September 2006

Hydro Plant Risk Assessment Guide

Appendix E2: Circuit Breaker Condition Assessment

E2.1 GENERAL

Circuit breakers are key components in the power train at hydroelectric powerplants and are appropriate for analysis under a condition assessment program. Circuit breaker failures can have a significant economic impact due to the high costs of equipment replacement and lost power generation during an extended repair outage.

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

E2.2 SCOPE / APPLICATION

Circuit breakers are obtained from a variety of manufacturers, and there is a large variety of designs. Breaker specifications apply only to the particular circuit breaker being evaluated, and are not necessarily applicable to those produced by other manufacturers. Even within a single manufacturer, different models may not have the same design or specifications. Therefore, it is necessary to refer to the manufacturer's specifications for each circuit breaker that is to be assessed.

The breaker condition assessment methodology outlined in this appendix applies to metal-clad, station class, and freestanding circuit breakers. Breakers in these classes can be any of a variety of types of interrupters including air magnetic, air blast, bulk oil, SF_6 gas (dual pressure and puffer), and vacuum. Due to design differences in the breakers, the inspections, tests, and measurements described in this appendix have varying applicability to the different types of breakers. The appropriate inspections, tests, and measurements for each type of breaker are described in section E2.10 below.

This appendix is not intended to define circuit breaker maintenance practices or describe in detail circuit breaker condition assessment inspections, tests, or measurements. Utility maintenance policies and procedures, as well as manufacturer's recommendations must be consulted for such information.

E2.3 CONDITION AND DATA QUALITY INDICATORS AND CIRCUIT BREAKER CONDITION INDEX

This appendix describes four condition indicators generally regarded as a sound basis for assessing circuit breaker condition:

- Dielectric Condition
- Operation and Maintenance History
- Contact Resistance
- Number of Operations

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 Circuit Breaker Condition Index.

Only Operation and Maintenance History is used for assessing the condition of vacuum circuit breakers. This is explained further in the vacuum breaker section.

An additional stand-alone indicator is used to reflect the quality of the information available for scoring the circuit breaker 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 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 Circuit Breaker Condition Index.

Additional information regarding circuit breaker condition may be necessary to improve the accuracy and reliability of the Circuit Breaker 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, depending on the specific issue or problem being addressed. Tier 2 tests 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 Circuit Breaker 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 Circuit Breaker Condition Index may indicate the need for immediate corrective actions and/or follow-up Tier 2 testing. After review by qualified personnel, the Circuit Breaker Condition Index is suitable for use as input to a risk-based economic analysis.

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

E2.4 INSPECTIONS, TESTING, AND MEASUREMENTS

Inspections, tests, and measurements should be conducted and analyzed by staff suitably trained and experienced in circuit breaker operation and maintenance.

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

Circuit breaker condition assessment may cause concern that justifies more frequent monitoring, in which case utilities should consider the possibility of making more frequent inspections. This will provide additional data for condition assessment and establish a certain amount of reassurance as circuit breaker repair or replacement alternatives are being investigated.

E2.5 SCORING

Condition indicator scoring is somewhat subjective, relying on personnel experienced in assessing circuit breaker conditions. Relative terms such as "Results Normal" and "Deterioration" refer to results that are compared to industry accepted levels; or to baseline or previously acceptable levels on this equipment; or to equipment of similar design, construction, or age operating in a similar environment.

E2.6 WEIGHTING FACTORS

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

E2.7 MITIGATING FACTORS

Every circuit breaker is unique and, therefore, the methodology described in this appendix cannot quantify all factors that affect individual circuit breaker condition. It is important that the Circuit Breaker Condition Index arrived at be reviewed by engineering experts. Mitigating factors specific to the utility may determine the final Circuit Breaker Condition Index and the final decision on circuit breaker replacement or rehabilitation.

E2.8 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 test results in subtractions to the Circuit Breaker Condition Index. Test results and reports, photographs, O & M records, or other documentation should accompany the Circuit Breaker Condition Assessment Summary form.

E2.9 CONDITION ASSESSMENT METHODOLOGY

The condition assessment methodology consists of analyzing each condition indicator individually to arrive at a condition indicator score; then the score is weighted and summed with scores from other condition indicators. The sum is the Circuit Breaker Condition Index.

Reasonable efforts should be made to perform Tier 1 inspections, tests, and measurements. However, when data is missing to properly score the condition indicator, it may be assumed that the score is "Good" or numerically 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 Circuit Breaker Condition Index.

E2.10 TIER 1 – INSPECTIONS, TESTS, AND MEASUREMENTS

Tier 1 tests include inspections, tests, and measurements 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 Circuit Breaker Condition Index. Tier 1 inspections, tests, and measurements may indicate abnormal conditions that can be resolved with standard corrective maintenance solutions. The results from Tier 1 inspections, tests, and measurements may also indicate the need for additional investigation, categorized as Tier 2 inspections, tests, and measurements.

Note: There are four different sub-sections below, each of which is written for a particular type of circuit breaker (air magnetic / air blast, oil tank, SF_6, and vacuum). Use the sub-section describing the Tier 1 tests that are appropriate for the type of circuit breaker being evaluated.

E2.10.a. Air Magnetic/Air Blast Circuit Breakers

Air Magnetic breakers are air insulated, spring operated, and use magnetically contoured arc chutes to elongate and cool the arc. They are often installed in metal clad switchgear and can be removed entirely for maintenance. The dielectric condition of the breaker can be measured and trended by performing megger and power factor tests on the fully assembled breaker including the arc chutes. The main and arcing contacts should be inspected for signs of wear including pitting, scoring, or overheating and burning. It is normal to show more wear on the arcing contacts than the main contacts. All components of the operating mechanism should be checked for loose or broken parts, missing retainers or other hardware, excessive wear on moving parts, and for binding during movement. The fully assembled circuit breaker should be tested to determine breaker operation and timing is within original manufacturer tolerances.

Air Blast breakers are air insulated and use high pressure air to operate the breaker and to elongate and cool the arc. They are often installed in station class switchgear and cannot be removed entirely for maintenance. The dielectric condition of the breaker can be measured and trended by performing megger and power factor tests on the fully assembled breaker including the arc chutes. The main and arcing contacts should be inspected for signs of wear including pitting, scoring, or overheating and burning. It is normal to show more wear on the arcing contacts than the main contacts. All components of the operating mechanism should be checked

for loose or broken parts, missing retainers or other hardware, excessive wear on moving parts, and for binding during movement. The compressed air system and control valves should be checked for proper operation, including compressor run times and start/stop controls. The complete circuit breaker should be tested to confirm correct breaker operation and that timing is within original manufacturer tolerances.

Air Magnetic/Air Blast Circuit Breaker Condition Indicator 1 – Dielectric Tests

Power Factor testing of air magnetic or air blast breakers can evaluate the overall dielectric condition of the breaker including bushings, arc chutes, operating rods, etc.

The results of these tests are analyzed and applied to Table 1 to arrive at a Condition Indicator Score.

Table 1 – Air Magnetic/Air Blast Dielectric Test Scoring

Results	Condition Indicator Score
Test results are normal. (Good - G)*	3
Test results show minor deterioration. (Deteriorated - D)*	2
Test results show significant deterioration. (Investigate - I)*	1
Test results show severe deterioration. (Bad - B)*	0 (May indicate serious problem requiring immediate evaluation, additional testing, consultation with experts, and remediation prior to re-energization.)

* Doble insulation rating shown in parentheses.

Air Magnetic/Air Blast Circuit Breaker Condition Indicator 2 – Operation and Maintenance History

Operation and maintenance (O & M) history may indicate overall circuit breaker condition. O & M history factors that may apply are:

- Difficult or expensive to bring mechanism into compliance for timing and travel. Timing and travel measurements are taken with the circuit breaker removed from service. It is expected that a circuit breaker will not be returned to service until it has been adjusted or repaired to result in satisfactory timing and travel measurements. If these adjustments or repairs are frequent or expensive, they may indicate that the mechanism is worn out or not well designed.
- High number of fault current operations. If the data is available, the fault currents and durations can be used to estimate the interrupting duty the breaker has seen. In general, as the energy level of the interrupted fault increases, the stress on the breaker increases.
- Numerous forced outages or outage extensions to correct problems.

- Excessive or frequent corrective maintenance.
- Difficulty in obtaining or very high cost of spare or replacement parts

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

Table 2 – Air Magnetic/Air Blast Circuit Breaker O & M History Scoring

Results	Condition Indicator Score
Operation and Maintenance are normal.	3
Some abnormal operating conditions experienced and/or additional maintenance above normal occurring.	2
Significant operation outside normal and/or significant additional maintenance is required; or forced outage occurs; or outages are regularly extended due to maintenance problems; or similar units are problematic.	1
Repeated forced outages; maintenance not cost effective; or severe mechanical problems; or similar units have failed.	0

Air Magnetic/Air Blast Circuit Breaker Condition Indicator 3 – Contact Resistance Tests

Performing a contact resistance test on the breaker in the closed position can detect abnormal conditions that could result in overheating of the breaker contacts. The test can be performed using a Digital Low-Resistance Ohmmeter (DLRO). The DLRO forces large currents (50-100 A or more) through the contacts and precisely measures the voltage drop across the breaker. The test is also referred to as a millivolt drop test.

Apply the test results to Table 3 to arrive at a Condition Indicator Score.

Table 3 – Air Magnetic/Air Blast Contact Resistance Test Scoring

Results	Condition Indicator Score
$<$ 25 percent increase since last test AND below manufacturer recommended maximum resistance.	3
$\geq$ 25 and $<$ 75 percent increase since last test AND below manufacturer recommended maximum resistance.	2
$\geq$ 75 percent increase since last test OR above manufacturer recommended maximum resistance.	1 (May indicate serious problem requiring immediate evaluation, additional testing, consultation with experts, and remediation prior to re-energization.)

Air Magnetic/Air Blast Circuit Breaker Condition Indicator 4 – Number of Operations

The number of operations that a breaker has been subject to is a measure of the used life of a breaker. Consideration should be given to treating the counter as "reset to zero" following a complete breaker overhaul or refurbishment.

Records are analyzed and applied to Table 4 to arrive at a Condition Indicator Score.

Table 4 – Air Magnetic/Air Blast Operations Scoring

Results	Condition Indicator Score
< 1,000 normal operations	3
≥ 1,000 and < 3,000 normal operations	2
≥ 3,000 and < 5,000 normal operations	1
≥ 5,000 normal operations	0

E2.10.b Oil Tank Circuit Breakers

Oil tank circuit breakers have their contacts submersed in oil within a tank. They are normally freestanding. The operating mechanism is located outside the tank and is transmitted to the moving contacts through operating rods. There are several tests that can be performed on the insulating oil in the breaker including dielectric breakdown, water content, power factor, color, and interfacial tension. These tests can indicate when it is necessary to recondition the breaker oil. Since the normal operation of the breaker will degrade the oil and bulk tank oil breakers are directly vented to the atmosphere, poor test results do not necessarily indicate a problem with the breaker itself. Therefore, these tests are not included in the condition assessment for oil breakers.

The dielectric condition of the breaker can be measured and trended by performing megger and power factor tests on the fully assembled breaker. The bushings themselves can also be power factor tested. The current carrying contacts of an oil breaker are not accessible during routine maintenance. Contact engagement may be discernible by measuring the travel of the operating mechanism (lift rod). All components of the operating mechanism should be checked for loose or broken parts, missing retainers or other hardware, excessive wear on moving parts, and for binding during movement. The complete circuit breaker should be tested to confirm correct breaker operation and that timing is within original manufacturer tolerances.

Oil Tank Circuit Breaker Condition Indicator 1 – Dielectric Tests

Power factor testing of the breaker can evaluate the overall dielectric condition of the breaker including bushings and interrupting grids. Low bushing power factors should not result in a lowered condition indicator for the entire breaker (since the bushing itself can be replaced).

The results of these tests are analyzed and applied to Table 5 to arrive at a Condition Indicator Score.

Table 5 – Oil Tank Dielectric Test Scoring

Results	Condition Indicator Score
Test results are normal. (Good – G)*	3
Test results show minor deterioration. (Deteriorated – D)*	2
Test results show significant deterioration. (Investigate – I)*	1
Test results show severe deterioration. (Bad – B)*	0 (May indicate serious problem requiring immediate evaluation, additional testing, consultation with experts, and remediation prior to re-energization.)

* Doble insulation rating shown in parentheses.

Oil Tank Circuit Breaker Condition Indicator 2 – Operation and Maintenance History

Operation and maintenance (O & M) history may indicate overall circuit breaker condition. O & M history factors that may apply are:

- Difficult or expensive to bring mechanism into compliance for timing and travel. Timing and travel measurements are taken with the circuit breaker removed from service. It is expected that a circuit breaker will not be returned to service until it has been adjusted or repaired to result in satisfactory timing and travel measurements. If these adjustments or repairs are frequent or expensive, they may indicate that the mechanism is worn out or not well designed.
- High number of fault current operations. If the data is available, the fault currents and durations can be used to estimate the interrupting duty the breaker has seen. In general, as the energy level of the interrupted fault increases, the stress on the breaker increases.
- Numerous forced outages or outage extensions to correct problems.
- Excessive or frequent corrective maintenance.
- Difficulty in obtaining or very high cost of spare or replacement parts.

Qualified personnel should make a subjective determination of scoring that encompasses as many operation and maintenance factors as possible under this Indicator. Results are analyzed and applied to Table 6 to arrive at a Condition Indicator Score.

Table 6 – Oil Tank O & M History Scoring	
Results	**Condition Indicator Score**
Operation and Maintenance are normal.	3
Some abnormal operating conditions experienced and/or additional maintenance above normal occurring.	2
Significant operation outside normal and/or significant additional maintenance is required; or forced outage occurs; or outages are regularly extended due to maintenance problems; or similar units are problematic.	1
Repeated forced outages; maintenance not cost effective; or severe mechanical problems; or similar units have failed.	0

Oil Tank Circuit Breaker Condition Indicator 3 – Contact Resistance Tests

Performing a contact resistance test on the breaker in the closed position can detect abnormal conditions that could result in overheating of the breaker contacts. The test can be performed using a Digital Low-Resistance Ohmmeter. The DLRO forces large currents (50-100 A or more) through the contacts and precisely measures the voltage drop across the breaker. The test is also referred to as a millivolt drop test.

Apply the test results to Table 7 to arrive at a Condition Indicator Score.

Table 7 – Oil Tank Contact Resistance Test Scoring	
Results	**Condition Indicator Score**
$<$ 25 percent increase since last test AND below manufacturer recommended maximum resistance.	3
$\geq$ 25 and $<$ 75 percent increase since last test AND below manufacturer recommended maximum resistance.	2
$\geq$ 75 percent increase since last test OR above manufacturer recommended maximum resistance.	1 (May indicate serious problem requiring immediate evaluation, additional testing, consultation with experts, and remediation prior to re-energization.)

Oil Tank Circuit Breaker Condition Indicator 4 – Number of Operations

The number of operations that a breaker has been subject to is a measure of the used life of a breaker. Consideration should be given to treating the counter as "reset to zero" following a complete breaker overhaul or refurbishment.

Records are analyzed and applied to Table 8 to arrive at a Condition Indicator Score.

Table 8 – Oil Tank Operations Scoring	
Results	**Condition Indicator Score**
< 250 normal operations	3
≥ 250 and < 750 normal operations	2
≥ 750 and < 1,500 normal operations	1
≥ 1,500 normal operations	0

E2.10.c SF_6 Circuit Breakers

SF_6 breakers utilize sulfur hexaflouride gas to both insulate the current carrying parts and to aid in interrupting the arc. SF_6 breakers can be installed in metal clad or station class switchgear as well as being freestanding. The dielectric condition of the breaker can be measured and trended by performing megger and power factor tests on the fully assembled breaker. The current carrying contacts of an SF_6 breaker are not accessible during routine maintenance. Contact engagement may be discernible by measuring the travel of the operating mechanism. All components of the operating mechanism should be checked for loose or broken parts, missing retainers or other hardware, excessive wear on moving parts, and for binding during movement. The complete circuit breaker should be tested to confirm correct breaker operation and that timing is within original manufacturer tolerances.

SF_6 Circuit Breaker Condition Indicator 1 – Dielectric Tests

Power factor testing of the breaker can evaluate the overall dielectric condition of the breaker including bushings.

The results of these tests are analyzed and applied to Table 9 to arrive at a Condition Indicator Score.

Table 9 – SF_6 Dielectric Test Scoring	
Results	**Condition Indicator Score**
Test results are normal. (Good – G)*	3
Test results show minor deterioration. (Deteriorated – D)*	2
Test results show significant deterioration. (Investigate – I)*	1
Test results show severe deterioration. (Bad – B)*	0 (May indicate serious problem requiring immediate evaluation, additional testing, consultation with experts, and remediation prior to re-energization.)

* Doble insulation rating shown in parentheses.

SF_6 Circuit Breaker Condition Indicator 2 – Operation and Maintenance History

Operation and maintenance (O & M) history may indicate overall circuit breaker condition. O & M history factors that may apply are:

- Difficult or expensive to bring mechanism into compliance for timing and travel. Timing and travel measurements are taken with the circuit breaker removed from service. It is expected that a circuit breaker will not be returned to service until it has been adjusted or repaired to result in satisfactory timing and travel measurements. If these adjustments or repairs are frequent or expensive, they may indicate that the mechanism is worn out or not well designed.
- High number of fault current operations. If the data is available, the fault currents and durations can be used to estimate the interrupting duty the breaker has seen. In general, as the energy level of the interrupted fault increases, the stress on the breaker increases.
- Numerous forced outages or outage extensions to correct problems.
- Excessive or frequent corrective maintenance.
- Difficulty in obtaining or very high cost of spare or replacement parts.

Qualified personnel should make a subjective determination of scoring that encompasses as many operation and maintenance factors as possible under this Indicator. Results are analyzed and applied to Table 10 to arrive at a Condition Indicator Score.

Table 10 – SF_6 O & M History Scoring

Results	Condition Indicator Score
Operation and Maintenance are normal.	3
Some abnormal operating conditions experienced and/or additional maintenance above normal occurring.	2
Significant operation outside normal and/or significant additional maintenance is required; or forced outage occurs; or outages are regularly extended due to maintenance problems; or similar units are problematic.	1
Repeated forced outages; maintenance not cost effective; or severe mechanical problems; or similar units have failed.	0

SF_6 Circuit Breaker Condition Indicator 3 – Contact Resistance Tests

Performing a contact resistance test on the breaker in the closed position can detect abnormal conditions that could result in overheating of the breaker contacts. The test can be performed using a Digital Low-Resistance Ohmmeter (DLRO). The DLRO forces large currents (50-100 A or more) through the contacts and precisely measures the voltage drop across the breaker. The test is also referred to as a millivolt drop test.

Apply the test results to Table 11 to arrive at a Condition Indicator Score.

Table 11 – SF_6 Contact Resistance Tests Scoring	
Results	**Condition Indicator Score**
< 25 percent increase since last test AND below manufacturer recommended maximum resistance.	3
≥ 25 and < 75 percent increase since last test AND below manufacturer recommended maximum resistance.	2
≥ 75 percent increase since last test OR above manufacturer recommended maximum resistance.	1 (May indicate serious problem requiring immediate evaluation, additional testing, consultation with experts, and remediation prior to re-energization.)

SF_6 Circuit Breaker Condition Indicator 4 – Number of Operations

The number of operations that a breaker has been subject to is a measure of the used life of a breaker. Consideration should be given to treating the counter as "reset to zero" following a complete breaker overhaul or refurbishment.

Records are analyzed and applied to Table 12 to arrive at a Condition Indicator Score.

Table 12 – SF_6 Operations Scoring	
Results	**Condition Indicator Score**
< 2,000 normal operations	3
≥ 2,000 and < 5,000 normal operations	2
≥ 5,000 and < 8,000 normal operations	1
≥ 8,000 normal operations	0

E2.10.d Vacuum Circuit Breakers

Vacuum circuit breakers utilize a pair of main contacts encapsulated in a sealed vacuum bottle. The actual contact separation is very small as there is no medium that the arc would ionize to sustain itself after the contacts open. The dielectric condition of the breaker can be measured and trended by performing power factor tests on the fully assembled breaker. The current carrying contacts of a vacuum breaker are not accessible. The operating rod for the moving contact is scribed with a mark whose position with the contacts closed can be noted and compared to a reference mark. If the scribe mark and the reference mark are in alignment, the contacts have worn to the point of needing to be replaced. All components of the operating mechanism should be checked for loose or broken parts, missing retainers or other hardware, excessive wear on moving parts, and for binding during movement. The complete circuit breaker should be tested to confirm correct breaker operation and that timing is within original

manufacturer tolerances. The vacuum level in the bottle can be checked by performing a hi-pot test on the bottle per the manufacturer's instructions. There can be no partial vacuum loss so this is a go /no-go type of test.

Vacuum circuit breakers have fewer components and lower operating forces than other types of breakers. When routine O & M testing indicates problems with vacuum breakers, the repair is very often to replace the suspect component. This includes almost all parts of the breaker including the vacuum bottle itself. Since the vast majority of detected problems with a vacuum breaker result in replacing the faulty component, the breaker is rarely returned to service in less than like new condition.

Some of the Tier 1 tests performed for other types of breakers do not provide meaningful results for vacuum breakers. Dielectric test results, contact resistance, or the number of operations are not useful in determining whether the breaker is a good candidate for upgrade or replacement. For these reasons, the only condition indicator used for vacuum breakers is O & M History.

Vacuum Circuit Breaker Condition Indicator 1 – Operation and Maintenance History

Operation and maintenance (O & M) history may indicate overall circuit breaker condition. O & M history factors that may apply are:

- Difficult or expensive to bring mechanism into compliance for timing and travel. Timing and travel measurements are taken with the circuit breaker removed from service. It is expected that a circuit breaker will not be returned to service until it has been adjusted or repaired to result in satisfactory timing and travel measurements. If these adjustments or repairs are frequent or expensive, they may indicate that the mechanism is worn out or not well designed.
- High number of fault current operations. If the data is available, the fault currents and durations can be used to estimate the interrupting duty the breaker has seen. In general, as the energy level of the interrupted fault increases, the stress on the breaker increases.
- Numerous forced outages or outage extensions to correct problems.
- Excessive or frequent corrective maintenance.
- Difficulty in obtaining or very high cost of spare or replacement parts.

Qualified personnel should make a subjective determination of scoring that encompasses as many operation and maintenance factors as possible under this indicator.

Results are analyzed and applied to Table 13 to arrive at a Condition Indicator Score.

Table 13 – Vacuum O & M History Scoring	
Results	**Condition Indicator Score**
Operation and Maintenance are normal.	3
Some abnormal operating conditions experienced and/or additional maintenance above normal occurring.	2
Significant operation outside normal and/or significant additional maintenance is required; or forced outage occurs; or outages are regularly extended due to maintenance problems; or similar units are problematic.	1
Repeated forced outages; maintenance not cost effective; or severe mechanical problems; or similar units have failed.	0

E2.11 TIER 1 – CIRCUIT BREAKER CONDITION INDEX CALCULATIONS

Enter the Circuit Breaker Condition Indicator scores from the tables above into the Circuit Breaker Condition Assessment Summary form at the end of this appendix. Multiply each condition indicator score by the Weighting Factor, and sum the Total Scores to arrive at the Tier 1 Circuit Breaker Condition Index. Attach supporting documentation. This index may be adjusted by the Tier 2 circuit breaker inspections, tests, and measurements described later in this document.

E2.12 TIER 1 – CIRCUIT BREAKER DATA QUALITY INDICATOR

The Circuit Breaker Data Quality Indicator reflects the quality of the inspection, test and measurement results used to evaluate the circuit breaker condition under Tier 1, as well as the age of the comparison between short circuit study results and the breaker interrupting rating. 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 the specific test or inspection.

Records are analyzed and applied to Table 14 to arrive at a Circuit Breaker Data Quality Indicator Score.

Table 14 – Circuit Breaker Data Quality Scoring	
Results	**Data Quality Indicator Score**
All Tier 1 inspections, tests and measurements were completed within the normal testing frequency and the results are reliable AND comparison of breaker interrupting rating with short circuit study results was performed within the last < 5 years.	10
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 6 and < 24 months past the normal testing frequency and results are reliable OR comparison of breaker interrupting rating with short circuit study results was performed ≥ 5 and < 10 years ago.	7
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 24 and < 36 months past the normal testing frequency, or some of the results are not available or are of questionable integrity OR comparison of breaker interrupting rating with short circuit study results was performed ≥ 10 and < 15 years ago.	4
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 36 months past the normal frequency, or no results are available or many are of questionable integrity OR comparison of breaker interrupting rating with short circuit study results was performed ≥ 15 years ago.	0

Enter the Circuit Breaker Data Quality Indicator Score from Table 14 into the Circuit Breaker Condition Assessment Summary form at the end of this document.

E2.13 TIER 2 – INSPECTIONS, TESTS, AND MEASUREMENTS

Tier 2 inspections, tests, and measurements generally require specialized equipment or training, may be intrusive, or may require an extended outage to perform. Tier 2 assessment is considered non-routine. Tier 2 inspections are intended to affect the Circuit Breaker Condition Index number established using Tier 1 but also may confirm or refute the need for more extensive maintenance, rehabilitation, or circuit breaker replacement.

For circuit breakers, there are only two Tier 2 tests: interrupter inspection and a comparison of available short circuit current with the breaker's interrupting rating. The comparison of the available short circuit currents and the breaker's interrupting rating requires expert analyses and up-to-date short circuit studies. Because of the importance of the results of the comparison, the adjustment to the Circuit Breaker Condition Index for poor comparison results is significant.

For Tier 2 assessments performed, apply only the appropriate adjustment factors per the instructions above and recalculate the Circuit Breaker Condition Index using the Circuit Breaker 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.

Test T2.1: Interrupter Inspection

Performing an inspection of a breaker's interrupter requires a significant outage of the breaker. The decision to perform an interrupter inspection would most likely be based on finding problems with the breaker's timing and travel adjustments or with excessive contact resistance. An interrupter inspection would include disassembly of the breaker and inspection of all moving and stationary internal components.

Results are analyzed and applied to Table 15 to arrive at a Condition Indicator Score.

Table 15 – Interrupter Inspection Scoring

Results	Adjustment to Circuit Breaker Condition Indicator Score
Interrupter component wear and condition is normal.	No Change
Interrupter components show signs of considerable wear, but components remain serviceable.	Subtract 2.0
One or more interrupter components show excessive wear, with minimal life remaining.	Subtract 4.0
One or more interrupter components show excessive wear or damage with questionable remaining life.	Subtract 6.0 (May indicate serious problem requiring immediate consultation with experts, and remediation prior to re-energization.)

A circuit breaker cannot be safely returned to service with unresolved deficiencies in the internal mechanisms that affect the breaker's performance. If the problems found can be repaired, the breaker should be repaired and the appropriate Tier I tests repeated. It may be appropriate to lower the O & M History indicator score based on the findings of the interrupter inspection and repair.

Test T2.2: **Circuit Breaker Ratings vs. Available System Fault Current**

Circuit breakers are chosen such that interrupting current ratings exceed the maximum available fault current, considering contributions from the generator and the connected system (which may include other generators on the same medium voltage bus). There is also an allowance provided for the system fault contribution to grow with time included in the calculations. Operating a circuit breaker under conditions exceeding the ratings of the breaker can result in failure of the breaker and considerable incidental damage to adjacent equipment and even to the generator itself.

It is prudent to periodically review the adequacy of the circuit breaker's ratings compared with the system growth in the area of the breaker. Therefore, the first step in assessing the condition of a circuit breaker should be comparing the interrupting current rating of the breaker with the present and projected system fault current that the breaker must be capable of interrupting. This will require an up-to-date system fault study in the area of the circuit breaker to provide the new and projected system contributions.

Circuit breaker experts should be consulted when comparing the breaker ratings with the projected system fault currents. The first rating standards applicable to circuit breakers, developed in the 1940s and 1950s, were based on the highest current to be interrupted, including both the ac symmetrical current and the dc component at the instant of contact separation. This basis for the rating is referred to as "total current" rating. The method of rating circuit breakers was gradually changed (in the late 1960s and 1970s) to include only the ac symmetrical current at the point of contact separation. The "total current" standards were rescinded in 1986. The new basis is referred to as "symmetrical current" rating. Breakers rated using the old standards cannot be directly compared to breakers rated under the new standards.

Note: If the fault currents that the breaker may be called on to interrupt exceed the rating of the breaker, steps must be taken to reduce the fault current to which the breaker is exposed and/or plans should be initiated to upgrade or replace the breaker.

Current interrupting test rating results are analyzed and applied to Table 16 to arrive at a Circuit Breaker Condition Index score adjustment.

Table 16 – Tier 2 Current Interrupting Rating Scoring	
Test Results	**Adjustment to Circuit Breaker Condition Index Score**
Ratio of circuit breaker interrupting rating to available system fault current ≥ 1.1	No Change
Ratio of circuit breaker interrupting rating to available system fault current ≥ 0.9 and < 1.1	Subtract 3.0
Ratio of circuit breaker interrupting rating to available system fault current < 0.9	Subtract 6.0

Test T2.3: Other Specialized Diagnostic Tests

Additional tests may be applied to evaluate specific circuit breaker 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 Circuit Breaker Condition Index.

E2.14 CIRCUIT BREAKER CONDITION INDEX CALCULATIONS

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

E2.15 CIRCUIT BREAKER CONDITION-BASED ALTERNATIVES

After review by qualified personnel, the Circuit Breaker Condition Index – either modified by Tier 2 tests or not – may be sufficient for decision making regarding circuit breaker 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 circuit breaker condition, the Circuit Breaker Condition Index may be directly applied to Table 17.

Table 17 – Circuit Breaker Condition-Based Alternatives	
Circuit Breaker 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.

E2.16 EXAMPLE CIRCUIT BREAKER CONDITION ASSESSMENT

The following Tier 1 test results are for a hypothetical air magnetic circuit breaker and are reported from the breaker's last routine maintenance work. The Condition Indicators for an air magnetic breaker are Dielectric Tests, Operations and Maintenance History, Contact Resistance, and Number of Operations. The raw data for each of the indicators is as follows.

- Dielectric Tests – Doble test reports indicate insulation rating for the breaker (all poles and arc chutes) is Good.

- Operations and Maintenance History – This breaker is 35 years old and occasionally requires intervention by an electrician to close the breaker after it has been tripped due to mechanism misalignment. The misalignment is caused by excessive wear in the operating mechanism. Replacement parts are not available. Project staff have fabricated replacement components for the mechanism in the past.

- Contact Resistance Tests – The measured contact resistance was below the maximum recommended by the manufacturer.

- Number of Operations – The breaker counter indicates a total of 1245 operations since the breaker was installed.

Data for Circuit Breaker Quality Indicator – The Doble tests were performed 6 months ago. The Contact Resistance test results are 30 months old and no previous results are on file. The last short circuit study was performed two years ago and the breaker rating was found to be in excess of the system requirements by a factor of 1.2.

The results of the various tests above are compared to the appropriate tables to develop a Score for each Condition Indicator, with the following results:

Table 18 – Circuit Breaker Example Results

Tier 1 Condition Indicator	Score
Dielectric Tests	3
Operations and Maintenance History	1
Contact Resistance Tests	3
Number of Operations	2

Tier 1 Data Quality Indicator	Score
Quality of Inspections, Tests, and Measurements	7

The raw Scores in Table 18 are then entered into the appropriate Condition Assessment Summary form which contains the Weighting Factors to account for the differing importance of the Tier 1 tests. (Refer to the following tables.)

Note: No change in score results from the Current Interrupting Rating Indicator, a Tier 2 test, as the ratio of breaker interrupting rating to available system fault current is 1.2.

EXAMPLE

AIR MAGNETIC/AIR BLAST CIRCUIT BREAKER
TIER 1 CONDITION ASSESSMENT SUMMARY

Date: _January 4, 2003_____ Location: __River Plant_____

Circuit Breaker Identifier: __Example 1___ Manufacturer: __OEM_____ Yr. Mfd.: ___1968__

Current Rating: _5000_A_____ Interrupting Rating: __50 kA_____ Voltage: _13.8_kV__

Tier 1 Circuit Breaker Condition Summary
(For instructions on indicator scoring, please refer to condition assessment guide)

No.	Condition Indicator	Score ×	Weighting Factor =	Total Score
1	Dielectric Condition of Breaker *(Score must be 0, 1, 2, or 3)*	3	0.877	2.631
2	Operation and Maintenance History *(Score must be 0, 1, 2, or 3)*	1	1.3156	1.316
3	Contact Resistance *(Score must be 1, 2, or 3)*	3	0.702	2.106
4	Number of Operations *(Score must be 0, 1, 2, or 3)*	2	0.439	0.878
Tier 1 Circuit Breaker Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*				**6.931**

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

Evaluator: _____ Technical Review: _____

Management Review: _____ Copies to: _____

(Attach supporting documentation.)

Circuit Breaker Condition-Based Alternatives	
Circuit Breaker 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.

EXAMPLE

AIR MAGNETIC/AIR BLAST CIRCUIT BREAKER
TIER 2 CONDITION ASSESSMENT SUMMARY

Date: _January 4, 2003_____ Location: __River Plant_____

Circuit Breaker Identifier: __Example 1___ Manufacturer: __OEM_____ Yr. Mfd.: ___1968__

Current Rating: _5000_A_____ Interrupting Rating: __50 kA_____ Voltage: _13.8_kV__

Tier 2 Circuit Breaker Condition Summary		
No.	**Tier 2 Test**	**Adjustment to Tier 1 Condition Index**
T2.1	Interrupter Inspection	0
T2.2	Current Interrupting Rating vs. Short Circuit Current Analysis	0
T2.3	Other Specialized Diagnostic Tests	0
Tier 2 Adjustments to Circuit Breaker Condition Index (Sum of individual Adjustments)		0

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

To calculate the Net Circuit Breaker Condition Index, subtract the Tier 2 Adjustments from the Tier 1 Circuit Breaker Condition Index:

Tier 1 Circuit Breaker Condition Index **__6.931__**

minus **Tier 2 Circuit Breaker Adjustments** **__0_____** = **_____6.931_____**

Net Circuit Breaker Condition Index

Evaluator: _____ Technical Review: _____

Management Review: _____ Copies to: _____

(Attach supporting documentation.)

Table 19 – Circuit Breaker Condition Assessment Summary		
Test	**Detects**	**Tool**
Breaker Common Tests:		
Megger and Power Factor Tests	Presence of dirt and moisture (tracking), Insulation deterioration, bushing insulation condition,	Electrical test equipment and experienced personnel
Contact Inspection	Pitted or scarred surfaces, embedded foreign material, discoloration, evidence of overheating	Experienced and qualified inspectors
Operating Mechanism Inspection	Missing, loose, or damaged parts; worn moving parts, binding during movement	Experienced and qualified inspectors
Overall Timing	Misadjusted contacts or limits, worn or binding mechanisms, proper dashpot or shock absorber action, overall circuit breaker mechanical condition.	Circuit breaker timing analyzer and sensors/attachments
Infrared Scan (while breaker is in service)	Overheated connections, abnormal heating	Thermographic camera and analysis software, experienced and qualified inspectors
Contact Resistance	Poor conducting surfaces, low contact pressure (weak springs)	Digital Low Resistance Ohmmeter or other high current source able to measure microvolt drops across contacts
Breaker Specific Tests:		
Hi-pot Test	Integrity of vacuum in interrupter	Electrical test equipment and experienced personnel
Oil Physical and Chemical Tests	Moisture, degraded interfacial tension (IFT), acidity, color, dielectric strength, and power factor.	Requires laboratory analysis
SF_6 Gas Analysis	Density, moisture, purity	Requires laboratory analysis
Interrupter Grid Inspection	Deterioration of arc extinguishing parts	Experienced and qualified inspectors
Compressed Air System	Adequate compressor performance, control valve condition, piping system leaks or damage	Experienced and qualified inspectors

AIR MAGNETIC/AIR BLAST CIRCUIT BREAKER
TIER 1 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Circuit Breaker Identifier: _____ Manufacturer: _____ Yr. Mfd.: _____

Current Rating: _____ Interrupting Rating: _____ Voltage: _____

Tier 1 Circuit Breaker Condition Summary
(For instructions on indicator scoring, please refer to condition assessment guide)

No.	Condition Indicator	Score ×	Weighting Factor =	Total Score
1	Dielectric Condition of Breaker *(Score must be 0, 1, 2, or 3)*		0.877	
2	Operation and Maintenance History *(Score must be 0, 1, 2, or 3)*		1.316	
3	Contact Resistance *(Score must be 1, 2, or 3)*		0.702	
4	Number of Operations *(Score must be 0, 1, 2, or 3)*		0.439	
Tier 1 Circuit Breaker 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.)

Circuit Breaker Condition-Based Alternatives	
Circuit Breaker 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.

AIR MAGNETIC/AIR BLAST CIRCUIT BREAKER
TIER 2 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Circuit Breaker Identifier: _____ Manufacturer: _____ Yr. Mfd.: _____

Current Rating: _____ Interrupting Rating: _____ Voltage: _____

Tier 2 Circuit Breaker Condition Summary		
No.	**Tier 2 Test**	**Adjustment to Tier 1 Condition Index**
T2.1	Interrupter Inspection	
T2.2	Current Interrupting Rating vs. Short Circuit Current Analysis	
T2.3	Other Specialized Diagnostic Tests	
Tier 2 Adjustments to Circuit Breaker Condition Index (Sum of individual Adjustments)		

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

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

Tier 1 Circuit Breaker Condition Index _____

minus **Tier 2 Circuit Breaker Adjustments** _____ = _____

Net Circuit Breaker Condition Index

Evaluator: _____ Technical Review: _____

Management Review: _____ Copies to: _____

(Attach supporting documentation.)

OIL TANK CIRCUIT BREAKER
TIER 1 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Circuit Breaker Identifier: _____ Manufacturer: _____ Yr. Mfd.: _____

Current Rating: _____ Interrupting Rating: _____ Voltage: _____

Tier 1 Circuit Breaker Condition Summary
(For instructions on indicator scoring, please refer to condition assessment guide)

No.	Condition Indicator	Score	× Weighting Factor	= Total Score
1	Dielectric Condition of Breaker *(Score must be 0, 1, 2, or 3)*		0.684	
2	Operation and Maintenance History *(Score must be 0, 1, 2, or 3)*		1.282	
3	Contact Resistance *(Score must be 1, 2, or 3)*		0.684	
4	Number of Operations *(Score must be 0, 1, 2, or 3)*		0.684	
Tier 1 Circuit Breaker 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.)

Circuit Breaker Condition-Based Alternatives	
Circuit Breaker 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.

OIL TANK CIRCUIT BREAKER
TIER 2 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Circuit Breaker Identifier: _____ Manufacturer: _____ Yr. Mfd.: _____

Current Rating: _____ Interrupting Rating: _____ Voltage: _____

Tier 2 Circuit Breaker Condition Summary		
No.	**Tier 2 Test**	**Adjustment to Tier 1 Condition Index**
T2.1	Interrupter Inspection	
T2.2	Current Interrupting Rating vs. Short Circuit Current Analysis	
T2.3	Other Specialized Diagnostic Tests	
Tier 2 Adjustments to Circuit Breaker Condition Index (Sum of individual Adjustments)		

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

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

Tier 1 Circuit Breaker Condition Index _____

minus **Tier 2 Circuit Breaker Adjustments** _____ = _____

Net Circuit Breaker Condition Index

Evaluator: _____ Technical Review: _____

Management Review: _____ Copies to: _____

(Attach supporting documentation.)

SF_6 CIRCUIT BREAKER
TIER 1 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Circuit Breaker Identifier: _____ Manufacturer: _____ Yr. Mfd.: _____

Current Rating: _____ Interrupting Rating: _____ Voltage: _____

Tier 1 Circuit Breaker Condition Summary
(For instructions on indicator scoring, please refer to condition assessment guide)

No.	Condition Indicator	Score ×	Weighting Factor =	Total Score
1	Dielectric Condition of Breaker *(Score must be 0, 1, 2, or 3)*		0.439	
2	Operation and Maintenance History *(Score must be 0, 1, 2, or 3)*		1.316	
3	Contact Resistance *(Score must be 1, 2, or 3)*		0.877	
4	Number of Operations *(Score must be 0, 1, 2, or 3)*		0.702	
Tier 1 Circuit Breaker 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.)

Circuit Breaker Condition-Based Alternatives	
Circuit Breaker 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.

SF_6 CIRCUIT BREAKER
TIER 2 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Circuit Breaker Identifier: _____ Manufacturer: _____ Yr. Mfd.: _____

Current Rating: _____ Interrupting Rating: _____ Voltage: _____

Tier 2 Circuit Breaker Condition Summary		
No.	**Tier 2 Test**	**Adjustment to Tier 1 Condition Index**
T2.1	Interrupter Inspection	
T2.2	Current Interrupting Rating vs. Short Circuit Current Analysis	
T2.3	Other Specialized Diagnostic Tests	
Tier 2 Adjustments to Circuit Breaker Condition Index (Sum of individual Adjustments)		

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

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

Tier 1 Circuit Breaker Condition Index _____

minus **Tier 2 Circuit Breaker Adjustments** _____ = _____

Net Circuit Breaker Condition Index

Evaluator: _____ Technical Review: _____

Management Review: _____ Copies to: _____

(Attach supporting documentation.)

VACUUM CIRCUIT BREAKER
TIER 1 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Circuit Breaker Identifier: _____ Manufacturer: _____ Yr. Mfd.: _____

Current Rating: _____ Interrupting Rating: _____ Voltage: _____

Tier 1 Circuit Breaker Condition Summary *(For instructions on indicator scoring, please refer to condition assessment guide)*				
No.	**Condition Indicator**	**Score** ×	**Weighting Factor** =	**Total Score**
1	Dielectric Condition of Breaker *(Score must be 0, 1, 2, or 3)*	– – – –	0	
2	Operation and Maintenance History *(Score must be 0, 1, 2, or 3)*		3.333	
3	Contact Resistance *(Score must be 1, 2, or 3)*	– – – –	0	
4	Number of Operations *(Score must be 0, 1, 2, or 3)*	– – – –	0	
Tier 1 Circuit Breaker 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.)

Circuit Breaker Condition-Based Alternatives	
Circuit Breaker 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.

VACUUM CIRCUIT BREAKER
TIER 2 CONDITION ASSESSMENT SUMMARY

Date: _____ Location: _____

Circuit Breaker Identifier: _____ Manufacturer: _____ Yr. Mfd.: _____

Current Rating: _____ Interrupting Rating: _____ Voltage: _____

Tier 2 Circuit Breaker Condition Summary		
No.	**Tier 2 Test**	**Adjustment to Tier 1 Condition Index**
T2.1	Interrupter Inspection	
T2.2	Current Interrupting Rating vs. Short Circuit Current Analysis	
T2.3	Other Specialized Diagnostic Tests	
Tier 2 Adjustments to Circuit Breaker Condition Index (Sum of individual Adjustments)		

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

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

Tier 1 Circuit Breaker Condition Index _____

minus **Tier 2 Circuit Breaker Adjustments** _____ = _____

Net Circuit Breaker Condition Index

Evaluator: _____ Technical Review: _____

Management Review: _____ Copies to: _____

(Attach supporting documentation.)