

Circuit Breaker, Single Pressure Puffer 34 kV								
Component Classification Categories								
Criticality	I	X				DC, SS, TDC, TSS locations that serve O'Hare & Midway Airports		
	II		X			Locations exclusive of ESS 34 kV, DCs and Criticality I locations		
	III			X		DC locations		
	IV				X	ESS locations 34 kV		
Duty Cycle	Heavy Load	N/A	N/A	N/A	N/A			
	Normal Load	N/A	N/A	N/A	N/A			
Service Condition	In Service	X	X	X	X			
	Spare	N/A	N/A	N/A	N/A	X	Designated spare equipment*	
Condition Monitoring Tasks		Task Frequencies				Failure Codes	Comments	
Check Red (Closed) Indicating Lamp		5W	10W	3M	6M	N/A	2a-b	
Monitor Compressor Run Time		5W	10W	3M	6M	N/A	1f	Where meters Installed
Visual Inspection		5W	10W	3M	6M	10W	1e-f, 2e-f, 3a, 3g-h, 5a-c, 6a-d, 7b	
Thermography		1Y	1Y	1Y	1Y	N/A	4a-b	
Contact Resistance (Ductor) Test		6Y	6Y	6Y	6Y	N/A	1d, 4a	
Power Factor Test		6Y	6Y	6Y	N/A	N/A	3j, 5a-b, 5e-f	Only required on breakers with TRV capacitors
Travel Test		6Y	6Y	6Y	6Y	N/A	1a-f, 2a-f, 3c-h, 4c	
Time Directed Tasks		Task Frequencies				Failure Codes	Comments	
Drain Air Receiver Moisture		5W	10W	3M	6M	N/A	1f	
Compressor Maintenance		2Y	2Y	2Y	2Y	N/A	1f	Pneumatic mechanisms only
Exercise Mechanism		3Y	3Y	3Y	3Y	N/A	1a, 1e, 2a-c, 2d, 3c, 3g	
Pressurized Vessel Inspection		AR	AR	AR	AR	AR	6b-c	As Required at Illinois locations.
Relief Valve Test or Replacement		AR	AR	AR	AR	AR	6e	As Required at Illinois locations.
Mechanism Lubrication / Maintenance		6Y	6Y	6Y	6Y	N/A	1c, 2c, 3e	
SF <sub>6</sub> Moisture Test		6Y	6Y	6Y	6Y	N/A	3b, 5d	
Internal Inspection		AR	AR	AR	AR	N/A	1d-e, 2d-e, 3f-g, 3i, 5e	
Failure Finding Tasks		Task Frequencies				Failure Codes	Comments	
Check Control Cabinet Heaters		5W	10W	3M	6M	10W	1b, 1e-f, 2b, 2e, 3d, 3g, 7b-c	Applicable to spare breakers, if stored outdoors in substation yards.
Functional Alarm Test		6Y	6Y	6Y	6Y	N/A	7b-d	
Check of Gauges and Pressure Switches		6Y	6Y	6Y	6Y	N/A	3a, 7a	
Condition Directed Tasks		Task Frequencies				Failure Codes	Comments	
None		N/A	N/A	N/A	N/A	N/A		

\* Designated Spare Equipment that is covered by this PM program is defined as circuit breakers placed in long-term, outdoor storage in substation yards and designated for use as replacements for breakers in previously defined applications or positions. Examples of equipment excluded from this PM program are: breakers stored for ongoing or future projects or installations, breakers removed from service and retired on-site, and breakers stored temporarily to be re-delivered to other locations.

## SINGLE PRESSURE PUFFER BREAKER FAILURE MODES

FAILURE MODE	FAILURE CAUSES	MAINTENANCE TASKS
1. Fails to Close	1a. Close Coil Failure	Exercise Mechanism
1. Fails to Close	1a. Close Coil Failure	Travel Test
1. Fails to Close	1b. Control Circuit Failure	Check Control Cabinet Heaters
1. Fails to Close	1b. Control Circuit Failure	Travel Test
1. Fails to Close	1c. Lack of Lubrication	Mechanism Lubrication / Maintenance
1. Fails to Close	1c. Lack of Lubrication	Travel Test
1. Fails to Close	1d. Interrupter Failure	Contact Resistance (Ductor) Test
1. Fails to Close	1d. Interrupter Failure	Internal Inspection
1. Fails to Close	1d. Interrupter Failure	Travel Test
1. Fails to Close	1e. Mechanical/Linkage Failure	Check Control Cabinet Heaters
1. Fails to Close	1e. Mechanical/Linkage Failure	Exercise Mechanism
1. Fails to Close	1e. Mechanical/Linkage Failure	Internal Inspection
1. Fails to Close	1e. Mechanical/Linkage Failure	Travel Test
1. Fails to Close	1e. Mechanical/Linkage Failure	Visual Inspection
1. Fails to Close	1f. Stored Energy Failure	Check Control Cabinet Heaters
1. Fails to Close	1f. Stored Energy Failure	Compressor Maintenance
1. Fails to Close	1f. Stored Energy Failure	Drain Air Receiver Moisture
1. Fails to Close	1f. Stored Energy Failure	Monitor Compressor Run Time
1. Fails to Close	1f. Stored Energy Failure	Travel Test
1. Fails to Close	1f. Stored Energy Failure	Visual Inspection
2. Fails to Open	2a. Open Coil Failure	Check Red (Closed) Indicating Light
2. Fails to Open	2a. Open Coil Failure	Exercise Mechanism
2. Fails to Open	2a. Open Coil Failure	Travel Test
2. Fails to Open	2b. Control Circuit Failure	Check Control Cabinet Heaters
2. Fails to Open	2b. Control Circuit Failure	Check Red (Closed) Indicating Light
2. Fails to Open	2b. Control Circuit Failure	Exercise Mechanism
2. Fails to Open	2b. Control Circuit Failure	Travel Test
2. Fails to Open	2c. Lack of Lubrication	Exercise Mechanism
2. Fails to Open	2c. Lack of Lubrication	Mechanism Lubrication / Maintenance
2. Fails to Open	2c. Lack of Lubrication	Travel Test
2. Fails to Open	2d. Interrupter Failure	Internal Inspection
2. Fails to Open	2d. Interrupter Failure	Travel Test
2. Fails to Open	2e. Mechanical/Linkage Failure	Check Control Cabinet Heaters
2. Fails to Open	2e. Mechanical/Linkage Failure	Exercise Mechanism

## SINGLE PRESSURE PUFFER BREAKER FAILURE MODES

FAILURE MODE	FAILURE CAUSES	MAINTENANCE TASKS
2. Fails to Open	2e. Mechanical/Linkage Failure	Internal Inspection
2. Fails to Open	2e. Mechanical/Linkage Failure	Travel Test
2. Fails to Open	2e. Mechanical/Linkage Failure	Visual Inspection
2. Fails to Open	2f. Stored Energy Failure	Travel Test
2. Fails to Open	2f. Stored Energy Failure	Visual Inspection
3. Fails to Interrupt	3a. Loss of SF6 or SF6 Pressure	Check of Gauges and Pressure Switches
3. Fails to Interrupt	3a. Loss of SF6 or SF6 Pressure	Visual Inspection
3. Fails to Interrupt	3b. Poor SF6 Quality	SF6 Moisture Test
3. Fails to Interrupt	3c. Open Coil Failure	Travel Test
3. Fails to Interrupt	3c. Open Coil Failure	Exercise Mechanism
3. Fails to Interrupt	3d. Control Circuit Failure	Check Control Cabinet Heaters
3. Fails to Interrupt	3d. Control Circuit Failure	Travel Test
3. Fails to Interrupt	3e. Lack of Lubrication	Mechanism Lubrication / Maintenance
3. Fails to Interrupt	3e. Lack of Lubrication	Travel Test
3. Fails to Interrupt	3f. Interrupter Failure	Internal Inspection
3. Fails to Interrupt	3f. Interrupter Failure	Travel Test
3. Fails to Interrupt	3g. Mechanical/Linkage Failure	Check Control Cabinet Heaters
3. Fails to Interrupt	3g. Mechanical/Linkage Failure	Exercise Mechanism
3. Fails to Interrupt	3g. Mechanical/Linkage Failure	Internal Inspection
3. Fails to Interrupt	3g. Mechanical/Linkage Failure	Travel Test
3. Fails to Interrupt	3g. Mechanical/Linkage Failure	Visual Inspection
3. Fails to Interrupt	3h. Stored Energy Failure	Travel Test
3. Fails to Interrupt	3h. Stored Energy Failure	Visual Inspection
3. Fails to Interrupt	3i. Teflon Interrupter Nozzle Erosion	Internal Inspection
3. Fails to Interrupt	3j. Contact Grading Capacitor Failure	Power Factor Test
4. Fails to Provide Conduction Path	4a. Contacts High Resistance	Contact Resistance (Ductor) Test
4. Fails to Provide Conduction Path	4a. Contacts High Resistance	Thermography
4. Fails to Provide Conduction Path	4b. Bus Connections Failure	Thermography
4. Fails to Provide Conduction Path	4c. Interrupter Failure	Travel Test
5. Fails to Provide Adequate Insulation Level	5a. External Contamination	Power Factor Test
5. Fails to Provide Adequate Insulation Level	5a. External Contamination	Visual Inspection
5. Fails to Provide Adequate Insulation Level	5b. Cracked/Broken Bushing	Power Factor Test

## SINGLE PRESSURE PUFFER BREAKER FAILURE MODES

FAILURE MODE	FAILURE CAUSES	MAINTENANCE TASKS
5. Fails to Provide Adequate Insulation Level	5b. Cracked/Broken Bushing	Visual Inspection
5. Fails to Provide Adequate Insulation Level	5c. Loss of SF6 or SF6 Pressure	Visual Inspection
5. Fails to Provide Adequate Insulation Level	5d. Poor SF6 Quality	SF6 Moisture Test
5. Fails to Provide Adequate Insulation Level	5e. Electrical Tracking of Operating Rod	Internal Inspection
5. Fails to Provide Adequate Insulation Level	5e. Electrical Tracking of Operating Rod	Power Factor Test
5. Fails to Provide Adequate Insulation Level	5f. Failure of TRV Capacitor	Power Factor Test
6. Fails to Maintain Boundary Integrity	6a. Gasket Failure	Visual Inspection
6. Fails to Maintain Boundary Integrity	6b. Weld Failure	Pressurized Vessel Inspection
6. Fails to Maintain Boundary Integrity	6b. Weld Failure	Visual Inspection
6. Fails to Maintain Boundary Integrity	6c. Tank Corrosion	Pressurized Vessel Inspection
6. Fails to Maintain Boundary Integrity	6c. Tank Corrosion	Visual Inspection
6. Fails to Maintain Boundary Integrity	6d. Loose Connections	Visual Inspection
6. Fails to Maintain Boundary Integrity	6e. Pressure Relief Valve Failure	Relief Valve Test or Replacement
7. Fails to Alarm	7a. Gauge / Pressure Switch Failure	Check of Gauges and Pressure Switches
7. Fails to Alarm	7b. Control Circuit Failure	Check Control Cabinet Heaters
7. Fails to Alarm	7b. Control Circuit Failure	Functional Alarm Test
7. Fails to Alarm	7b. Control Circuit Failure	Visual Inspection
7. Fails to Alarm	7c. Aux Relay Failure	Check Control Cabinet Heaters
7. Fails to Alarm	7c. Aux Relay Failure	Functional Alarm Test
7. Fails to Alarm	7d. Scada Failure	Functional Alarm Test

## SINGLE PRESSURE PUFFER BREAKER MAINTENANCE TASK DEFINITION

TASK	DEFINITION
Check Control Cabinet Heaters	Visual / physical verification that cabinet heaters are operational
Check of Gauges and Pressure Switches	Perform functional test of pressure switch pick up and drop out using the pressure gauge in the breaker control cabinet. Perform an external inspection, to include as applicable, testing of gas and/or air system low pressure alarms and trips.
Check Red (Closed) Indicating Lamp	Verify red indicating lamp is lit on all closed breakers to ensure trip circuit continuity and control fuses.
Compressor Maintenance	Change compressor oil, replace air filter, check condition of belt and if needed replace, check alignment of motor and pulley. Drain air receiver down to verify compressor pick up and shut down. Measure and record time required for compressor to go from low limit to shut off.
Contact Resistance (Ductor) Test	Apply DC current (100 Amps DC) between terminals of equipment under test to measure current path resistance. Contact resistance testing is done prior to performing maintenance and after completion of maintenance. The as-found and as-left resistance values are used to verify maintenance effectiveness.
Drain Air Receiver Moisture	Purge condensed moisture from air compressor tank unless ambient temperature is below 40 deg F.
Exercise Mechanism	Open and close breaker electrically.
Functional Alarm Test	Verify alarm at breaker is sent to the substation control house and system operations. Test should be performed by bringing up an alarm at the equipment and verifying it is received in the substation control house and system operations.
Internal Inspection	<p>Interrupting chamber inspection and refurbishment of contact and interrupting assemblies. Replacement of components, as required. Scope includes:</p> <ul style="list-style-type: none"> <li>-- Measure contact resistance across bushing terminals</li> <li>-- Measure contact engagement by performing a slow-close operation</li> <li>-- Measure resistance of voltage dividing resistors</li> <li>-- Check oil dashpots, over-travel stop clearances, pole unit lever system settings</li> <li>-- Check for loose or worn components</li> <li>-- Check for implementation of modifications based on OEM advisories</li> </ul> <p>Recommended spare parts should be obtained prior to inspections.</p>

## SINGLE PRESSURE PUFFER BREAKER MAINTENANCE TASK DEFINITION

TASK	DEFINITION
Mechanism Lubrication / Maintenance	Off-line detailed inspection of the operating mechanism. Checks include: -- Operate breaker from local and remote control -- Trip from manual trip device and check electrical interlocks -- Check solenoids, limit switches, dash pots, position indicators and counter for proper operation -- Verify all clearance dimensions (stops, latches, rollers, switches and links) -- Check wiring terminal blocks for tightness -- Rebuild pilot valve using available rebuild kit. Replace if required. -- Check closing control and pilot valves for leaks -- Check for leaks in the operator -- Wipe and clean accessible linkages and wear points -- Apply approved lubricants to bearings and other specified areas on mechanism, including linkage wear points. Lubrication should not be added to sealed bearings. -- For 345kV Siemens 3AT2 Models only: Replace heat sink compound on the heat sink assembly per applicable Technical or Manufacturer bulletin
Monitor Compressor Run Time	If meter installed, observe and record cumulative air compressor or hydraulic motor run time hours / starts.
Power Factor Test	Electrical loss measurement, usually performed using Doble power factor equipment, which helps to prove the insulating level of the device.
SF <sub>6</sub> Moisture Test	A measurement of the moisture level in the SF <sub>6</sub> Gas.
Thermography	Infrared inspection of electrical equipment and power path components to identify any hot spots that may exist either in the contacts, bus connections or within control cabinets. Comparisons should be made phase to phase or on tank walls to determine if contact heating can be found or to determine oil levels within all tanks and verify level gauge.
Pressurized Vessel Inspection	Periodic inspection and re-certification of operating pressure vessels, conducted by the State certified inspector at most substations or IEMA at nuclear sites in Illinois.
Relief Valve Test or Replacement	Test or replace relief valve for breakers in nuclear switchyards in Illinois.
Travel Test	Measure and record the speed, timing, contact velocity and acceleration, contact penetration, contact rebound and sequence of operation during open, close and trip-free operations.

## SINGLE PRESSURE PUFFER BREAKER MAINTENANCE TASK DEFINITION

TASK	DEFINITION
Visual Inspection	<p>Visual assessment of the condition of the equipment. Items to check include:</p> <ul style="list-style-type: none"> <li>-- Check mech operating pressures are within specification</li> <li>-- Listen for air leakage or excessive compressor run time</li> <li>-- Verify mechanical position indicator for correct position and check/record operations counter</li> <li>-- Check mechanism cabinet for general cleanliness, evidence of moisture and signs of wildlife or insect infestation</li> <li>-- Check for signs of loose or worn parts in mechanism</li> <li>-- Check compressor oil level</li> <li>-- Check compressor belts for wear, tension and alignment</li> <li>-- Check cabinet door for degradation of the door seal and for proper operation of the door latch. Check interior components, wiring terminals and fuse holders for rust or corrosion.</li> <li>-- Check for proper grounding on breaker tank(s) and control cabinet(s)</li> <li>-- Ensure alarm cutouts are in proper configuration</li> <li>-- Check closing and trip solenoid coils for evidence of heating. Check closing contactors for cleanliness and heating or burning of contacts.</li> <li>-- Check for fluid leaks on hydraulic mechanisms</li> <li>-- Check SF<sub>6</sub> Pressure / Temp / Density</li> <li>-- Check mechanism springs charged</li> </ul>

# SINGLE PRESSURE PUFFER BREAKER MAINTENANCE BASIS

## Single Pressure Puffer Breaker Template Summary

The Preventive Maintenance program is documented via maintenance templates. Templates have been developed that address transmission, substation, and distribution equipment that is owned and maintained by Exelon Utilities. Each template documents the program tasks, frequencies, failure modes, and maintenance basis for the associated equipment. Tasks and associated frequencies are designed to address known failure modes of the equipment covered by the template. In general, the tasks included in the maintenance templates are the result of good industry practices, industry experience, and manufacturer recommendations.

### References:

Standard 62 IEEE Guide for Diagnostic Field Testing of Electric Power Apparatus

Internal reports and operating experience

OEM Maintenance Manuals and Interviews

EPRI 1001779 Guidelines for the Life Extension of Substations

Nuclear Electric Insurance Limited (NEIL) Loss Control Manual - January 2018 Edition

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### Boundary Definition

The boundary of the breaker (live tank and dead tank) for the purpose of this document is defined to include:

- Live parts and bushings
- Drive mechanism
- Compressor
- Control cabinet
- CT's
- Grading Capacitors
- TRV Capacitors

Excluded from this treatment are: protective relays, DC supply, AC supply

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### Failure Experience

Failures are subject to ACE/RCI investigation. Findings/recommended corrective actions are incorporated into the template as required.

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### Vendor Recommendations

# SINGLE PRESSURE PUFFER BREAKER MAINTENANCE BASIS

OEM manuals were referenced and interviews conducted during the development of this template.

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## Disposition of Vendor Recommendations

Recommendations were incorporated into the template as appropriate based on operating experience.

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## Basis For Template Tasks

**Check Control Cabinet Heaters:** Continuous heater operation mitigates corrosion of components in the control cabinet.

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**Check of Gauges and Pressure Switches:** Perform functional test as a tool for identifying problems with the various controls and indicators.

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**Check Red (Closed) Indicating Lamp:** The red light is in series with the trip coil and when lit, indicates integrity of the trip circuit.

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**Compressor Maintenance:** Routine maintenance of the compressor will ensure extended life of the machine. Failure of the compressor may adversely affect the pressure reduction fill valve when called upon to operate excessively.

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**Contact Resistance (Ductor) Test:** Performed bushing terminal to bushing terminal. Measures increased resistance along the current conduction path. Used to diagnose, or determine, problems internal to the breaker that would require an inspection.

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**Drain Air Receiver Moisture:** This task serves the dual purpose of maintaining dry air supply to the breaker air system as well as reducing internal corrosion of the air receiver tank walls.

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**Exercise Mechanism:** This redistributes the lubricants in bearings and on other surfaces and prevents bearing set at pressure points.

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**Functional Alarm Test:** Intent of this task is to verify that any alarm initiated by a device or sensor at the equipment results in a notification at the control building and/or at the control / operations center. Timely and appropriate response to abnormal equipment conditions is contingent on proper operation of the alarm systems.

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# SINGLE PRESSURE PUFFER BREAKER MAINTENANCE BASIS

**Internal Inspection:** This task is intended to identify internal problems that may be developing and not identified through diagnostic testing.

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**Mechanism Lubrication / Maintenance:** The mechanism of a circuit breaker is composed of multiple bearing and sliding surfaces that require periodic re-lubrication due to minimum movement of parts during breaker operation. CIGRE studies have concluded that the dominant failure mode of older style breakers is mechanism failure.

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**Monitor Compressor Run Time:** Applicable where run-time meters are installed. Run-time monitoring will enable early detection and proactive repair of air system leaks.

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**Power Factor Test:** Power Factor test provides indication of insulation degradation and, in some instances, component failure. Scope of test should include entrance bushings, grading capacitors, resistors, support columns and operating rods, and current transformer. For breakers with grading capacitors or TRV capacitors, limit scope of test to measure the capacitance of the capacitors. The test is best applied as a trending tool.

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**Pressurized Vessel Inspection:** Periodic inspection and re-certification of operating pressure vessels is required by state code.

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**Relief Valve Test or Replacement:** Testing of the relief valve is required on breakers in nuclear switchyards in Illinois. It has been determined that it is more cost effective and less risky to replace the in-service valve with an ASME VIII pre-tested valve. Note: ASME VIII code stamped relief valves are pre-tested by the valve supplier.

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**SF<sub>6</sub> Moisture Test:** Verifies proper operation of SF<sub>6</sub> desiccant systems. Gas moisture readings below manufacturer recommended limits are required to maintain adequate dielectric insulation levels.

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**Thermography:** IEEE Standard 62 identifies thermography as a primary tool for detection of connection issues, bushing issues, and issues with the cooling systems.

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## SINGLE PRESSURE PUFFER BREAKER MAINTENANCE BASIS

**Travel Test:** Circuit breaker timing and travel test measures the speed and acceleration of breaker movable parts during open, close and trip-free operations. The test addresses failure modes associated with excessive unlatching friction, mechanism binding or contact friction, inadequate lubrication, improper spring adjustments, improper stop adjustments, worn contacts, malfunctioning shock absorbers or dashpots, excessive rebound or improper velocity through the arcing zone of operation.

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**Visual Inspection:** This inspection approximates real-time condition monitoring that can detect developing problems and degradation, and provides condition data used to initiate corrective actions.

## SINGLE PRESSURE PUFFER BREAKER TEMPLATE DEVELOPMENT HISTORY

<b>Revision 0</b>		<b>Date 06/23/2015</b>
Writer	Chris Stefanski (Exelon Utilities)	
Reviewer(s)	Ken Wendt, Greg Hitzke, Tu Liang	
Approver(s)	Michael Moy (UFAM ComEd)	
Reason Written	Created to document the ComEd maintenance program tasks, frequencies, failure modes, and maintenance basis.	

<b>Revision 1</b>		<b>Date 11/30/2016</b>
Writer	Hugo Castaneda (Material Condition)	
Reviewer(s)	Greg Hitzke, Tu Liang, Dale Player, Nitin Patel	
Approver(s)	Michael Moy (UFAM ComEd)	
Reason Written	Revisions resulting from EU Substation Breaker Process Assessment/Productivity initiative. Revised Power Factor Test maintenance basis to limit scope of test to only capacitors for breakers with external capacitors. Revised SF6 Moisture Test task definition to clarify.	

<b>Revision 2</b>		<b>Date 05/31/2019</b>
Writer	Hugo Castaneda (Material Condition)	
Reviewer(s)	Suneetha Parupalli, Manager Material Condition (ComEd); Tu Liang, Senior Engineer (ComEd); Greg Hitzke, Principal Engineer (ComEd); Tony O'Connor (Sr Engineer, T&S Engineering Standards & Applications); Betsy Spolarich (Prin Work Plan Coordinator, ComEd T&S Equipment Stds), Terrence Myelle (Byron Strategic Elec Eng Branch Manager), Joe Haluska (Quad Cities Eng Manager), Adam Kambic (Braidwood Strategic Engineering Branch Manager), Joseph Welch (Dresden Engineering Manager), Ismael Rivera Jr (Dresden Sr Staff Engineer), Aaron Kulow (Exelon Corporate Switchyard Engineer)	
Approver(s)	Michael Moy (UFAM ComEd)	
Reason Written	Revised maintenance tasks to reflect recent NEIL Standard requirements (2018): Modified NEIL comments for SF6 moisture test and pressure Gauges / Pressure Switches tasks. Modified Lubrication / Maintenance task definition to replace heat sink compound on 345kV Siemens 3AT2 breakers.	