder.	2
Seals, stems, cylinders, hydraulic piping/valves/controls, and gate position indicators are in adequate condition; coating is in adequate condition; hydraulic oil condition is contaminated or hasn't been tested; hydraulic system has not been tested but is exercised regularly; no gate drift while suspended from the cylinder.	1
Seals, stems, cylinders, hydraulic piping/valves/controls, and gate position indicators are in poor condition; coating is in poor condition; hydraulic oil condition is contaminated or hasn't been tested; hydraulic system has not been tested or exercised regularly; the gate drifts while suspended from the cylinder. External oil leaks into the water.	0

Electric-Driven Mechanical Hoist

This section covers only ***fixed*** hoists. Items to examine or note from maintenance records include: condition of wire rope/chain, condition of sockets on wire ropes, linkages, gearbox condition, leaks, motors, brake condition and adjustment, motor controls, indicators, backup

power supply, inspections, exercising of the system on a regular basis, wrap of rope/chain onto drums, replacement part availability.

Results are analyzed and applied to Table 5 to arrive at an appropriate Gate Operator (Electric Hoist) Physical Condition Indicator Score.

Note: Bridge and gantry cranes that are used for emergency closure ***shall not*** be inspected or rated using this section. Bridge and gantry cranes have specific inspection requirements that are described in applicable Federal, State, Provincial laws and regulations. See the Crane Condition Assessment Guide, Appendix E9.

Table 5 – Gate Operator (Electric Hoist) Physical Condition

Results	Electric Hoist Condition Indicator Score
Hoist surfaces and coatings are free of corrosion; no structural damage or cracks; couplings are tight and properly aligned; moving parts are lubricated; gearbox oil is free from contaminants and moisture and tested regularly; no groove wear on drums or sheaves; bearings are checked for wear and lubrication; oil seals do not leak; gears are properly aligned and have no wear; the hoist ropes are inspected for broken strands, hoist chain is free of cracked, deformed, or severely corroded links; the rope/chain is laying properly on the drum; limit switches are properly set and functioning properly; hoist brakes have no wear and operate properly; no unusual noises or binding of the mechanism during operation; electrical components are clean and function; the hoist system has been tested and exercised regularly.	3
Hoist surfaces and coatings have minor defects or corrosion; no structural damage or cracks; couplings are tight and properly aligned. moving parts are lubricated; gearbox oil is not tested regularly or minor contaminates noted; no groove wear on drums or sheaves; oil seals do not leak; gears are properly aligned and have no wear; hoist ropes have no broken strands or evidence of corrosion; hoist chain has some corrosion but no cracks or deformed links; the rope/chain is laying properly on the drum; limit switches are properly set and functioning properly; hoist brake pads have ≥ 50% of the lining left and operate properly; no unusual noises or binding of the mechanism during operation; the electrical components are not very clean; the hoist system has been tested and exercised regularly.	2
Hoist surfaces and coatings have minor defects or corrosion; minimal structural damage with no cracks; couplings are tight and properly aligned; gearbox oil is not tested regularly or minor contaminates or water is noted; some groove wear on drums or sheaves; oil seals have minor leaks; gears are mis-aligned but no major wear or damage to the gears; hoist ropes have no broken strands or evidence of corrosion; hoist chain has moderate corrosion but no cracks or deformed links;	1

limit switches are properly set and functioning properly; hoist brakes pads have ≥ 20 and < 50% of the lining left and operate properly; some unusual noises are noted during operation; the electrical components are not very clean; the hoist system has not been tested and exercised regularly; there are multiple trouble reports on record such as repairs to the electrical controls.	
There are serious concerns with the condition such as: major corrosion on the critical components, wire rope corrosion or broken strands; corroded or deformed chain links; < 20% of brake pads left; significant lubricating oil contamination; unusual noises or vibrations during operation; and frequent trouble reports.	0

Intake Valve Operators (Hydraulic or Electric)

Typical operators for emergency closure valves are:

- Hydraulic Cylinders
- Rotary Hydraulic
- Motor-Operated Actuators

Use Table 6 for evaluating the valve operator.

Items to examine or note from maintenance records with regard to the intake valve operators include: availability and testing of backup power system (accumulator, engine/generator/batteries), hydraulic or motor system tested and repaired as needed, greasing system operable, retractable seals operable, closure in event of power failure, controls are updated or in excellent condition with replacement parts available, pressure differential indicators up/downstream of valve is operational, linkages in good condition, wear on stem.

Table 6 – Intake Valve Operator (Hydraulic or Electric) Physical Condition	
Results	**Intake Valve Condition Indicator Score**
Seals, stems, cylinders, hydraulic system, gate position indicators, and controls are in good condition with replacement parts available; backup power is available and tested regularly; slow-down mode has been tested and verified; pressure differential indicators up/downstream are operational and tested; operational testing performed on an annual basis; the system is exercised regularly.	3
Seals, stems, cylinders, hydraulic system, gate position indicators, and controls are updated or in good condition; backup power is available; slow-down mode functions but could use a minor adjustment; pressure differential indicators up/downstream are operational but not calibrated; the system is exercised frequently.	2
Seals, stems, cylinders, hydraulic system, gate position indicators, and controls are in fair condition; backup power is not regularly tested; slow-down mode functions but could use a minor adjustment; pressure differential indicators up/downstream are operational but not calibrated. The timed cycle of operation has changed slightly; the system is exercised rarely.	1
Seals, stems, cylinders, hydraulic system, gate position indicators, and controls are in poor condition; backup power is not available or not reliable; slow-down mode and limit switches are out of adjustment; pressure differential indicators up/downstream are not functioning; the timed cycle of operation has changed significantly; the system is never exercised.	0

Condition Indicator 4 – Operations History

Normal operations are defined as meeting the requirements of the gate or valve's operational design criteria. Examples of deficiencies include: excessive gate drift, significant changes in travel time and pressures, abnormal noise or vibration, changes to the configuration that would impact the availability of emergency closure within the originally-specified time period. Backup power or reliability of the power source is important for reliable operations of the device under emergency situations.

Operational Criteria:

- Does the existing system design meet closure rate requirements (e.g., Army Corps of Engineers-required less than 10-minute closure for gates; less than 2-minute closure for valves)?
- Does the existing system design meet the unbalanced gate closure requirements?
- Does the gate/valve position indicator work?
- Does the remote closure capability (if present) operate correctly?
- Does the annunciation system give adequate warning of a gate closure?

- No abnormal noises.
- No leaks of hydraulic oil or lube oil.
- Does the backup power system for the emergency closure function?
- Does the gate/valve drift in any position? (This assumes it is not latched or dogged.)
- Has the opening or closing pressures (on hydraulic systems) changed from baseline?

Qualified personnel should make a subjective determination of scoring that encompasses as many factors as possible under this indicator. Results are analyzed and applied to Table 7 to arrive at an appropriate Operations History Condition Indicator Score.

Table 7 – Operations History Scoring

Results	Operations Condition Indicator Score
Meets original operational criteria, tested as required, no known design and operational deficiencies.	2
System is functional, but may not meet all operating criteria. Tests as required have been performed. No known design deficiencies.	1
Does not meet original operational criteria or not tested as required or has a known design and operational deficiency.	0

Condition Indicator 5 – Maintenance History

This condition indicator only addresses the amount of maintenance that the system currently requires. A lack of maintenance will be reflected in the Condition Indicator for Physical Condition. The Maintenance Indicator is broken into the following 3 categories:

- Small – It is assumed that a small amount of routine annual preventative maintenance is required for every gate or valve.
- Moderate – Moderate (normal) levels of maintenance would include some corrective maintenance.
- Excessive – Excessive maintenance is intended to include labor-intensive items. Frequent corrosion repairs or abnormal wear to components would be considered excessive.

Results are analyzed and applied to Table 8 to arrive at an appropriate Maintenance History Condition Indicator Score.

Table 8 – Maintenance History Scoring

Amount of Required Maintenance	Maintenance Condition Indicator Index Score
Small	2
Moderate	1
Excessive	0

E11.11 TIER 1 – EMERGENCY CLOSURE SYSTEM CONDITION INDEX CALCULATIONS

Enter the Emergency Closure Systems condition indicator scores from the tables above into the Emergency Closure Systems Assessment Summary Form at the end of this document. Multiply each indicator score by its respective Weighting Factor, and sum the total scores to arrive at the Tier 1 Emergency Closure System Condition Index.

E11.12 TIER 1 – EMERGENCY CLOSURE SYSTEM DATA QUALITY INDICATOR

The Emergency Closure Systems Data Quality Indicator reflects the quality of the inspection, test, and measurement results used to evaluate the condition of the emergency closure system under Tier 1. The more current and complete the results are, the higher the rating for this indicator. A condition assessment schedule appropriate for scoring the Data Quality Indicator is shown in Table 9. Alternatively, an organization's recommended or standard practice for performing the emergency closure system tests and inspections may be substituted for the time intervals given in the table.

Results are analyzed and applied to Table 9 to arrive at an appropriate Emergency Closure System Data Quality Indicator Score.

Table 9 – Emergency Closure System Data Quality Indicator Scoring

Years Since Last Condition Assessment	Data Quality Indicator Score
< 8 years	10
≥ 8 and < 17 years	7
≥ 17 and < 25 years	4
≥ 25 years	0

Enter the Emergency Closure System Data Quality Indicator Score from Table 9 into the Emergency Closure System Condition Assessment Summary form at the end of this document.

E11.13 TIER 2 – INSPECTIONS, TESTS, AND MEASUREMENTS

Tier 2 inspections, tests, and measurements require specialized personnel to interview plant O & M staff and inspect the emergency closure system. The work may involve an outage to perform a proper assessment. A Tier 2 assessment is not considered routine. Tier 2 inspections may affect the Emergency Closure System Condition Index established using Tier 1.

A team consisting of the plant O & M representatives and technical specialists should perform Tier 2 assessments. The tasks to be performed for Tier 2 are summarized below:

1. Technical specialists will be responsible to:

    - Visit the plant to perform a physical inspection of an emergency closure gate or valve.
    - Interview plant O & M staff.
    - Determine current condition of the emergency closure system.
    - Review results and, if necessary, adjust the Tier 1 Condition Index based upon the inspection and comparison with the condition of other similar emergency closure systems.

2. Plant O & M representatives will be responsible to:

    - Provide necessary support and information to technical specialists.
    - Assist in the assessment process.

For each Tier 2 test performed, add or subtract the appropriate amount to/from the Emergency Closure System Condition Index. The Tier 2 evaluation is divided into different categories: Gates, Valves, and Gate and Valve Operators. When evaluating a particular emergency closure, only evaluate based on the applicable evaluation criteria (i.e., do not evaluate a gate using the valve criteria). If some evaluation criteria are unknown or cannot be inspected, do not adjust the score. An adjustment to the Data Quality Indicator score may be appropriate if additional information or test results were obtained during the Tier 2 assessment.

Note: As in the case of Tier 1 evaluations, any single condition may be severe enough to justify immediate corrective action even if the overall condition index does not indicate such a response.

Test T2.1: Gates

Gates – Structural Integrity

The physical deterioration of emergency closure gates is likely to result from one or more of the following factors:

- Corrosion
- Yielding, Fracture, Fatigue, and Fabrication Discontinuities
- Improper Field Repair and/or Modifications

- Miscellaneous Damage or Other Conditions

Test T2.1.1: Gates – Corrosion

Corrosion typically causes the most damage to emergency closure gates. Special attention should be paid to critical areas such as welds, member interfaces, and connectors. Corrosion nodes should be chipped off to reveal the true extent of metal deterioration.

Table 11 – Corrosion

Results	Adjustment to Condition Index Score
Good – Corrosion has not caused significant loss of cross-sectional area for structural members, corrosion buildup has not caused separation in adjacent members, localized corrosion has not reduced weld areas significantly, protective coatings in good condition, little or no cavitation.	Add 1.0
Moderate – Small amounts of cross-sectional area has been lost in some members, there is isolated plate separation caused by corrosion, some pitting, some weld area reduction in some welds, protective coating in fair condition, moderate cavitation.	No Change
Severe – Significant cross-sectional area loss in critical members, widespread plate and/or member separation, significant weld size loss due to corrosion, significant pitting protective coating in poor condition, severe cavitation damage.	Subtract 1.0

Test T2.1.2: Gates – Yielding, Fracture, Fatigue, and Fabrication Discontinuities

Yielding and fracture of structural members and weldments can compromise structural integrity and deserve special attention. They can occur from a variety of causes including, but not limited to:

- Impact
- Fatigue loading
- Material defect
- Design overload

Fractures usually occur where there are local stress raisers. This occurs where there is a local geometry change. Examples of this are bolt/rivet holes, sharp inside corners, corrosion pits, and weldments. Cracking of weldments or base metals is particularly problematic where thick members are welded together or there are dimensioning errors. Improper welding techniques and welding in an inaccessible area can also lead to problematic discontinuities. Welding discontinuities take many forms and are usually identified by visual inspection. Visual inspection however cannot locate many weld discontinuities such as incomplete joint penetration. Non-destructive testing on welds is the best way to determine weld condition.

Table 12 – Yielding, Fracture, Fatigue, and Fabrication Discontinuities	
Results	**Adjustment to Condition Index Score**
Good – No visible yielding or buckling, there is little to no cracking near welds and/or stress concentrators. Any cracks have not propagated significantly.	Add 1.0
Moderate – May be slight yielding; cracking near stress concentrators or welds is intermittent with little or no propagation. Can justify the use of non-destructive testing on some welds.	No Change
Severe – Significant yielding or buckling in critical members, cracking in a sequence of welds, crack propagation in many cracks. Usually justifies the use of non-destructive testing on most welds.	Subtract 1.0

Test T2.1.3: Gates **–** Improper Field Repair and/or Modifications

Gates that have been significantly modified in the field without proper engineering and quality control may be structurally compromised. Improper repairs include, but are not limited to:

- Replacing parts with lesser quality or strength parts than the gate was engineered for (bolts, skin plates, picking eyes, structural steel, etc.)
- Protective coatings that are improperly formulated or applied
- Cutting of beam webs or flanges
- Improper welding/rewelding

Table 13 – Improper Field Repair and/or Modifications	
Results	**Adjustment to Condition Index Score**
Good – No field repairs or modifications done without proper engineering analysis.	No Change
Moderate – Some minor repairs, not likely to cause failure.	Subtract 0.5
Severe – Major modifications that severely compromise the structural integrity of the gate.	Subtract 1.0

Gates – Functional Operation

Test T2.1.4: Gates **–** Raising/Lowering Performance

This evaluation criterion is based on the overall performance of the emergency closure system. The gate should lower and raise in a certain amount of time as specified by organizational standards. Performance tests should be implemented where reasonable. This section is concerned if the gate binds or hangs up in the gate slot due to dimensional alignment deficiencies, not the gate operator itself.

Note: If the gate performs unacceptably and the reason relates to the gate operator itself, score a "No Change" for this section and make an adjustment in the *Gates – Operators Performance* section.

Table 14 – Raising/Lowering Performance

Results	Adjustment to Condition Index Score
Acceptable – Gates lower as designed in time specified by performance standards or design.	No Change
Unacceptable – Gates severely bind or hang-up and/or do not raise and lower as designed in time specified by organizational performance standards or design specifications.	Subtract 1.0

Test T2.1.5: Gates – Slots, Seals, and Sealing Surfaces

Sealing problems can arise from any number of conditions. Seals degrade over time and allow leakage. Some leakage is normal. Tier 1 assessment should have estimated leakage rate. Tier 2 assessment should be mainly concerned with the cause of leakage. Possible causes for gate leakage include:

- Seal worn or damaged
- Sealing surface worn or damaged
- Sealing surface corroded
- Sealing surface not straight
- Seal out of adjustment
- Dimensional error of gate or gate slot
- Damaged gate
- Dam superstructure has moved over time, changing the dimensions of the intake
- Obstruction(s) in gate slot
- Cracked or missing concrete or grout around sealing surface

Table 15 – Slots, Seals, and Sealing Surfaces	
Results	**Adjustment to Condition Index Score**
Good – Seals are in good condition with less than normal leakage (< 25 gpm or < 1.6 liters/s), seal surfaces are parallel (to each other) and in good condition with minimal pitting and cavitation damage. Seal will function adequately for ≥ 10 years.	Add 0.5
Moderate – Seals and sealing surfaces are in serviceable condition with moderate leakage (≥ 25 and < 50 gpm or ≥ 1.6 and < 3.2 liters/s). There is some small dimensional discrepancy causing leakage. Seal will function adequately for ≥ 7 and < 10 years.	No Change
Severe – Large volume of leakage (≥ 50 gpm or ≥ 3.2 liters/s) caused by significant damage or dimensional discrepancy. Seal does not, or will function adequately for < 7 years.	Subtract 0.5

Test T2.1.6: Gates **–** Wheels, Rollers, Roller Chains, Bearings, and Bushings

Gate rollers and bearings take on a variety of forms and suffer from wear, corrosion, and damage over many years of service. Rollers should rotate easily without excessive play. Excessive corrosion could lead to cracking or flat spots on rollers or wheels. Chain roller bushings should not have excessive wear, corrosion, or play. Chain links should be structurally sound.

Slide gate bearing surfaces should be square to each other with a uniform wear pattern. Bearing surfaces should not have abnormal gouging or deep corrosion that could compromise function.

Table 16 – Wheels, Rollers, Roller Chains, Bearings, and Bushings	
Results	**Adjustment to Condition Index Score**
Good – Rollers rotate as designed, rollers do not have significant corrosion damage, are not cracked, and do not have abnormal play or flat spots. Bearings surfaces have uniform wear with no excessive grooves. Roller chains are structurally sounds with good bushing condition.	Add 0.5
Moderate – No major damage, some roller corrosion, some small flat spots, rollers rotate acceptably. Some uneven or moderate wear on bearings surfaces. Moderate to significant corrosion on roller chain links, some bushing wear. Some rollers cracked.	No Change
Severe – Significant roller damage including, but not limited to, cracking, pitting, and flat spots. Excessive play or bearing seizure of rollers. Bearing surfaces deeply grooved, galled, or unevenly worn. Severe corrosion and bushing wear on roller chain. Grout cracked or missing around bearing surfaces.	Subtract 0.5

Test T2.2: Valves

Valves – Structural Integrity

The physical deterioration of emergency closure valves is likely to be from one or more of the following factors:

1) Corrosion
2) Yielding, Fracture, Fatigue and Fabrication Discontinuities
3) Field Repair and Modification
4) Miscellaneous Damage and Conditions

Test T2.2.1: Valves **–** Corrosion

Some major contributing factors to corrosion are: the pH and ion concentration of the river, relative humidity of 40% or more, ineffective protective coatings (due to age, improper formulation, or improper application), cavitation, and malfunctioning or improperly maintained cathodic protection systems. Also, dissimilar metals in contact can cause a dielectric reaction and cause one of the metals (usually carbon steel) to corrode at an accelerated pace. For valves, cavitation is typically more significant than oxidation.

Table 17 – Corrosion

Results	Adjustment to Condition Index Score
Good – Corrosion has not caused significant loss of cross-sectional area for structural elements, localized corrosion has not reduced weld area significantly, protective coating in good condition, little or no cavitation.	Add 1.0
Moderate – Small amounts cross-sectional area has been lost in some elements, there is isolated plate separation from corrosion, some pitting, some weld area reduction in some welds, protective coating in fair condition, moderate cavitation.	No Change
Severe – Significant cross-sectional area loss in critical members, significant weld size loss due to corrosion, significant pitting protective coating in poor condition, severe cavitation damage.	Subtract 1.0

T2.2.2: Valves **–** Yielding, Fracture, Fatigue, and Fabrication Discontinuities

Yielding and fracture of structural members and weldments can compromise structural integrity and deserve special attention. They can occur from a variety of causes including, but not limited to: impact, fatigue loading, material defect, and design overload.

Fractures usually occur where there are local stress raisers. This occurs where there is a local geometry change. Examples of this are bolt/rivet holes, sharp inside corners, corrosion pits, and weldments. Cracking of weldments or base metals is particularly problematic where thick members are welded together or there are dimensioning errors. Improper welding techniques

and welding in an inaccessible area can also lead to problematic discontinuities. Welding discontinuities take many forms and are usually identified by visual inspection. Visual inspection however cannot locate many weld discontinuities such as incomplete joint penetration. Non-destructive testing on welds is the best way to determine weld condition.

Table 18 – Yielding, Fracture, Fatigue, and Fabrication Discontinuities	
Results	**Adjustment to Condition Index Score**
Good – No visible yielding or buckling, there is little to no cracking near welds and/or stress concentrators. Any cracks have not propagated significantly.	Add 1.0
Moderate – May be slight yielding; cracking near stress concentrators or welds is intermittent with small amount of propagation. Can justify the use of non-destructive testing on some welds.	No Change
Severe – Significant yielding or buckling in critical members, cracking in a sequence of welds, crack propagation in many cracks. Usually justifies the use of non-destructive testing on some welds.	Subtract 1.0

Test T2.2.3: Valves **–** Improper Field Repair and/or Modifications

Valves that have been significantly modified in the field without proper engineering and quality control may be structurally compromised, depending on the magnitude of the modification or fix. Improper repairs include, but are not limited to:

- Replacing parts with lesser quality or strength parts than the valve was engineered for
- Protective coatings that are improperly formulated or applied
- Cutting of structural elements
- Improper welding/rewelding

Table 19 – Improper Field Repair and/or Modifications	
Results	**Adjustment to Condition Index Score**
Good – No field repairs or modifications done without proper engineering analysis.	No Change
Moderate – Some minor repairs, not likely to cause failure.	Subtract 0.5
Severe – Major modifications that severely compromise the structural integrity of the valve.	Subtract 1.0

Valves – Functional Operation

Test T2.2.4: Valves **–** Actuation Performance

Valve actuation performance is concerned with the timeframe and smoothness that an emergency closure valve can operate within. Emergency closure valves typically have some sort of performance standard stating that the valve must move from the completely open to completely closed position (usually in a runaway turbine condition) within a certain timeframe (e.g., less than 2 minutes for Army Corps of Engineers). Obviously, it is not reasonable to perform this test; however, best efforts should be made to assess the valve actuation performance.

Note: If valve performs unacceptably and the reason relates to the valve operator itself, score a "No Change" for this section and make an adjustment in the *Valves – Operators Performance* section.

Table 20 – Actuation Performance

Results	Adjustment to Condition Index Score
Acceptable – Valve actuates from fully open to fully closed in the required timeframe.	No Change
Unacceptable – Valve does not actuate from fully open to fully closed in the required timeframe. ***Performance based on some deficiency of the valve assembly***.	Subtract 1.0

Test T2.2.5: Valves **–** Seals, Sealing Surfaces, and Packing

Valve seals that seal the penstock can either be made of a resilient (i.e. rubber or nylon) or metal such as stainless steel or bronze. As with gates, some leakage is not necessarily indicative of a defective seal, but valves usually leak less since they usually have a smaller seal length than gates. Excessive leakage can be a sign of damage, wear, maladjustment, fabrication deficiency, or movement of the valve or valve body. Valve shaft trunnions also have a seal or packing that can leak for the same reasons. Packing will normally leak at a controlled rate even when new.

Note: If sealing problems are related to bushing or bearing wear or damage, assess a condition adjustment based on the next section, *Valves – Bearings and Bushings,* so that the same problem is not scored twice.

Table 21 – Seals, Sealing Surfaces, and Packing	
Results	**Adjustment to Condition Index Score**
Good – Seals are in good condition with less than normal leakage (< 12.5 gpm or < 0.8 liters/s), seal surfaces are parallel (to each other) and in good condition with minimal pitting and cavitation damage. Seal will function adequately for ≥ 10 years.	Add 0.5
Moderate – Seals and sealing surfaces are in serviceable condition with moderate leakage (≥ 12.5 and < 25 gpm or ≥ 0.8 and < 1.6 liters/s). There are some small dimensional discrepancies or cavitation damage. Seal or seal surface can be adjusted for a better seal. Seal will function adequately for ≥ 7 and < 10 years.	No Change
Severe – Large volume of leakage (≥ 25 gpm or ≥ 1.6 liters/s) caused by significant damage or dimensional discrepancy. Seal will function adequately for < 7 years. Shaft trunnion seals or packing leak excessively. Seal or seal surface cannot be adjusted for a better seal.	Subtract 0.5

Test T2.2.6: Valves **–** Bearings and Bushings

Valve bearings and bushings tend to have a limited amount of wear since they do not experience very many cycles per year of operation. Deficiencies are usually from improper installation, manufacturing or material defect, and/or lack of preventative maintenance. Bushings are very difficult to inspect while installed; usually the poor condition of a bushing is not known until total failure. A grade of moderate should be given unless bearings and bushings can be inspected directly.

Table 22 – Bearings and Bushings	
Results	**Adjustment to Condition Index Score**
Good – Bearings and bushings are in good shape with no apparent eccentric wear or misalignment.	Add 0.5
Moderate – Bearings and bushings are worn in accordance with their age and are still in serviceable condition.	No Change
Severe – Bearings and bushings are wearing eccentrically and/or are not installed concentrically with shaft. Apparent manufacture or material defect. Total failure.	Subtract 0.5

Test T2.3: Gates and Valves Operators

Operators – Structural Integrity

Gate and valve operators are usually hydraulic cylinders, hydraulic hoists, or electric-driven hoists. This section is concerned with the structural integrity of the gate and valve operators including:

- Corrosion
- Anchoring
- Yielding, Fracture and Fatigue and Fabrication Discontinuities
- Improper Field Repair and Modification
- Miscellaneous Damage and Condition

Note: Bridge and gantry cranes that are used for emergency closure ***shall not*** be inspected or rated using this section. Bridge and gantry cranes have specific inspection requirements that are described in applicable Federal, State, Provincial laws and regulations. See Appendix E9: Crane Condition Assessment.

Test T2.3.1: Operators **–** Corrosion

Some major contributing factors to corrosion are: the pH and ion concentration of the river, relative humidity of 40% or more, ineffective protective coatings (due to age, improper formulation, or improper application), cavitation, and malfunctioning or improperly maintained cathodic protection systems. Also, dissimilar metals in contact can cause a dielectric reaction and cause one of the metals (usually carbon steel) to corrode at an accelerated pace.

Table 23 – Corrosion

Results	Adjustment to Condition Index Score
Good – Corrosion is mainly superficial, hoist drums and sheaves are in good shape, little or no pitting, welds have not been reduced in area, corrosive protective coating is in serviceable condition.	Add 1.0
Moderate – There is some pitting and more sever corrosion. Protective coating needs some attention in the near future. Corrosion will not affect structural integrity for ≥ 7 and < 10 years.	No Change
Severe – Metal is deeply pitted and/or has reduced metal cross-sectional area significantly in structural elements such as lifting beams, anchor bolts, shafts, etc. Corrosion will likely effect structural integrity in < 7 years.	Subtract 1.0

Test T2.3.2: Operators **–** Anchoring

For inspection purposes, it is very difficult to adequately assess if anchoring was properly designed and is adequate, however, portions of the anchoring can be inspected for failure.

Table 24 – Anchoring	
Results	**Adjustment to Condition Index Score**
Good – Operators are solidly anchored with original equipment, concrete is not spalled near anchors, all anchors are present and in good condition. Epoxy or grout is in good shape.	Add 1.0
Moderate – Some deficiencies including a small amount of concrete spalling or missing grout or epoxy. Anchor bolts are present and in marginal condition. No apparent movement of operators.	No Change
Severe – Operators have visibly moved. Anchor bolts are loose, missing, or yielded. Additional anchors installed by project to help secure the operator, spalling and/or epoxy bonds broken.	Subtract 1.0

Test T2.3.3: Operators **–** Yielding, Fracture, Fatigue, and Fabrication Discontinuities

Yielding, Fracture, Fatigue, and Fabrication Discontinuities will be consistent with those found in gates and valves. See descriptions in the corresponding *Gates* and *Valves* sections.

Table 25 – Yielding, Fracture, Fatigue, and Fabrication Discontinuities	
Results	**Adjustment to Condition Index Score**
Good – No visible yielding or buckling, there is little to no cracking near welds and/or stress concentrators. Any cracks have not propagated significantly.	Add 1.0
Moderate – May be slight yielding; cracking near stress concentrators or welds is intermittent with small amount of propagation. Can justify the use of non-destructive testing on some welds.	No Change
Severe – Significant yielding or buckling in critical members, cracking in a sequence of welds, crack propagation in many cracks. Usually justifies the use of non-destructive testing on some welds.	Subtract 1.0

Test T2.3.4: Operators **–** Improper Field Repair and/or Modifications

Valves that have been significantly modified in the field without proper engineering and quality control may be structurally compromised, depending on the magnitude of the modification or fix. Improper repairs include, but are not limited to:

- Replacing parts with lesser quality or strength parts than the valve was engineered for
- Protective coatings that are improperly formulated or applied
- Cutting of structural elements
- Improper welding/rewelding

Table 26 – Improper Field Repair and/or Modifications	
Results	**Adjustment to Condition Index Score**
Good – No field repairs or modifications done without proper engineering analysis.	No Change
Moderate – Some minor repairs, not likely to cause failure.	Subtract 0.5
Severe – Major modifications that severely compromise the structural integrity of the valve.	Subtract 1.0

Hydraulic Operators – Functional Operation

Test T2.3.5: Hydraulic Operators **–** Actuation Performance

The operating performance of the gate or valve in this section is concerned with overall system performance directly affected by the gate or valve operator itself. Such issues can include misalignment, speed, and reliability.

Note: If the gate or valve performs unacceptably, and the reason does not relate to the gate or valve operator itself, score a "No Change" for this section and make an adjustment in the corresponding *Gates – Raising/Lowering Performance* or *Valves – Actuation Performance* section.

Table 27 – Actuation Performance	
Results	**Adjustment to Condition Index Score**
Acceptable – Gate or valve actuates from fully open to fully closed in the required timeframe.	No Change
Unacceptable – Valve does not actuate from fully open to fully closed in the required timeframe. ***Performance based on some deficiency of the hydraulic system***.	Subtract 1.0

Test T2.3.6: Hydraulic Operators **–** Pistons

Dirty hydraulic fluid can cause piston rod to gouge or wear prematurely, especially for pistons near the bottom of the hydraulic system. Chrome plated piston rods can corrode. Ceramic-coated pistons with an improperly applied coating can corrode underneath and chip off, which will cause a failure of the piston seals. Ceramic coatings are also brittle and can crack if the piston rod is flexed or impacted.

Without taking piston apart, it is difficult to determine the condition of the internal parts. A drift test can be performed to estimate the performance of the unit. Cylinders that suspend loads under pressure naturally leak fluid through the internal seals over time, which causes the gates to drift; the hydraulic system automatically corrects this. This cycle is repeated many times, sometimes thousands of times per month, causing undo wear on a small a length of the piston stroke.

Drift Test -- suspend the working load for one hour on a hydraulically isolated piston and determined the hydraulic fluid leaked through piston rings. The following performance estimates are rules of thumb:

$N = V/(\pi Dt)$ in terms of volume leaked [units = ml/(cm-h) = cm^2/h]

or

$N = LD/(4t)$ in terms of length drifted [units = ml/(cm-h) = cm^2/h]

where

N = piston drift number
V = fluid volume leaked (1 ml = 1 cm^3)
D = internal piston stroke diameter (cm)
t = test time (hours)
L = length of drift (cm)

Note: 11.64 ml/(cm-h) = 1 oz/(in-h)

For resilient piston rings, leakage for a properly working piston should be very small [N < 2 ml/(cm-h)]; for cast iron rings, leakage is much more, on the order of N ≈ 40 ml/(cm-h). For multistage cylinders, the piston drift number applies to each stage individually; e.g., a 3-stage, telescoping cylinder with cast iron piston rings will have an allowable leakage limit of N = 3 times ≈ 40 ml/(cm-h) ≈ 120 ml/(cm-h) of cylinder drift.

Table 28 – Pistons

Results	Adjustment to Condition Index Score
Good – Normal internal leakage, N < 40 ml/(cm-h) for cast iron piston rings, N < 2 ml/(cm-h) for resilient piston rings and packing. No noticeable scoring, cracking, or chipping on piston rods, corrosion minimal. No external leakage into a sensitive environment.	Add 0.5
Moderate – Some internal leakage, N ≥ 40 and < 200 ml/(cm-h) for cast iron piston rings and packing, N ≥ 2 and < 10 ml/(cm-h) for resilient piston rings. Some piston rod wear with no external leakage into a sensitive environment.	No Change
Severe – Large volume of internal leakage N ≥ 200 ml/(cm-h) for cast iron piston rings and packing, N ≥ 10 ml/(cm-h) for resilient piston rings and packing. Significant piston rod wear and danger of failure or significant external leakage into a sensitive environment.	Subtract 0.5

Test T2.3.7: Hydraulic Operators – Hydraulic Systems

This rating adjustment applies to the entire hydraulic system other than the pistons themselves. Since hydraulic systems can be relatively simple or fairly complex, the rater must use their best judgment to rate the overall condition of the hydraulic system.

Table 29 – Hydraulic Systems	
Results	**Adjustment to Condition Index Score**
Good – Overall condition indicates the need for little or no attention, leakage is minimal; valves, solenoids relays, and heat exchangers are in working condition. Fittings, lines and hoses are in good condition. Hydraulic fluid is clean and uncontaminated. Replacement parts are in stock or readily available.	Add 0.5
Moderate – Some attention required but system in service able condition. Some hoses and fittings worn and/or leaking. Some components are not working optimally. Hydraulic fluid is dirty. Replacement parts are hard to obtain.	No Change
Severe – System frequently needs repair; spare parts unavailable or very hard to find. Major leakage. Dirty or contaminated fluid. Overall condition poor.	Subtract 0.5

Test T2.3.8: Hydraulic Operators **–** Electric Motors

Motors powering hydraulic systems may be tested in accordance with IEEE 112 if the motors a suspected of being deficient. IEEE 112 contains a multitude of tests, some which may not need to be performed. If the motor(s) is not tested, the score will not be adjusted.

Table 30 – Electric Motors	
Results	**Adjustment to Condition Index Score**
Good – Performance passes given performance tests.	No Change
Moderate – Some non-critical performance tests are failed (e.g., efficiency) but motor is in still serviceable condition.	Subtract 0.5
Severe – Motor fails one or more critical test. Is deemed not serviceable and in need of repair or replacement.	Subtract 1.0

Test T2.3.9: Hydraulic Operators – Electric Controls

Table 31 – Electric Controls Results	Adjustment to Condition Index Score
Good – Control wiring is clean, with no excessive soil, fatigue, or wear apparent on insulation or jacket material. Wiring is securely connected to devices, or is loosely connected but can be corrected without spare parts or special tools. Control devices (pushbuttons, contactors, switches, coils) are clean and function as designed. Control enclosures are clean, with no excessive soil, corrosion, or physical damage.	No Change
Fair – Control wiring, enclosures, and devices are clean and in good overall condition, but spare parts are no longer available. Wiring insulation or jacket is polyvinyl chloride (PVC) compound.	Subtract 0.25
Moderate – Control wiring has minor wear, fatigue, or soil apparent on insulation or jacket material. Some control wiring appears loosely connected to devices, and cannot be corrected, or cannot be corrected without spare parts or special tools. Control devices (pushbuttons, contactors, switches, coils) are not clean or do not function as designed. Control enclosures have some soil, corrosion, or physical damage.	Subtract 0.5
Severe – Control wiring has wear, fatigue, or soil apparent on insulation or jacket material. Control wiring has become disconnected from corresponding devices, and cannot be corrected. Control devices (pushbuttons, contactors, switches, coils) do not function. Control enclosures have excessive soil, corrosion, or physical damage.	Subtract 1.0

Electric Operators – Functional Operation

Test T2.3.10: Electrical Operators – Actuation Performance

The operating performance of the gate or valve in this section is concerned with overall system performance directly affected by the gate or valve operator itself. Such issues can include misalignment, speed, and reliability.

Note: If the gate or valve performs unacceptably, and the reason does not relate to the gate or valve operator itself, score a "No Change" for this section and make an adjustment in the corresponding *Gates – Raising/Lowering Performance* or *Valves – Actuation Performance* section.

Table 32 – Actuation Performance	
Results	**Adjustment to Condition Index Score**
Acceptable – Gate or valve actuates from fully open to fully closed in the required timeframe. (Takes < 2 minutes for valves and < 10 minutes for gates if requirement is not known.)	No Change
Unacceptable – Gate or valve does not actuate from fully open to fully closed in the required timeframe. (Takes ≥ 2 minutes for valves and ≥ 10 minutes for gates if requirement is not known.) ***Performance based on some deficiency of the electric-powered gate or valve operator***.	Subtract 1.0

Test T2.3.11: Electrical Operators **–** Electric Controls

Table 33 – Electric Controls	
Results	**Adjustment to Condition Index Score**
Good – Control wiring is clean, with no excessive soil, fatigue, or wear apparent on insulation or jacket material. Wiring is securely connected to devices, or is loosely connected but can be corrected without spare parts or special tools. Control devices (pushbuttons, contactors, switches, coils) are clean and function as designed. Control enclosures are clean, with no excessive soil, corrosion, or physical damage.	No Change
Fair – Control wiring, enclosures, and devices are clean and in good overall condition, but spare parts are no longer available. Wiring insulation or jacket is polyvinyl chloride (PVC) compound.	Subtract 0.25
Moderate – Control wiring has minor wear, fatigue, or soil apparent on insulation or jacket material. Some control wiring appears loosely connected to devices, and cannot be corrected, or cannot be corrected without spare parts or special tools. Control devices (pushbuttons, contactors, switches, coils) are not clean or do not function as designed. Control enclosures have some soil, corrosion, or physical damage.	Subtract 0.5
Severe – Control wiring has wear, fatigue, or soil apparent on insulation or jacket material. Control wiring has become disconnected from corresponding devices, and cannot be corrected. Control devices (pushbuttons, contactors, switches, coils) do not function. Control enclosures have excessive soil, corrosion, or physical damage.	Subtract 1.0

Test T2.3.12: Operators – Electric Motors

Motors powering electric-operated systems may be tested in accordance with IEEE 112 if the motors a suspected of being deficient. IEEE 112 contains a multitude of tests, some which may not need to be performed. If the motor(s) is not tested, the score will not be adjusted be given.

Table 34 – Electric Motors

Results	Adjustment to Condition Index Score
Good – Performance passes given performance tests.	No Change
Moderate – Some non-critical performance tests are failed (e.g., efficiency) but motor is in still serviceable condition.	Subtract 0.5
Severe – Motor fails one or more critical test. Is deemed not serviceable and in need of repair or replacement.	Subtract 1.0

Test T2.3.13: Electrical Operators – Electric Brakes

Table 35 – Electric Brakes

Results	Adjustment to Condition Index Score
Good – Brake and enclosure are clean, with no significant soil, corrosion, or physical damage. Brake actuator (coil or thruster) is clean, with no significant soil, corrosion, or physical damage, and functions as designed. Thruster unit has no leaks. Brake torque rating is ≥ 125% of motor torque rating, and if field-adjustable, is set to 100% or greater torque rating. Brake wheel and pads are in contact with each other for ≥ 80% of the wheel surface and exhibit minimal wearing.	No Change
Fair – Brake, enclosure, actuator, wheel, and pads are clean and in good overall condition, but spare parts are no longer available, or brake pads contain asbestos.	Subtract 0.25
Moderate – Brake and enclosure have some soil, corrosion, or physical damage. Brake actuator (coil or thruster) has some soil, corrosion, or physical damage, or does not function as designed. Thruster unit, if present, exhibits minimal leakage. Brake torque rating is ≥ 100 and < 125% of motor torque rating. Brake wheel and pads are in contact with each other for ≥ 50 and < 80% of the wheel surface and exhibit moderate wearing.	Subtract 0.5
Severe – Brake and enclosure have extensive soil, corrosion, or physical damage. Brake actuator (coil or thruster) has extensive soil, corrosion, or physical damage, or does not function as designed. Thruster unit, if present, exhibits leakage. Brake torque rating is < 100% of motor torque rating. Brake wheel and pads are in contact with each other for < 50% of the wheel surface or exhibit	Subtract 1.0

extensive wearing.	
Extreme – Brake does not release, or is not able to hold load (slips).	Subtract 1.5

Test T2.3.14: Electrical Operators **–** Wire Ropes and Chains

Wire ropes and chain carry the load of emergency closure gates and must be in serviceable condition. Failure or these devices could cause significant economic and life safety impact.

Hoists that are difficult to inspect often are not. It is important to examine the entire length of wire rope, especially the underside of the rope that commonly comes in contact with the hoist drum or sheaves as the top of the rope can be in good condition while the bottom side can be severely worn. Other problems with wire rope include, but are not limited to: corrosion (loss of cross-sectional area) and broken wires, strands, and cores from abrasion, fatigue, deformation, and material defect.

Traditionally, tests have been visual, but there is now a non-destructive test method called Magnetic Flux Leakage (MFL) test that can be performed on wire rope that will reveal deficiencies not easily identified by visual inspections. MFL may be justified for critical applications such as emergency closures.

Hoist chain is difficult to inspect and is not usually cost effective (if thought to be defective) as it can be easily replaced relatively inexpensively.

Table 36 – Wire Ropes and Chains

Results	Adjustment to Condition Index Score
Good – Wire rope in good condition with no significant loss in cross-sectional area, no broken wires, corrosion is superficial. Rope greased sufficiently. Chain in good condition; withstands proof loads.	No Change
Moderate – Less than 12 randomly broken wires in one lay and/or < 4 broken wires in one strand in one lay. Less than 1/3 diameter loss from wear or corrosion in outside individual wires and/or < 10% loss in cross-sectional area at any point in rope. No crushing or kinking. Chain in marginal condition with < 10% loss in cross-sectional area; withstands proof loads. ***Wire ropes or chains should be replaced as soon as reasonably possible.***	Subtract 0.5
Severe – 12 or more randomly broken wires in one lay and/or ≥ 4 broken wires in one strand in one lay. 1/3 or more diameter loss from wear or corrosion in outside individual wires and/or ≥ 10% loss in cross-sectional area at any point in rope. Wire crushed or kinked; evidence of heat damage. Chain in poor condition with ≥ 10% loss in cross-sectional area. ***Wire ropes or chains should be changed immediately before emergency closure is used.***	Subtract 1.0

Test T2.3.15: Electrical Operators – Power Screws

Power screws are typically made of carbon or stainless steel with bronze mating nuts to avoid galling. They should be exercised and inspected for such things as: wear on mating surfaces (both screw and mating nut), straightness of screw, thread damage, corrosion, surface finish condition, and brake condition (if equipped).

Table 37 – Power Screws

Results	Adjustment to Condition Index Score
Good – Power screw in good condition, no major deficiencies.	Add 0.5
Moderate – Power screw in serviceable condition, no deficiencies that could compromise safety.	No Change
Severe – Serious wear, defect or damage that could compromise proper operation of the gate or valve.	Subtract 0.5

Test T2.3.16: Electrical Operators – Drums and Sheaves

Hoist drums and sheaves should be checked for wear and general operating condition. Structural deficiencies should have already been noted in the *Structural Integrity* section.

Table 38 – Drums and Sheaves

Results	Adjustment to Condition Index Score
Good – Hoist drum in good condition, no major deficiencies. Wire rope is secured to drum correctly; wire rope is not over spooled when gate is in the 100%-up condition.	Add 0.5
Moderate – Drums and sheaves in service able condition with normal wear.	No Change
Severe – Drum highly worn in grooves, alignment incorrect, sheaves worn, cathodes not working correctly or used up.	Subtract 0.5

Test T2.3.17: Electrical Operators – Gearboxes, External Gearing, and Chain Sprockets

A gearbox should be operated through a full operation cycle and observed for abnormal sounds that may indicate internal problems. Opening, draining, cleaning, and inspection of gearbox internals may be justified. Lube oil may be sampled to test the condition. External leakage should also be noted.

Table 39 – Gearboxes, External Gearing, and Chain Sprockets	
Results	**Adjustment to Condition Index Score**
Good – Gearbox in good working condition. Gearbox internals (if inspected) are in good working order, gear tooth wear is minimal with even wear pattern, bushing and bearings are in good shape, seals do not leak externally. External gearing and chain sprockets are in good shape.	Add 0.5
Moderate – Gearbox is serviceable. Gearing (if inspected) is in good shape, no cracking, moderate tooth wear and/or uneven wear pattern. Some metal accumulation in bottom of gearbox. Gearbox, gearing, and chain sprockets serviceable for ≥ 7 and < 10 years.	No Change
Severe – Gearbox in poor condition. Extreme wear and/or cracking on teeth, substantial metal accumulation in gearbox, dirty or insufficient gear lube, seals leak extensively, bearings or bushings in poor condition. Gearbox, gearing, and chain sprockets serviceable for < 7 years.	Subtract 0.5

Test T2.3.18: Electrical Operators **–** Bearings and Bushings

Bearings and bushings are subject to normal wear and tear and are subject to a finite life span. Bearing and bushings (those inside gearbox were inspected as part of the section on Gearboxes, External Gearing, and Chain Sprockets) should be inspected where possible for wear, damage, installation error, and manufacture malfunction. Since this section rating could encompass many bearings and bushing, the rater should rate the overall condition of all the bearings, noting individual bearings or bushings that need immediate repair.

Table 40 – Bearings and Bushings	
Results	**Adjustment to Condition Index Score**
Good – Bearings and bushings are in good shape and need little or no attention.	Add 0.5
Moderate – Some repair needed on individual bearings or bushings.	No Change
Severe – System wide poor condition of bearings and bushings, easier to overhaul everything than attempt individual repair to select bearings and bushings.	Subtract 0.5

Test T2.4: Miscellaneous Deficiencies

Any deficiencies not listed in the previous sections should be noted. The Tier 2 rater should use their judgment to assess a negative condition assessment adjustment to the *Gate*, *Valve*, or *Operator* condition.

Table 41 – Miscellaneous Deficiencies	
Results	**Adjustment to Condition Index Score**
Moderate – May affect the function of emergency closure system.	Subtract 0.5
Severe – Will severely affect performance or structure of the emergency closure system to the point where there is risk of significant economic or life loss.	Subtract 1.0

Test T2.5: Annunciation

Inspection of annunciation is concerned with any sensor that indicates position, condition, level, or status of the emergency closure gate, valve, or operator. Remote controlled plants may have more elaborate controls than a manned facility. Annunciation to be checked includes, but is not limited to:

- High/low level indicators
- Gate or valve position indicators
- Hydraulic pump run time indicators

Table 42 – Annunciation	
Results	**Adjustment to Condition Index Score**
Good – Annunciation is in proper working order.	No Change
Moderate – Annunciation works for the most part, fulfilling the requirements of the project. Any discrepancies can be easily fixed.	Subtract 0.25
Severe – System wide failure of annunciation possibly compromising function or safety of the facility. Annunciation does not fulfill the current needs for emergency closure systems.	Subtract 0.5

Test T2.6: Maintenance Escalation

Maintenance escalation for equipment is normal. Equipment is engineered for some finite service life that is rarely shortened but often exceeded. Maintenance history should be examined to determine maintenance escalation. Findings may justify performing a cost benefit analysis based on increased maintenance costs and anticipated downtime. A risk assessment based on safety may also be justified.

Table 43 – Maintenance Escalation	
Results	**Adjustment to Condition Index Score**
Good – Maintenance escalation is less than expected. Equipment age is less than expected service life.	Add 0.5
Moderate – Maintenance escalation is in keeping with estimates and is manageable by the project staff. No anticipated significant risk of system failure.	No Change
Severe – Maintenance escalation is dramatic, required maintenance has increased beyond the capacity of the project. Anticipated significant risk of system failure.	Subtract 0.75

Test T2.7: Other Specialized Diagnostic Tests

Additional tests may be applied to evaluate specific emergency closure gate and valve problems. Some of these diagnostic tests may be considered to be of an investigative research nature. When conclusive results from other diagnostic tests are available, they may be used to make an appropriate adjustment to the Emergency Closure Gate and Valve Condition Index.

E11.15 TIER 2 EMERGENCY CLOSURE SYSTEM CONDITION INDEX CALCULATIONS

Tier 2 scoring adjusts the Tier 1 score. There are four different scoring sheets; hydraulic-operated gates, electric-operated gates, hydraulic-operated valves, and electric-operated valves. Choose the one that best describes the particular emergency closures. Action may be required for a low overall score or for a low score in any one major category (Structural Integrity, Functional Operation, etc.). Note that any adjustments cannot lower any major category score to less than 0 or more than the highest possible Tier 1 weighted score. Attach supporting documentation. An adjustment to the Data Quality Indicator score may be appropriate if additional information or test results were obtained during the Tier 2 assessment.

E11.16 TIER 2 EMERGENCY CLOSURE SYSTEM DATA QUALITY INDICATOR

An adjustment to the Data Quality Indicator score may be appropriate if additional information or test results were obtained during the Tier 2 assessment.

E11.17 EMERGENCY CLOSURE SYSTEM CONDITION-BASED ALTERNATIVES

The Emergency Closure Systems Condition Index – either modified by Tier 2 tests or not – may be sufficient for decision-making regarding emergency closure systems alternatives. The Index is also suitable for use in a risk-and-economic analysis model. Where it is desired to consider alternatives based solely on generator condition, the Emergency Closure System Condition Index

may be directly applied to the Emergency Closure Systems Condition Index-Based Alternatives table.

Table 44 – Emergency Closure Systems Condition Index-Based Alternatives

Condition Index	Suggested Course of Action
≥ 7.0 and ≤ 10 (Good)	Continue O & M without restriction. Repeat Tier 1 assessment during next outage.
≥ 3.0 and < 7 (Fair) OR Condition Indicators #2 or #3 with weighted scores of 1 or less	Continue operation but reevaluate O & M practices. Schedule Tier 2 assessment within < 4 years.
≥ 0 and < 3.0 (Poor) OR Condition Indicators #2 or #3 with weighted scores of 0	Consultation with experts. Adjust O & M as prudent. Schedule Tier 2 assessment within < 2 years.

EMERGENCY CLOSURE GATES & VALVES
TIER 1 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Unit: _____ Type of Gate or Valve: _____

Tier 1 Emergency Closure Gates & Valves Condition Summary *(For instructions on indicator scoring, please refer to condition assessment guide)*				
No.	**Condition Indicator**	**Score** ×	**Weighting Factor** =	**Total Score**
1	Age *(Score must be 0, 1, 2, or 3)*		0.8	
2	Physical Condition – Gates or Valves *(Score must be 0, 1, 2, or 3)*		1	
3	Physical Condition – Operators *(Score must be 0, 1, 2, or 3)*		1	
4	Operations History *(Score must be 0, 1, or 2)*		0.4	
5	Maintenance *(Score must be 0, 1, or 2)*		0.4	
Tier 1 Emergency Closure System Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*				

Tier 1 Data Quality Indicator *(Value must be 0, 4, 7 or 10)*	

Evaluator: _____ Technical Review: _____

Management Review: _____ Copies to: _____

(Attach supporting documentation.)

Emergency Closure System Condition Index-Based Alternatives	
Condition Index	**Suggested Course of Action**
≥ 7.0 and ≤ 10 (Good)	Continue O & M without restriction. Repeat Tier 1 assessment during next outage.
≥ 3.0 and < 7 (Fair) OR Condition Indicators #2 or #3 with weighted scores of 1 or less	Continue operation but reevaluate O & M practices. Schedule Tier 2 assessment within < 4 years.
≥ 0 and < 3.0 (Poor) OR Condition Indicators #2 or #3 with weighted scores of 0	Consultation with experts. Adjust O & M as prudent. Schedule Tier 2 assessment within < 2 years.

EMERGENCY CLOSURE SYSTEM
TIER 2 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Unit: _____ Type of Gate: _____

Part I: Determine Adjustment to Tier 1 Emergency Closure System Condition Index.

Emergency Closure System – Gates with Hydraulic Operators		
No.	**Tier 2 Test (Table No.)**	**Adjustment to Tier 1 Condition Index**
Gates (Structural Integrity and Functional Operation):		
T2.1.1	Corrosion (11)	
T2.1.2	Yielding, Fracture, Fatigue, and Fabrication Discontinuities (12)	
T2.1.3	Improper Field Repair and/or Modifications (13)	
T2.1.4	Raising/Lowering Performance (14)	
T2.1.5	Slots, Seals, and Sealing Surfaces (15)	
T2.1.6	Wheels, Rollers, Roller Chains, Bearings, and Bushings (16)	
Hydraulic Operators (Structural Integrity and Functional Operation):		
T2.3.1	Corrosion (23)	
T2.3.2	Anchoring (24)	
T2.3.3	Yielding, Fracture, Fatigue, and Fabrication Discontinuities (25)	
T2.3.4	Improper Field Repair and/or Modifications (26)	
T2.3.5	Actuation Performance (27)	
T2.3.6	Pistons (28)	
T2.3.7	Hydraulic Systems (29)	
T2.3.8	Electric Motors (30)	
T2.3.9	Electric Controls (31)	
Miscellaneous Tests and Conditions:		
T2.4	Miscellaneous Deficiencies (41)	
T2.5	Annunciation (42)	
T2.6	Maintenance Escalation (43)	
T2.7	Other Specialized Diagnostic Tests	
Tier 2 Adjustments to Condition Index (Sum of individual Adjustments)		

Tier 2 Data Quality Indicator *(Value must be 0, 4, 7, or 10)*	

Go to Part II.

EMERGENCY CLOSURE SYSTEM
TIER 2 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Unit: _____ Type of Gate: _____

Part I: Determine Adjustment to Tier 1 Emergency Closure System Condition Index.

Emergency Closure System – Gates with Electric Operators		
No.	**Tier 2 Test (Table No.)**	**Adjustment to Tier 1 Condition Index**
Gates (Structural Integrity and Functional Operation):		
T2.1.1	Corrosion (11)	
T2.1.2	Yielding, Fracture, Fatigue, and Fabrication Discontinuities (12)	
T2.1.3	Improper Field Repair and/or Modifications (13)	
T2.1.4	Raising/Lowering Performance (14)	
T2.1.5	Slots, Seals, and Sealing Surfaces (15)	
T2.1.6	Wheels, Rollers, Roller Chains, Bearings, and Bushings (16)	
Electric Operators (Structural Integrity and Functional Operation):		
T2.3.1	Corrosion (23)	
T2.3.2	Anchoring (24)	
T2.3.3	Yielding, Fracture, Fatigue, and Fabrication Discontinuities (25)	
T2.3.4	Improper Field Repair and/or Modifications (26)	
T2.3.11	Actuation Performance (32)	
T2.3.12	Electric Controls (33)	
T2.3.13	Electric Motors (34)	
T2.3.14	Electric Brakes (35)	
T2.3.15	Wire Ropes and Chains (36)	
T2.3.16	Power Screws (37)	
T2.3.17	Drums and Sheaves (38)	
T2.3.18	Gearboxes, External Gearing, and Chain Sprockets (39)	
T2.3.19	Bearings and Bushings (40)	
Miscellaneous Tests and Conditions:		
T2.4	Miscellaneous Deficiencies (41)	
T2.5	Annunciation (42)	
T2.6	Maintenance Escalation (43)	
T2.7	Other Specialized Diagnostic Tests	

Tier 2 Adjustments to Condition Index (Sum of individual Adjustments)	

Tier 2 Data Quality Indicator *(Value must be 0, 4, 7, or 10)*	

Go to Part II.

EMERGENCY CLOSURE SYSTEM
TIER 2 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Unit: _____ Type of Valve: _____

Part I: Determine Adjustment to Tier 1 Emergency Closure System Condition Index.

Emergency Closure System – Valves with Hydraulic Operators		
No.	**Tier 2 Test (Table No.)**	**Adjustment to Tier 1 Condition Index**
Valves (Structural Integrity and Functional Operation):		
T2.2.1	Corrosion (17)	
T2.2.2	Yielding, Fracture, Fatigue, and Fabrication Discontinuities (18)	
T2.2.3	Improper Field Repair and/or Modifications (19)	
T2.2.4	Actuation Performance (20)	
T2.2.5	Seals, Sealing Surfaces, and Packing (21)	
T2.2.6	Bearings and Bushings (22)	
Hydraulic Operators (Structural Integrity and Functional Operation):		
T2.3.1	Corrosion (23)	
T2.3.2	Anchoring (24)	
T2.3.3	Yielding, Fracture, Fatigue, and Fabrication Discontinuities (25)	
T2.3.4	Improper Field Repair and/or Modifications (26)	
T2.3.5	Actuation Performance (27)	
T2.3.6	Pistons (28)	
T2.3.7	Hydraulic Systems (29)	
T2.3.8	Electric Motors (30)	
T2.3.9	Electric Controls (31)	
Miscellaneous Tests and Conditions:		
T2.4	Miscellaneous Deficiencies (41)	
T2.5	Annunciation (42)	
T2.6	Maintenance Escalation (43)	
T2.7	Other Specialized Diagnostic Tests	
Tier 2 Adjustments to Condition Index (Sum of individual Adjustments)		

Tier 2 Data Quality Indicator *(Value must be 0, 4, 7, or 10)*	

Go to Part II.

EMERGENCY CLOSURE SYSTEM
TIER 2 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Unit: _____ Type of Valve: _____

Part I: Determine Adjustment to Tier 1 Emergency Closure System Condition Index.

Emergency Closure System – <u>Valves with Electric Operators</u>		
No.	**Tier 2 Test (Table No.)**	**Adjustment to Tier 1 Condition Index**
Valves (Structural Integrity and Functional Operation):		
T2.2.1	Corrosion (17)	
T2.2.2	Yielding, Fracture, Fatigue, and Fabrication Discontinuities (18)	
T2.2.3	Improper Field Repair and/or Modifications (19)	
T2.2.4	Actuation Performance (20)	
T2.2.5	Seals, Sealing Surfaces, and Packing (21)	
T2.2.6	Bearings and Bushings (22)	
Electric Operators (Structural Integrity and Functional Operation):		
T2.3.1	Corrosion (23)	
T2.3.2	Anchoring (24)	
T2.3.3	Yielding, Fracture, Fatigue, and Fabrication Discontinuities (25)	
T2.3.4	Improper Field Repair and/or Modifications (26)	
T2.3.11	Actuation Performance (32)	
T2.3.12	Electric Controls (33)	
T2.3.13	Electric Motors (34)	
T2.3.14	Electric Brakes (35)	
T2.3.15	Wire Ropes and Chains (36)	
T2.3.16	Power Screws (37)	
T2.3.17	Drums and Sheaves (38)	
T2.3.18	Gearboxes, External Gearing, and Chain Sprockets (39)	
T2.3.19	Bearings and Bushings (40)	
Miscellaneous Tests and Conditions:		
T2.4	Miscellaneous Deficiencies (41)	
T2.5	Annunciation (42)	
T2.6	Maintenance Escalation (43)	
T2.7	Other Specialized Diagnostic Tests	

Tier 2 Adjustments to Condition Index (Sum of individual Adjustments)	

Tier 2 Data Quality Indicator *(Value must be 0, 4, 7, or 10)*	

Go to Part II.

Part II: Calculate the Net Emergency Closure System Condition Index

To calculate the Net Emergency Closure System Condition Index *(Value should be between 0 and 10)*, subtract the Tier 2 Adjustments from the Tier 1 Emergency Closure System Condition Index:

Tier 1 Emergency Closure System Condition Index _____

minus **Tier 2 Emergency Closure System Adjustments** _____ = _____

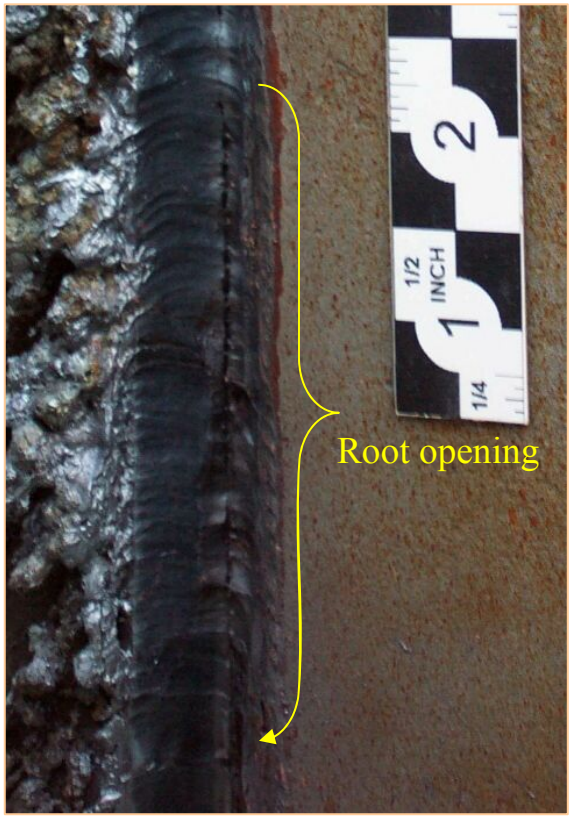
Net Emergency Closure System Condition Index

Evaluator: _____ Technical Review: _____

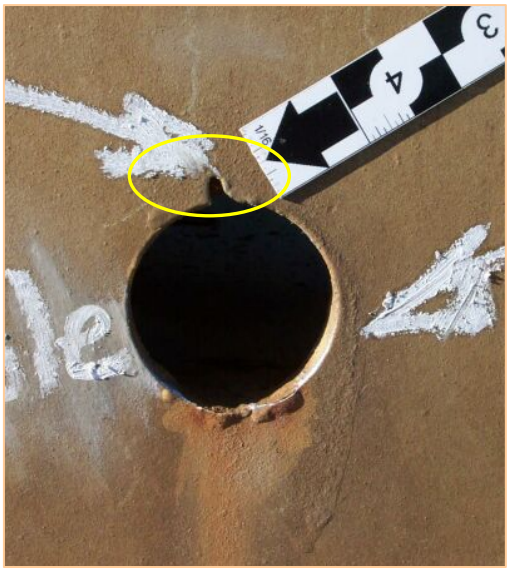
Management Review: _____ Copies to: _____

(Attach supporting documentation.)

Appendix A: Structural Deficiency Pictures



Incomplete penetration in CJP weld – can usually only be identified by non destructive testing methods



Notch from burning machine – example of fabrication or improper field modification

Crack at flange diaphragm plate

Missing fillet weld

Improper profile

Cavitation & corrosion on weld

Weld performed by non-qualified welder

Substantial loss of weld area from corrosion

Undercut from corrosion

Moderate loss of weld area from corrosion