September 2006

Hydro Plant Risk Assessment Guide

Appendix E9: Crane Condition Assessment

E9.1 GENERAL

Cranes are key safety components to support the power train at hydroelectric powerplants. Crane failure can have a significant economic impact due to the high cost of emergency repairs and lost revenues during an extended outage. A crane failure risks an even greater impact to personal safety if an accident as a result of equipment failure should occur.

Determining the present condition of a crane is an essential step in analyzing the risk of failure. This appendix provides a process for arriving at a Crane Condition Index which may be used to develop a business case addressing risk of failure, economic consequences, and other factors.

E9.2 SCOPE / APPLICATION

The condition assessment methodology outlined in this appendix applies to hydroelectric powerplant cranes. The condition assessment primarily focuses on overhead and gantry cranes used at the intake deck, generator/turbine room, and tailrace decks of hydroelectric powerplants. The appendix can be used to evaluate monorail hoists used for handling draft tube bulkheads/gates.

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.

E9.3 CONDITION AND DATA QUALITY INDICATORS, AND CRANE 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 crane. The following indicators are used to separately evaluate the condition of the crane:

- Physical Condition
- Design Criteria
- Maintenance Requirements
- Age

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 Crane 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 In some cases, data may be missing, out-of-date, or of questionable integrity.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 Crane 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 Crane Condition Index.

Additional information regarding crane condition may be necessary to improve the accuracy and reliability of the Crane 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 Crane 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 Crane 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 Crane Condition Index may indicate the need for immediate corrective actions and/or follow-up Tier 2 testing. The Crane 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 placing the crane out of service and requiring corrective action before returning the crane into service, regardless of the Crane Condition Index score.

E9.4 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 staff that is 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 the electric utility.

E9.5 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.

E9.6 WEIGHTING FACTORS

Weighting factors used in the condition assessment methodology recognize that some Condition Indicators affect the Crane 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.

E9.7 MITIGATING FACTORS

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

E9.8 DOCUMENTATION

Substantiating documentation is essential to support findings of the assessment, particularly where a Tier 1 Condition Indicator score is less than 3 or where a Tier 2 analysis results in subtractions to the Crane Condition Index. Test reports, facility review reports, special exams, photographs, O & M records, and other documentation should accompany the Crane Condition Assessment Summary Form.

E9.9 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 Crane Condition Index.

E9.10 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. In this case, the identified corrective action should be completed immediately; after which, adjustments can be made to the Condition Indicator and Condition Index. The Tier 1 results may also indicate the need for an additional investigation, categorized as a Tier 2 analysis.

E9.11 TIER 1 – CRANE CONDITION INDICATORS

Condition Indicator 1 – Physical Condition of Crane

The known physical condition of the crane is a helpful indicator of crane reliability. This indicator is based on maintenance records and the most recent inspection reports only. Use the score of the worst component of the crane regardless of the overall or general condition of the crane. Results of the crane physical inspection are analyzed and applied to Table 1 to arrive at a Condition Indicator Score.

Table 1 – Crane Physical Condition

Results	Condition 1 Indicator Score
Excellent Condition: • Crane surfaces and coatings are free of corrosion; • No structural damage or cracks; no loose bolts or rivets found; • Couplings are tight and properly aligned; • Moving parts are lubricated; • Gearbox oil is free from contaminants and moisture; • No groove wear on drums or sheaves; • Bearings have no wear and are well lubricated; • Oil seals do not leak; • Gears are properly aligned and have no wear; • Hoist ropes have no broken strands or deformation; • The rope is laying properly on the drum; • Limit switches are properly set and functioning properly; • Brakes have no wear and operate properly; there is no record of loads slipping with the brakes applied; • No unusual noises or binding of any mechanism during operation; • Electrical components are clean and function properly; • Controls function properly; • Motors are clean and current draw is within limits; motor brushes and rings show minimal wear; • Hooks or grapples are free of nicks, gouges and cracks and swivel freely; hook latches function properly; • All wheels contact the rails, run smoothly and show no signs of wear; • Below-the-block lifting devices are in good condition; • Spare parts are readily available.	3

Good Condition: • Crane surfaces and coatings have minor defects or corrosion; • No structural damage or cracks; no loose bolts or rivets found; • Couplings are tight and properly aligned; • Moving parts are lubricated; • Gearbox oil has minor contaminants 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 deformation; • The rope is laying properly on the drum; • Limit switches are properly set and functioning properly; • Brake pads have ≥ 50% of the lining left and operate properly; • No unusual noises or binding of the mechanism during operation; • Electrical components are clean and functional; • Controls function properly; • Motors are clean and current draw is within limits; motor brushes and rings show minimal wear; • Hooks or grapples are free of nicks, gouges and cracks and swivel freely; hook latches function properly; • All wheels contact the rails, run smoothly and have minimal wear; • Below-the-block lifting devices are in good condition; • Spare parts are somewhat available.	2
Fair Condition: • Crane surfaces and coatings have minor defects or corrosion; • Minimal structural damage with no cracks; • Couplings are tight and properly aligned; • Gearbox oil has minor contaminants or water is noted; • Some groove wear on drums or sheaves; • Oil seals have minor leaks; • Gears are misaligned but no major wear or damage to the gears; • Hoist ropes have broken strands within the allowable limit of ASME B30.2; • Limit switches are properly set and functioning properly; • Brakes pads have ≥ 20% of the lining left and operate properly; • Some unusual noises are noted during operation; • Electrical components are dirty; • Controls have minor problems; • Motor current draw is excessive; • Hooks have minor defects and some wear; • All wheels contact the rails but have some wear noted; • There are multiple trouble reports on record such as repairs to the electrical controls; • Spare parts are somewhat difficult to obtain.	1

Poor Condition: • There are serious concerns with the crane's condition such as: • Operational restrictions or limits have been placed on the crane; • Major corrosion on the critical components; • Indication of frame skewing or ≥ 10% loose fasteners; • Wire rope corrosion, broken strands or deformation; • Brake pads have < 20% of the lining left; • Significant lubricating oil contamination; • Unusual noises or vibrations during operation; • Control problems; • Motors often trip out, vibrate or run hot; brittle or asbestos containing wiring insulation; • Hooks and grapples have increased throat opening or are bent; have cracks, nicks or gouges or abnormal wear; • Wheels do not contact rail or racking and binding of wheels occur during travel; wheels are worn extensively; • Frequent trouble reports; • Spare parts are very difficult to obtain.	0

Note: A severely negative result of ANY inspection, test, or measurement may be adequate in itself to require immediate placing the crane out of service and requiring corrective action before returning the crane into service, regardless of the Crane Condition Index score.

Condition Indicator 2 – Design Criteria

This condition indicator only addresses the conformity of the crane design to current and future needs and to the requirements specified in current regulations and codes. Use the score of the most severe design criteria deficiency regardless of the overall or general condition of the crane.

Design factors that may apply are:

- Crane capacity criteria (Can the crane lift the heaviest load without exceeding its rated capacity?);
- Crane duty criteria (Is the crane being used, or will be used, for more severe duty than for which it was designed? Is there an upcoming powerhouse rehabilitation requiring heavy crane usage?);
- Different handling needs (Is the crane being used, or does it need, to lift bulkier or different types of equipment than for which it was designed?);
- Regulations and crane codes requirements (Does the crane meet present standards and regulations, or are there deficiencies?).

Table 2 – Design Criteria Scoring	
Results	**Condition 2 Indicator Score**
• Heaviest lift < 100% of rated capacity. • Crane usage is appropriate for its duty classification. • Crane configuration is adequate for handling intended loads. • Crane has no regulation and code violations.	3
• Heaviest lift < 100% of rated capacity. • Crane usage is slightly higher than appropriate for its duty classification. • Crane configuration is adequate for handling intended loads. • Crane has no regulation and code violations; however may not have features required in new regulations and codes that are not required for older cranes.	2
• Heaviest lift is ≥ 100 and < 110% of rated capacity. • Crane usage is moderately higher than appropriate for its duty classification. • Crane has minor handling deficiencies, may need modifications to handle loads properly. • Crane has minor regulation and code violations. Also, may not have features required in new regulations and codes that are not required for older cranes.	1
• Heaviest lift ≥ 110% of rated capacity. • Crane usage is considerably higher than appropriate for its duty classification. • Crane has serious handling deficiencies, needs modifications to handle loads properly. • Crane has major regulation and code violations.	0

Note: A severely negative result of ANY inspection, test, or measurement may be adequate in itself to require immediate placing the crane out of service and requiring corrective action before returning the crane into service, regardless of the Crane Condition Index score.

Condition Indicator 3 – Maintenance Requirements

This condition indicator addresses the amount of maintenance that the crane currently requires. A lack of maintenance will be reflected in the Condition Indicator for Physical Condition. The Maintenance Requirements Indicator is broken into 3 categories: Small, Moderate and Extensive.

- Small: A small amount of routine annual preventative maintenance is required for the crane.
- Moderate: Moderate levels of maintenance would include some corrective maintenance.
- Excessive: Excessive maintenance is intended to include labor-intensive items. Frequent repairs or abnormal wear to components would be considered excessive.

Table 3 – Maintenance Requirements Scoring	
Results	**Condition 3 Indicator Score**
Small	3
Moderate	2
Excessive	1

Condition Indicator 4 – Age of Crane

Age is a factor to consider when assessing the condition of a crane. Rate the system on the oldest (not rehabilitated or refurbished) major component (mechanical equipment, crane structure, electrical equipment). Use the year a component was last completely rehabilitated or refurbished; otherwise, use the year it was put into service.

Results of the age analyses are applied to Table 4 to arrive at an appropriate Crane Age Indicator Score.

Table 4 – Age of Crane	
Results	**Condition 4 Indicator Score**
< 20 years	3
≥ 20 and < 35 years	2
≥ 35 years	1

E9.12 TIER 1 – CRANE CONDITION INDEX CALCULATIONS

Enter the Crane condition indicator scores from Tables 1-4 above into the Crane 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 Crane Condition Index. This index may be adjusted by the Tier 2 Crane inspections, tests, and measurements described later in this document.

E9.13 TIER 1 – CRANE DATA QUALITY INDICATOR

The Crane Data Quality Indicator reflects the quality of the inspection, test and measurement results used to evaluate the crane condition under Tier 1. The more current and complete the results are, the higher the rating for this indicator. The normal testing frequency is defined as the organization's recommended frequency for performing crane periodic inspection.

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 5 to arrive at a Crane Data Quality Indicator Score.

Table 5 – Crane Data Quality	
Results	**Crane Data Quality Indicator Score**
The last crane periodic inspection was performed within the normal inspection frequency and results are reliable.	10
The last crane periodic inspection was performed < 36 months past the normal inspection frequency and results are reliable.	7
The last crane periodic inspection was performed ≥ 36 and < 60 months past the normal inspection frequency OR some of the results are not available or are of questionable integrity.	4
The last crane periodic inspection was performed ≥ 60 months past the normal inspection frequency OR many results are of questionable integrity or no results are available.	0

Enter the Crane Data Quality Indicator Score from Table 5 into the Crane Condition Assessment Summary form at the end of this document.

E9.14 TIER 2 – CRANE INSPECTIONS, TESTS, AND MEASUREMENTS

Tier 2 inspections, tests, and measurements require specialized personnel to inspect the cranes and interview plant O & M staff. A Tier 2 assessment is not considered routine. Tier 2 inspections may affect the Crane Index established using Tier 1.

A team consisting of the Plant O & M Representative and Technical Support Staff should perform Tier 2 assessments.

The tasks to be performed for Tier 2 are summarized below:

1. Technical support staff will be responsible to:

    - Visit the plant to perform a physical inspection of the crane being evaluated and interview O & M staff.
    - Determine current condition of the crane.
    - Review and, if necessary, adjust the Tier 1 Condition Index based upon the inspection and comparison with the condition of other similar cranes.

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

    - Provide necessary assistance and information to Technical Support staff.
    - Assist in the assessment process.

For each Tier 2 test performed, add or subtract the appropriate amount to/from the appropriate Tier 1 Condition Indicator and recalculate the Crane Condition Index using the Crane Condition Assessment Summary form at the end of this document. 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 Tier 1 evaluations, any single condition that is severe enough could justify corrective action even if the overall condition index does not indicate as such.

E9.5 TIER 2 – CRANE CONDITION INDICATORS

The Tier 2 evaluation is divided up into sections:

- Structural Integrity
- Mechanical Integrity
- Electrical Integrity
- Operation
- Miscellaneous Deficiencies
- Maintenance Escalation
- Other Specialized Diagnostic Tests

Test T2.1: Structural Integrity

The physical deterioration of the crane structure is likely to be from one or more of the following factors evaluated here:

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

Test T2.1.1: Corrosion

Corrosion typically causes the most damage to cranes. 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 6 – Corrosion	
Rating	**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 have 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.	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.	Subtract 1.0

Test T2.1.2: 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. Weldments can also be tested by nondestructive methods if necessary.

Table 7 – Yielding, Fracture, Fatigue, and Fabrication Discontinuities	
Rating	**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 nondestructive 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 nondestructive testing on most welds.	Subtract 1.0

Test T2.1.3: Field Repair and Modification

Cranes 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 crane 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 8 – Field Repair and Modification

Rating	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 crane.	Subtract 1.0

Test T2.1.4: Miscellaneous Damage or Condition

Any damage or condition that is not explicitly in the categories of corrosion, yielding, fracture, design discontinuities, improper field repair and modification, or unforeseen loadings.

Table 9 – Miscellaneous Damage or Condition

Rating	Adjustment to Condition Index Score
Good	No Change
Moderate	Subtract 0.5
Severe	Subtract 1.0

Test T2.2: Mechanical Integrity

The integrity of the following mechanical components of the crane is evaluated here:

- Wire Rope/Chain
- Drums and Sheaves
- Gearbox, External Gearing, and Chain Sprockets
- Bearings, Bushings, and Couplings
- Wheels
- Hooks and Load Blocks

Test T2.2.1: Wire Rope/Chain

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

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 closure cranes and hoists.

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 10 – Wire Rope/Chain

Rating	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 – Few broken wires, no broken strands or cores. Corrosion and or lubrication could be better. Wire rope in serviceable condition. Minor wire kinking or crushing. Chain in marginal condition but withstands proof loads.	Subtract 0.5
Severe – Broken core or strands, neglected cable with significant corrosion, 15% or more reduction in cross sectional area reduction at any point in cable. Wire kinked or crushed severely. Chain in poor condition usually justifying replacement.	Subtract 1.0

Test T2.2.2: 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 11 – Drums and Sheaves	
Rating	**Adjustment to Condition Index Score**
Good – Hoist drum in good condition, no major deficiencies. Wire rope is correctly secured to drum, wire rope is not over spooled when load blocks are in 100% up condition.	Add 0.5
Moderate – Drums and sheaves in service able condition with normal wear.	No Change
Severe – Drum highly worn in groves, alignment incorrect, sheaves worn.	Subtract 0.5

Test T2.2.3: Gearbox, External Gearing, and Chain Sprockets

Gearbox should be operated through a full operation cycle and be 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 12 – Gearbox, External Gearing, and Chain Sprockets	
Rating	**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, and seals don't 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 or gearbox. Gearbox, gearing, and chain sprockets serviceable for ≥ 7 to < 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 0 to < 7 years.	Subtract 0.5

Test T2.2.4: Bearings, Bushings, and Couplings

Bearings, bushings, and couplings 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 *Gearbox and External Gearing* section) 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, bushings, or couplings that need immediate repair.

Table 13 – Bearings, Bushings, and Couplings	
Rating	**Adjustment to Condition Index Score**
Good – Bearings, bushings, and couplings are in good shape and need little or no attention.	Add 0.5
Moderate – Some repair needed on individual bearings, bushings, and couplings.	No Change
Severe – System wide poor condition of bearings, bushings, and couplings, easier to overhaul everything than attempt individual repair to select bearings, bushings and couplings.	Subtract 0.5

Test T2.2.5: Wheels

Wheels are subject to normal wear and tear and are subject to a finite life span. Since this section rating could encompass many wheels, the rater should rate the overall condition of all the wheels, noting individual wheels that need immediate repair.

Table 14 – Wheels	
Rating	**Adjustment to Condition Index Score**
Good – Wheels are in good shape and need little or no attention.	Add 0.5
Moderate – Wheels have wear, but still serviceable.	No Change
Severe – Wheels need replacing.	Subtract 0.5

Test T2.2.6: Hooks and Load Blocks

Hooks and load blocks are subject to normal wear and tear and are subject to a finite life span. Since this section rating could encompass several hooks and load blocks, the rater should rate the overall condition of all the hooks and load blocks, noting individual hooks or load blocks that need immediate repair.

Table 15 – Hooks and Load Blocks	
Rating	**Adjustment to Condition Index Score**
Good – Hooks and load blocks are in good shape and need little or no attention.	Add 0.5
Moderate – Some repair needed on individual hooks and load blocks.	No Change
Severe – Major repairs or replacement required.	Subtract 0.5

Test T2.3: Electrical Integrity

The integrity of the electrical system of the crane is evaluated under these focus areas:

- Incoming Power Source
- Power and Ancillary Systems Components
- Control System Components
- Availability of Spare Parts

Test T2.3.1: Incoming Power Source

The crane's incoming power source should be evaluated for overall condition and performance. Systems and equipment included in this part of the evaluation include the power supply feeder, runway conductors and collectors, and cable reel mechanisms, diesel generator sets or other devices used to transfer power to the crane.

Table 16 – Incoming Power Source

Rating	Adjustment to Condition Index Score
Good – Power source functions continuously on the entire length of the crane's runway. No power loss or nuisance trips due to loss of contact with power source or excessive voltage drop observed. Cable reel has enough cable available to service the entire runway from available outlets, and no splices or damaged areas are noted in the cable. Diesel generator set functions properly.	Add 0.5
Moderate – Power source functions continuously on ≥ 75% of the crane's runway, and the < 25% of non-continuous operation occurs on sections of the runway where the crane does not perform frequent service. Cable reel mechanism is problematic or cable appears worn, but continues to deliver uninterrupted power to the crane. Diesel generator set requires routine to frequent maintenance.	No Change
Severe – Power source does not function continuously on the entire length of the runway. Nuisance trips are frequent. Runway conductors are misaligned, have excessive insulated expansion gaps, or experience excessive sag due to environmental or loading conditions. Cable reel mechanism is severely worn or damaged. Diesel generator set requires frequent maintenance or is poorly suited to the duty required.	Subtract 0.5

Test T2.3.2: Power and Ancillary Systems Components

The integrity of the power and ancillary systems should be evaluated independently of other factors. Power system components as related to this assessment include power disconnect switches, breakers, and other power protective devices; power conductors, conduit, and raceways resident on the crane; and motors, brakes and motion control resistors. Ancillary systems include lighting equipment and other low-voltage (120 VAC) devices such as load cells and wind meters.

Table 17 – Power and Ancillary Systems Components	
Rating	**Adjustment to Condition Index Score**
Good – Main power disconnect switch is operational and acts to remove power from the entire crane. Breakers and power contactors are sized appropriately and operate properly. Power conductors are in good overall condition, with no excessive wear, splices or damaged portions. Motors, brakes, and resistors do not exhibit excessive heating, whining, or grinding, and are adequate for their use. Lighting system adequately illuminates the crane, and other low-voltage equipment functions as designed.	Add 0.5
Moderate – Main power disconnect may or may not operate properly, but other safety measures are in place to remove power from the crane. Breakers and power contactors operate properly. Wiring is excessively worn or aged but does not pose safety hazard. Motors, brakes, and resistors function properly. Lighting system may or may not illuminate adequately, but can be marginally corrected by replacing lamps. Other low-voltage equipment functions as designed.	No Change
Severe – Main power disconnect does not operate properly. Several breakers or power contactors are not functioning properly or contacts are welded. Power and lighting conductors are damaged or severely aged, posing safety hazard. Motors exhibit excessive heating, whining, or grinding. Brakes fail to release completely, fail to hold the load while set, are missing parts, chatter, or show signs of excessive heating. Resistors are not functioning as designed, as evidenced by missing speed points or nuisance tripping during dynamic braking. Lighting system offers poor illumination and can not be corrected by replacing lamps. Low voltage equipment does not function properly.	Subtract 0.5

Test T2.3.3: Control System Components

The integrity of the control system should be evaluated independently of other factors. Control system components as related to this assessment include operator's control apparatus; control panels and enclosures; control conductors, conduit, and raceways resident on the crane; and limit switches and other control devices.

It should be noted that live, 480 VAC, operator controls are considered somewhat of a potential safety hazard. While no safety standard prohibits 480 VAC operator controls on cab-operated cranes, there is an OSHA, as well as ASME, restriction against pendant controls having greater than 150 VAC or 300 VDC control circuit voltage. To be conservative, it is recommended that a crane that has operator control circuit voltage of greater than 150 VAC or 300 VDC be prohibited from receiving better than a "Moderate" rating for the Control System Components evaluation.

Table 18 – Control System Components	
Rating	**Adjustment to Condition Index Score**
Good – Operator's master switches and other control switches operate properly, with no "dead" speed points. Control panels and enclosures are clean, undamaged, and function as designed. Control panels and enclosures have adequate environmental ratings for their service (indoor, outdoor). Control wiring is in good overall condition. Limit switches and other control devices function as designed.	No Change
Moderate – Operator's switches have one or two "dead" speed points but function as designed otherwise. Control panels and enclosures are dirty, slightly damaged, or do not have an adequate environmental rating for their service, but continue to function as designed. Control wiring is aged or worn but does not pose a safety hazard. Hoist and travel limit switches and other control devices do not function as designed, but may be replaced or repaired.	Subtract 0.5
Severe – Operator's switches have more than two "dead" speed points or otherwise do not function properly. Control panels are dirty, damaged, do not have an adequate environmental rating, or otherwise do not function as designed. Control wiring is severely aged or worn and poses a safety hazard. Limit switches or other control devices do not function properly and can not be replaced or repaired.	Subtract 1.0

Test T2.3.4: Availability of Spare Parts

Spare parts are essential to maintaining the health and integrity of the crane's power, ancillary, and control systems components. As cranes age, their control systems may become technologically outdated, rendering spare parts impossible to find on short notice, or at all. Because powerhouses often do not have mobile cranes or other alternative methods available for moving large loads, it is essential for powerhouse cranes to have new spare parts available from multiple vendors.

Spare parts addressed in this section include breakers, contactors, motors, electric brakes, limit switches, conductor and collector systems, control system electrical or electronic devices, and operator's control switches.

Table 19 – Availability of Spare Parts	
Rating	**Adjustment to Condition Index Score**
Good – All motors, brakes, electronic devices, and ≥ 75% of other spare parts of the types listed above are available and are either stored on-site or are readily available from three or more domestic vendors. Spare parts are not special-order items.	No Change
Moderate – All motors, brakes, electronic devices, and ≥ 75% of other spare parts are not available on-site but are readily available from two or three domestic vendors. Spare parts are not special-order items.	Subtract 0.5
Severe – Any hoist motor or hoist brake is not available on-site or from one or more vendors. Electronic devices and other spare parts are not available on-site, are not available by more than one domestic vendor, or are not available at all. Spare parts are special-order items only. Spare parts are available by international vendors only.	Subtract 1.0

Test T2.4: Operation

Operation of crane in this section is concerned with overall system operation including misalignment, speed, and reliability.

Table 20 – Operation	
Rating	**Adjustment to Condition Index Score**
Acceptable – All hoists and travel drives operate smoothly, no vibrations or unusual noises, no control problems, no racking or binding.	No Change
Marginal – At least one hoist or travel drive operates with some vibration or unusual noises, some control problems, or some racking or binding.	Subtract 0.5
Unacceptable – At least one hoist or travel drive with severe vibration or unusual noises, severe control problems, or severe racking or binding.	Subtract 1.0

Test T2.5: Miscellaneous Deficiencies

Any deficiencies not previously 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 *Crane* condition.

Table 21 – Miscellaneous Deficiencies	
Rating	**Adjustment to Condition Index Score**
Good – Deficiency will not affect the safety or functionality of crane.	No Change
Moderate – May affect the function of crane.	Subtract 0.5
Severe – Will severely affect performance or structure of crane to the point where there is risk of significant economic or life loss.	Subtract 1.0

Test T2.6: Maintenance Escalation

Maintenance escalation for equipment is normal. Usually equipment is engineered for some finite service life 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 22 – Maintenance Escalation	
Rating	**Adjustment to Condition Index Score**
Good – Maintenance escalation is less than expected.	Add 0.5
Moderate – Maintenance escalation is in keeping with estimates, but 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 0.5

Test T2.7: Other Specialized Diagnostic Tests

Additional tests may be applied to evaluate specific crane 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 Crane Condition Index.

E9.16 TIER 2 – CRANE CONDITION INDEX CALCULATIONS

Enter the Tier 2 adjustments from the tables above into the Crane Condition Assessment Summary form at the end of this guide. Subtract the sum of these adjustments from the Tier 1 Crane Condition Index to arrive at the Net Crane Condition Index. 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.

E9.17 CRANE CONDITION-BASED ALTERNATIVES

After review by a crane expert, the Crane Condition Index is suitable for use in a risk-and-economic analysis model. The condition index may be deemed sufficient in itself for decision-making regarding crane alternatives.

Table 23 – Crane Condition-Based Alternatives

Generator Condition Index	Suggested Course of Action
≥ 7.0 and ≤ 10 (Good)	Continue O & M without restriction. Repeat condition assessment as needed.
≥ 3.0 and < 7 (Fair)	Continue operation but reevaluate O & M practices. Consider using appropriate Tier 2 tests. Repeat condition assessment process as needed.
≥ 0 and < 3.0 (Poor)	Immediate evaluation including additional Tier 2 testing. Consultation with experts. Adjust O & M as prudent. Begin replacement/rehabilitation process.

CRANE
TIER 1 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Name of Crane: _____

Crane Manufacturer: _____ Yr. Installed: _____

Type of Crane: _____ Capacity of Crane: _____

Function of Crane: _____

Tier 1 Crane Condition Summary *(For instructions on indicator scoring, please refer to condition assessment guide)*				
No.	**Condition Indicator**	**Score x**	**Weighting Factor =**	**Total Score**
1	Physical Condition *(Score must be 0, 1, 2, or 3)*	3	1.2	
2	Design Criteria *(Score must be 0, 1, 2, or 3)*	3	1.0	
3	Maintenance Requirements *(Score must be 1, 2, or 3)*	3	0.8	
4	Age *(Score must be 1, 2, or 3)*	3	0.333	
Tier 1 Crane 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.)

Crane Condition Index-Based Alternatives	
Condition Index	**Suggested Course of Action**
≥ 7.0 and ≤ 10 (Good)	Repeat Tier 1 assessment during next periodic inspection.
≥ 3.0 and < 7 (Fair)	Schedule Tier 2 assessment within 2 years.
≥ 0 and < 3.0 (Poor)	Perform crane repairs, if possible, and repeat Tier 1 assessment. Otherwise, schedule Tier 2 assessment as soon as possible.

CRANE
TIER 2 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Name of Crane: _____

Crane Manufacturer: _____ Yr. Installed: _____

Type of Crane: _____ Capacity of Crane: _____

Function of Crane: _____

Tier 2 Crane Condition Summary		
No.	**Tier 2 Test (Table No.)**	**Adjustment to Tier 1 Crane Condition Index**
Structural Integrity:		
T2.1.1	Corrosion (6)	
T2.1.2	Yielding, Fracture, Fatigue, and Fabrication Discontinuities (7)	
T2.1.3	Field Repair and Modification (8)	
T2.1.4	Miscellaneous Damage or Condition (9)	
Mechanical Integrity:		
T2.2.1	Wire Rope/Chain (10)	
T2.2.2	Drums and Sheaves (11)	
T2.2.3	Gearbox, External Gearing, and Chain Sprockets (12)	
T2.2.4	Bearings, Bushings, and Couplings (13)	
T2.2.5	Wheels (14)	
T2.2.6	Hooks and Load Blocks (15)	
Electrical Integrity:		
T2.3.1	Incoming Power Source (16)	
T2.3.2	Power and Ancillary Systems Components (17)	
T2.3.3	Control System Components (18)	
T2.3.4	Availability of Spare Parts (19)	
Miscellaneous Tests and Conditions:		
T2.4	Operation (20)	
T2.5	Miscellaneous Deficiencies (21)	
T2.6	Maintenance Escalation (22)	
T2.7	Other Specialized Diagnostic Tests	
Tier 2 Adjustments to Crane Condition Index (Sum of individual Adjustments)		

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

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

Tier 1 Crane Condition Index _____

minus **Tier 2 Crane Adjustments** _____ = _____

Net Crane Condition Index

Evaluator: _____ Technical Review: _____

Management Review: _____ Copies to: _____

(Attach supporting documentation.)