OPERATIONS BULLETINS INDEX

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Unitil

Operations Bulletin OP2.00

SUBJECT: Transmission Inspections
EFFECTIVE: 12/1/00

ISSUED BY: G. Appleton
CONTENT TEAM: C. Dube, D. Nudd, G. Appleton

1.0 PURPOSE

- To provide a uniform method for maintaining and inspecting overhead transmission lines within the Unitil system
- To ensure compliance with applicable state requirements
- To ensure the integrity of the poles and equipment
- To ensure the safe operation of the transmission system
- To establish requirements for record keeping and performance measures

2.0 SCOPE

These maintenance guidelines apply to transmission systems with a primary voltage up to 69 kV.

3.0 MAINTENANCE – FREQUENCY AND CATEGORY SUMMARY

Semi-Annual Inspection – A visual patrol from the ground and/or air to be performed twice annually.

Annual Inspection –Visual Inspection of steel towers to be performed annually.

Three-Year Inspection – Infrared inspection for hot connections to be performed every three years.

Five-Year Inspection – Clearances to be measured every five years at designated locations as required by state regulation.

FG&E204

Ten-Year Test – After a pole has been in the ground for twenty years it will be tested every ten years.

4.0 FREQUENCY AND CATEGORY DESCRIPTIONS

4.10 Semi-Annual Inspection

A visual observation of exposed components of transmission lines, their supporting structures and the condition of the right of way shall be made at least twice a calendar year.

1. Inspections by foot or vehicle are preferred. At least one semi annual inspection must be made in this manner, preferably in the spring. The foot patrol should consist of a visual inspection of the pole, insulators, and all the hardware, conductor clearances, sag, tree trimming and clearing in and along the Right Of Way, ease of access for vehicles during emergencies and any infringements on the Right Of Way.
2. An aerial patrol may be performed in lieu of one foot patrol, if deemed appropriate, preferably in the fall to primarily check for broken insulators and cross-arm rot. The aerial patrol may also be done every three years in conjunction with the infrared inspection.

4.20 Annual Inspection

Inspection of steel towers for signs of deterioration such as rusting, the deterioration of foundations, or the need for painting, shall be performed annually.

4.30 Three-Year Inspection

Infrared inspections for hot connections (resistance testing) shall be done every three years for existing lines. The infrared inspections can be combined and done in conjunction with the aerial patrol.

4.40 Five-Year Inspection

Per CMR 220.125, vertical clearances for 69 Kv lines in Massachusetts shall be measured at all crossings over water and limited access highways, permits for which were granted with designated clearances.

4.50 Ten-Year Test

Wood pole testing in the vicinity of the ground level shall be made to determine the soundness of the wood within twenty (20) years after installation and within ten-year intervals thereafter.

5.0 OTHER CONSIDERATIONS

5.10 Air break and In-Line switches

Air break and in-line switches shall be periodically lubricated with an approved lubrication to ensure smooth operation when called upon. Any switch, which has not been operated within a 12-month period, shall be lubricated whenever the site is visited.

5.20 Resistance testing of new lines

- For new lines and extension at 34.5 Kv, infrared inspections shall be done 6 months after the in-service date.
- For new lines and extensions at 69 Kv, infrared inspections shall be done 6 months, 18 months and 36 months after the in-service date. The infrared inspections can be combined and done in conjunction with the aerial patrol.

5.30 Inspection following Transmission Line Relay Operation

When the cause is not apparent, and as soon as practical, a line inspection shall be conducted following any line relay operation(s) to determine the cause and if necessary, to schedule appropriate repairs.

6.0 RECORD KEEPING

The results of all cycle inspections and tests and corrective action taken shall be recorded, and retained for a period of six (6) years. Appropriate measures shall be taken on a timely schedule to correct any defects and/or deficiencies found on test or inspections. Inspection forms shall identify all poles/towers visited. All non compliant findings shall be noted indicating corrective action to be taken and close out date (i.e., when corrective action was completed)

6.10 Forms

Forms to be used for inspection and record keeping purposes are included as Attachments A, B, C, & D.

6.1 PERFORMANCE MEASURES

6.11 Overview

Performance measures are intended to provide the means to monitor performance with respect to this guideline and to assess effectiveness. The metrics used for Transmission Inspections shall be:

- **Cycle Inspection Cost / Mile**
- **Pole Test Cost / Pole**

The following accounts shall be utilized for budgeting and tracking related costs and provide the data source for the performance metrics, above.

A	563.01	Trans Oper Patrol Lines	Cycle inspection costs
B	563.02	Trans Oper Pole Tests	10 year pole test costs
C	571.01	Trans Maint Unsched	Maint repairs due to trouble
D	571.02	Trans Maint Scheduled	Maint repairs due to cycle Inspections

6.12 Reporting

Metrics shall be reported quarterly
By January 1 of each year planned cycle inspection and pole testing work for the year shall be specified:

- **Semi-Annual**

  Inspection 1: X miles of line
  Inspection 2: X miles of line
  Total miles to be inspected = 2X = **Y**

- **Infrared Inspection** Planned or Unplanned
  (3 Year Cycle)

- **Clearance Inspection** Planned or Unplanned
  (5 Year Cycle)

- **Ten Year Test**

  Number of poles to be tested = **Z**

6.13 Metric Calculations

Cycle Inspection Cost/Mile (Quantities are January to date)

A = _____
Y = _____

Cycle Inspection Metric = A / Y

Pole Test Cost/Pole (Quantities are January to date)

B = _____
Z = _____

Pole Test Metric = B / Z

UNITIL TRANSMISSION LINE INSPECTION REPORT

Semi-Annual Inspection A visual patrol from the ground and/or air to be performed twice annually							
Line #:		**From - Substation:**		To – Substation:			
Patrol Date:		**Patrolled By:**		**Page**		**of**	

Place a check in the appropriate column if there is a substandard condition, **A-U**, the item. Make a brief note in the "Comments" column describing the problem(s).

	Structure #																
A	Conductors																
B	Pole Condition																
C	X-Arms																
D	X-Arm Braces																
E	Insulators																
F	Lighting Arrestors																
G	Ties/Armor Rodding																
H	Clamps/Connectors																
I	Taps																
J	Pole Ground																
K	Guy(s)																
L	Anchor(s)																
M	Guy Markers/Shields																
N	Other Hardware																
O	Anti-Climbing Barriers																
P	Warning Signs																
Q	Climbing Steps																
R	Tree Clearance																
S	Danger Trees/Deadwood																
T	ROW Condition																
U	Other																
Z	**ALL OK**																
COMMENTS	Reference to this form on each repair order. (T-line #, date, page & structure #)																

UNITIL TRANSMISSION STEEL TOWER INSPECTION REPORT

Annual Inspection A visual inspection of steel towers to be performed annually							
Line #:		**From - Substation:**		**To – Substation:**			
Date:		**Inspected By:**		**Page**		**of**	

Place a check in the appropriate column if there is a substandard condition, **A-U**, the item. Make a note in the "Comments" column describing the problem(s).

	Tower #						
A	Foundation Condition						
B	Insulators						
C	Lighting Arrestors						
D	Clamps/Connectors						
E	Grounds						
F	Other Hardware						
G	Anti-Climbing Barriers						
H	Warning Signs						
I	Climbing Steps						
J	Paint						
U	Other						
Z	**ALL OK**						
COMMENTS	Reference to this form on each repair order. (Tower #, date, page)						

UNITIL TRANSMISSION LINE INFRARED INSPECTION REPORT

Three-Year Inspection Infrared inspection for hot connections to be performed every three years.							
Line #:		**From - Substation:**		**To – Substation:**			
Date:		**Inspected By:**		**Page**		**of**	

Individual Infrared inspection reports will be required for each problem, which will include the following information:

- Company name, Reference number, Line number, Equipment, and Component;
- Photographs of the problem area as viewed by the infrared camera, and as viewed by a normal camera;
- Time, Date and Ambient temperatures in degrees C;
- Other significant factors and Repair action.

The action is based on the following criteria:

CRITICAL	Above 70C (158F)	Failure is imminent. Shut down & repair as soon as possible.
SERIOUS	40 – 60C (87 – 158F)	Failure is certain. Repair as soon as shutdown can be scheduled.
MODERATE	21 – 40C (51 – 86F)	Failure probable. Repair within 30 days.
ADVISORY	1 – 10C (34 – 50F)	Monitor and repair during next preventive maintenance shutdown.

Summary Listing of Infrared Inspection Reports	
Reference Number	**Repair Schedule**

UNITIL TRANSMISSION POLE TESTING REPORT

Ten-Year Pole Test After a pole has been in the ground for twenty years it will be tested every ten years.							
Line #:		**From - Substation:**		**To – Substation:**			
Date:		**By:**			**Page**		**of**

Pole #	Year Set	Height / Class	Type of Treatment	Original G / L	Effect G / L	Type of Test	Remarks and Notes

FG&E212

Unitil

Operations Bulletin OP3.00

SUBJECT: Substation Inspection, Test, & Maintenance
EFFECTIVE: 11/1/00

ISSUED BY: G. Appleton
CONTENT BY: S. Baker, T.Biklen, M Deschambeault, P.Stagno, A. Zogopoulos, R. Bisson

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1.0 PURPOSE

- To provide a uniform method for maintaining and inspecting substations within the Unitil system
- To ensure the integrity of the equipment
- To ensure the safe operation of the system
- To establish requirements for record keeping and performance measures

2.0 SCOPE

These maintenance guidelines apply to substations with a primary voltage up to 69 kV.

3.0 GENERAL INFORMATION

These guidelines fall into two general categories –Substation Inspections and Maintenance/Test. The following Bulletins are issued separately but collectively serve to provide a complete set of documents to effectively cover the subject of Substation Inspection Test and Maintenance:

Substation Inspections:
3A.14 Monthly Substation V&O
3A.15 Annual Substation V&O

Maintenance/Test
3.01 Transformers
3.02 Interrupting Devices

FG&E213

3.03 Tap Changers and Regulators
3.04
3.05 Isolating Devices
3.06 SCADA
3.07 Relays
3.08 Infrared Survey
3.09 Capacitors
3.10
3.11
3.12 Batteries

4.0 PERFORMANCE MEASURES

4.10 Overview

Performance measures are intended to provide the means to monitor performance with respect to this guideline and to assess effectiveness. The metrics used for Substation Maintenance shall be:

- Projected units scheduled for maintenance vs actual units maintained (month by month)
- Projected $'s spent for scheduled maintenance vs actual $'s spent for scheduled maintenance (month by month)
- Projected man-hours required for scheduled maintenance vs actual man-hours expended (month by month)

4.20 Reporting

Metrics shall be reported on a quarterly basis.

4.10 Metric Calculations

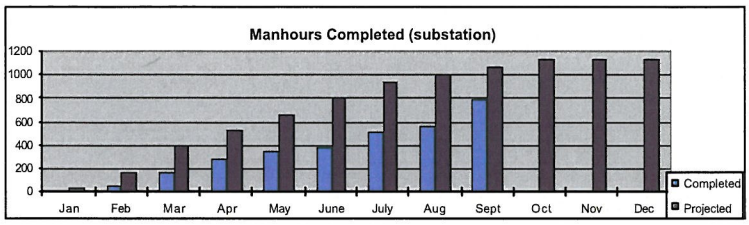
The measures shall be done in a chart format as shown below.

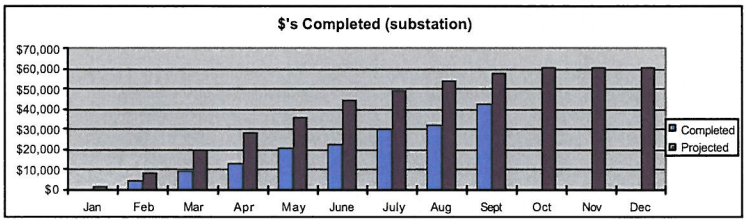
Substation Maintenance for Year XXXX

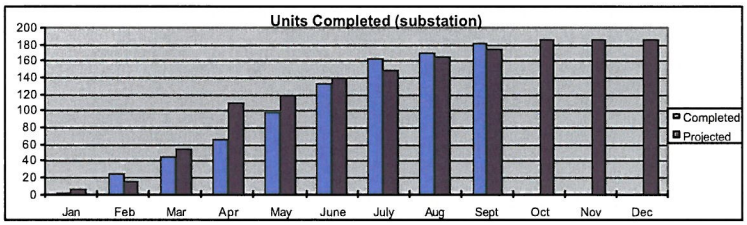
(Until Distribution Company XYZ - Scheduled)

Manhours (substation)		Units (substation)	
Manhours Completed (substation	779.5	Units Completed (substation)	181
Total Manhours	1125	Total Units	185
% Complete	69.29%	% Complete	97.84%

$'s (substation)	
$'s Completed (substation)	$42,780
Total $'s	$61,100
% Complete	70.02%







Unitil

Operations Bulletin #OP3.01

SUBJECT: Substation Transformers
EFFECTIVE: 11/1/00

ISSUED BY: G. Appleton
CONTENT BY: S. Baker, T.Biklen, M Deschambeault, P.Stagno, A. Zogopoulos, R. Bisson

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1.0 PURPOSE

- To provide a uniform method for inspecting, maintaining and testing substation transformers within the Unitil system
- To ensure the integrity of the equipment
- To ensure the safe operation of the system
- To establish requirements for record keeping and performance measures to identify problems and analyze trends.

2.0 SCOPE

These maintenance guidelines apply to substation transformers with a primary voltage up to 115 kV. Where oil needs to be handled or processed consult Engineering for additional instructions.

3.0 MAINTENANCE/TEST CATEGORY and FREQUENCY

3.10 Monthly Maintenance - Routine inspections and readings to be performed monthly.

3.20 Annual Maintenance - Extensive inspections and testing to be performed annually.

3.30 De-energized Maintenance - Inspection and testing that is not critical for continued operation and can wait until a convenient time when the transformer can be de-energized. Refer to Testing Procedures

3.40 Optional Tests - Additional tests and inspections useful in identifying problem conditions. Refer to Testing Procedures

3.50 New Transformer Tests - Testing and inspection of a new transformer when it arrives, after installation, and during the warranty period. Refer to Engineering Acceptance Procedures

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4.0 MONTHLY MAINTENANCE

The purpose of monthly maintenance is to make sure the transformer is operating within its design limits, tabulate gauge readings, and inspect for damage or leaks. Gauge values should be recorded, not just looked at, to see if they are out of limits. Limits should be set for gauge readings where practical.

1. Pressure - A value should be recorded. This is to ensure that the transformer stays within the design limits and that its seal is intact. Pressure should typically range from zero to five pounds. Several readings of zero could indicate a lost seal and should be checked.
2. Nitrogen supply - Record pressure to determine when nitrogen tank will need replacement. Compare with previous readings to determine trending which can be an early indicator of a leak requiring attention.
3. Oil Level - Verify the oil level is correct for the existing oil temperature and record ambient temperature.
4. Oil Temperature - A value should be recorded. Verify consistency with previous readings and loading conditions.
5. Oil Temperature, Drag Hand (Max.) - Verify consistency with previous readings and within the transformer's safe loading limits. Record the value and reset draghand where accessible.
6. Winding Temperature - Record the value and compare with previous readings based on loading conditions.
7. Winding Temperature, Drag Hand (Max.) - Record value and reset. Verify that it is consistent with previous readings and transformer safe loading limits.
8. Check the condition of all gauges for physical damage, moisture in the glass. Make sure the values are changing monthly to ensure that the needle is not stuck.
9. Check the level of any oil filled bushing.
10. Check the bushings for contamination and physical damage.
11. If the transformer has fans/oil pumps - Are they running? If they are not running, run them on manual for a short period to ensure they are operable.
12. Inspect transformer for leaks, rust and other physical damage. Report any abnormal condition

5.0 ANNUAL MAINTENANCE

The purpose of annual maintenance is to do a thorough inspection and testing of all critical equipment that can be done while the transformer is energized. This should include a review of data since the last annual maintenance to look for trends or potential problems.

1. Pressure - Check the condition of the gauge. Do the monthly maintenance values show any potential problems like stuck gauge or negative values or zero pressure?
2. Oil Level - Check the condition of the gauge. Do the monthly maintenance values show any potential problems like running below what would be expected or the needle not moving?
3. Oil Temperature - Again, check the condition of the gauge and review the minor maintenance logs to see if the temperature was as anticipated for the load it was carrying.
4. Oil Flow - Check for oil flow (flow gauge) with oil pump running.
5. Winding Temperature - Check the condition of the gauge. Do the monthly maintenance values show any potential problems like a stuck gauge?
6. Bushing and Arrestor Inspection - Perform a close visual inspection of all bushings to ensure no cracks, chips or leaks.
7. Fans /Oil Pumps- Test and inspect all fans/oil pumps to ensure that they will operate automatically when the transformer heats up.
8. Physical Inspection - Thoroughly inspect the entire transformer for leaks, gasket problems, pressure relief system, rust, damages, cooling fans, and visually or with infrared inspection equipment inspect leads and termination's for overheating and tightness.
9. Oil and Gas Testing - Take oil samples to have both the oil and the gases in the oil tested in accordance with ASTM Testing Standards. The oil testing should include color, visual, IFT, neutrality, dielectric and moisture content. The gas test should include parts per million of hydrogen, oxygen, nitrogen, methane, carbon monoxide, ethane, carbon dioxide, ethylene, acetylene, total gas content and total combustible gas content.

6.0 DE-ENERGIZED MAINTENANCE

The purpose of de-energized maintenance is to perform more extensive inspection and testing of the transformer beyond major maintenance. These items should be performed when the unit is taken out of service. Refer to Unitil Test Procedures.

1. Transformer-Turns Ratio (TTR) Test - Test and record ratios for all phases on all taps.
2. Megger Test - Test high to low, high to ground, and low to ground with a 1000V megger and record the values. Also test core ground when accessible.
3. Leads - Check all connections for tightness and closely inspect for overheating and mechanical stress
4. Oil / Gas analysis
5. Pressure Relief device

7.0 OPTIONAL TESTS

The following testing and inspections are optional. They should be performed (along with the De-energized Maintenance procedures) whenever problems are indicated in the transformer. Refer to Unitil Testing Procedures.

1. Visual Inspection - Open the transformer to visually inspect the top of the transformer windings and the internal leads. Purge and cover with nitrogen blanket when complete.
2. Power Factor - Perform Doble tests at 10kV to help pinpoint possible problems within the transformer (winding, oil, and bushing where applicable).
3. Excitation - By Doble test method to determine if the windings or magnetic geometry has shifted or changed since the previous tests.
4. Winding resistance measurements to determine if there has been any change in the resistance of windings, no load tap changers or connections.

8.0 NEW TRANSFORMER TESTS

Testing of a new transformer is to be performed during the warranty period to verify it will operate as guaranteed.

1. Visual - A very extensive visual inspection should be performed when the transformer is received to verify no damage in transit and that no leaks have developed.
2. Electrical - Verify and test, where possible, all electrical control, monitoring and alarm circuitry.
3. Gauges - Inspect and test, where possible, all gauges.
4. Oil and Gas - Take oil samples of the transformer before energizing and have analyzed for basic oil test, PCB content and combustible gas analysis. A second test should be taken for gas analysis one week after energizing. Optional follow-up test at one month, then four months for gas testing depending on initial results and size of unit. A final test should be taken one month before the end of the warranty period.
5. Perform all de-energized maintenance and optional tests including the above
6. Refer to Engineering Acceptance Test Recommendations

9.0 TRANSFORMER OIL HANDLING

Oil shall always be pumped through a filter whenever it will be reused in equipment. Special attention shall be given to keeping the filter and transfer hoses free of moisture and other contaminants.

Transfer pumps should be used only on oil which will be discarded.

Storage containers, (drums or tankers) shall be clean and dry. Tankers shall be steam cleaned and hand wiped dry.

Ground all equipment involved, filter press, piping, equipment tank, bushings, winding leads, etc., and leave the grounds attached for at least one hour after all work has been completed.

Oil tests, dielectric & PCB, shall be performed every time the oil is passed from one party to the next to identify the responsible party in the event that the oil should become contaminated in the process of loading, unloading or processing. Large transformer oil quantities range from 3,000 to 10,000 gallons and therefore can represent a substantial cost to decontaminate the oil.

Due to weight considerations, large transformers are shipped / moved without oil and therefore require special procedures to control and verify the moisture in the oil and the winding insulation. Dry nitrogen / dry compressed air shall be placed in the transformer and maintained at a positive pressure of 3 psi. Whenever dew point measurements will be made to determine transformer dryness, the internal atmosphere must be stable. If pressure is changed by the addition of dry nitrogen or dry compressed air, the unit shall rest for 24 hours to stabilize the internal atmosphere prior to taking a dew point.

For transformers rated 69000 volts and greater, extra caution must be used to maintain the dryness of the oil and conductor insulation system. Vacuum dehydration oil handling equipment shall be used to dry and fill the transformer with oil. The transformer shall be sealed and subjected to a vacuum of 4 microns for 12 hours + 1 hr. for every 2 hrs. that the transformer has been opened (with compressed dry air continuously injected). If transformer dryness is questionable, break the vacuum with oil, pressurize with dry nitrogen or air, let set for 24 hrs., then perform a dew point test. If the dew point is unsatisfactory, the core and coils may be warmed using hot oil to enhance vaporization of the remaining moisture and then subjecting the transformer to another period of vacuum. The cycle of flashing with hot oil and vacuum shall be repeated until the transformer is satisfactorily dried. No one shall be allowed to walk on or bump the transformer while it is under vacuum; as this could cause mechanical failure (collapse) of the case. When satisfied that the unit is dry, break the vacuum and fill with dehydrated oil.

Transformers shall rest a minimum of 24 hours to let all the bubbles work out of the oil prior to energizing. If the transformer has been stored without oil then the transformer should remain at rest for 48 - 72 hours to allow the oil to re-impregnate the insulation system. Note, the force of gravity causes the oil to drain out of the insulation system with time, re-impregnating the insulation system with oil (a slow process) necessitates a longer rest time. During the rest time, units with oil pumps should be operated in 2 hour cycles, 2 hours on, 2 hours off, etc. while the unit is resting. The circulation of the oil will assist in moving air bubbles to the headspace at the top of the transformer.

Unitil

Operations Bulletin #OP3.02

SUBJECT: Substation Interrupting Devices
EFFECTIVE: 08/01/06
SUPERSEDES: 11/1/00

ISSUED BY: R. Letourneau
CONTENT BY: S. Baker, T.Biklen, M Deschambeault, P.Stagno, A. Zogopoulos, R. Bisson, J. Goudreault

1.0 PURPOSE

- To provide a uniform method for inspecting, maintaining and testing substation current Interrupting Devices such as circuit breakers, circuit switchers, sectionalizers and reclosers within the Unitil system
- To ensure the integrity of the equipment
- To ensure the safe operation of the system
- To insure proper operation of the interrupting device for de-energizing and energizing electrical lines, circuits and equipment during normal and abnormal system conditions
- To establish requirements for record keeping and performance measures to identify problems and analyze trends.

2.0 SCOPE

This maintenance/test policy is for current interrupting devices rated from 2.4 - 115kV utilizing air, vacuum, SF-6 gas or oil for an insulation medium. The continuous current and short circuit interrupting ratings vary according to system characteristics at the point of application.

3.0 MAINTENANCE/TEST CATEGORY AND FREQUENCY

SCHEDULED MAINTENANCE INTERVALS

	Maintenance Intervals			Oil Analysis Intervals (Note 5)	
	Monthly # Months	Annual # Years	Major # Years (Note 4)	# Years	Fault # Operations
115 kV oil, breaker	1	1	6 Note 1	2	15
69 kV oil, breaker	1	1	6 Note 1	2	20
34.5 kV oil, breaker	1	1	6	2	30
34.5 kV oil, recloser	1	1	6	2	30
34.5 kV vac. in oil, recloser	1	1	6	2	Not specified
Air breaker	1	1	1		8
4 & 15 kV oil, breaker, recloser, or sectionalizer	1	1	6	2	30
4 & 15 kV vacuum, breaker, recloser or sectionalizer	1	1	6	N/A	Not specified
SF-6 Gas breaker, recloser, sectionalizer or circuit switcher	1	1	6	N/A	Not specified
4, 15 & 34.5 kV single phase distribution recloser (Note 3)	1	N/A	10	N/A	120

NOTES:

1) This interval is also dependent upon oil characteristics. The critical characteristic is dielectric breakdown voltage. Minimum acceptable dielectric breakdown voltage for 69 and 115 kV class is provided within the oil sample section of Annual Maintenance.

2) There may be equipment on the system which, for reasons specific to that device, warrant closer attention than the prescribed intervals. There should be quantifiable evidence, however, that demonstrates a need to adjust these intervals.

3) Although the intention of this bulletin is to prescibe the maintenance procedures for susbtation equipment, distribution reclosers are also included since the monthly maintenace procedures are identical to substation devices.

4) Major maintenance as outlined in Section 3.3 will be performed on this interval regardless of oil analysis results.

5) Oil anaylsis will be performed based on the time interval unless the number of fault interruptions listed is exceeded. Additional maintenance shall be performed in accordance with Section 3.4.

3.1 MONTHLY MAINTENANCE

The purpose of monthly maintenance is to insure the interrupting device and its ancillary equipment is functional and suitable to switch and/or interrupt load and short circuit currents. Gauge values and/or sight glass readings should be recorded. For pole mounted reclosers, monthly maintenance will involve the visual inspections which may be performed from the ground.

1. Oil level - check and record the oil level in the site gauge for the tank, verify the level is correct.
2. SF6 Gas insulated breakers or bushings – The gas levels are temperature sensative, ambient temperature should also be noted and verified with the manufacturers Bar chart to determine sufficient dielectric gas pressures.
3. Circuit Switchers – SF6 Gas level is monitored by a mechanical (normally grey/white in color) target located on the interrupting chamber. This target should be visually checked prior to an operation as well as monthly. The device should not be operated and investigated immediately if a red colored target is found.
4. Oil leaks - check the tank for evidence of oil leaks or weeps, near drain valve and directly below the breather on the foundation or ground.
5. Bushings - check visually for cracks, chips, crazing, burn marks, or glaze discoloration. Check oil level and color of all oil filled bushings.
6. Pneumatic operator mechanisms - check and record air pressure in the air receiver tank and listen for evidence of leaks. Open the drain valve on the air receiver to blow down any moisture collected in the bottom of the tank. Ensure the air compressor starts, builds pressure and shuts off automatically.
7. Hydraulic operator mechanisms - check and record hydraulic pressure in the accumulator. Perform a visual check for evidence of any oil leaks.
8. Operation counter - read and record the number of operations on the operation counter, compare with previous readings, interruption reports or notes on log at the breaker to identify and track the number operations associated with fault interruptions versus load or maintenance operations.
9. Indicating lamps - check for burned out trip/close indicating lamp, replace as needed.
10. Electrical interlock / Automatic Reclosing - check electrical interlock switch in the reset or permissive position.
11. Check heater operations.
12. Power supply - check AC and/or DC voltage supplies to interrupting device operator mechanism, controls, compartment heater, lamps and receptacles. Check condition of all supply fuses.

3.2 ANNUAL MAINTENANCE

The purpose of annual maintenance is to perform a thorough, in service examination of all interrupting device components accessible. All checks done under monthly maintenance should be performed as well.

1. Bushings - examine the metal flange at the top of the insulator for pits or small holes caused by arcing or lightning. Check the oil or gas reservoir glass for cracks or signs of oil leakage. Check gasket areas at the top of the insulator and at the flange area on top of the tank.
2. Conductor connections - Inspect to identify excessive heating via thermovision where available. Hot connections will require cleaning and reconnection; or may require transition plates or even replacement. Check connections for tightness and clean as necessary. Check that bus or conductor does not place excessive force (cantilever loading) on the bushing because this may crush gaskets and lead to failures in the flange area.
3. Check oil levels in air compressor / accumulator reservoir, and restore to factory recommended levels.
4. Oil sample - take an oil sample (draw off one to two quarts to insure all water at the bottom of the tank has been removed. Use a new jar to draw off the sample for testing. Observe the color, if light carbon or discoloration is observed filter the oil to remove the carbon or foreign matter. Perform a dielectric breakdown test on the oil "as found" and "after" filtering. If carbon is excessive, flush unit with fresh oil and then replace with new oil or reprocess oil and test for acceptable values prior to refilling the breaker.
5. Minimum dielectric breakdown voltage, by voltage class, are outlined below. These values assume a machine with a 0.10 inch gap using 1 inch diameter discs. Maintenance should be scheduled when the oil dielectric breakdown voltage is below these values.

Minimum dielectric breakdown

115	kV Breakers	35 kV
69	kV Breakers	30 kV
34.5	kV & below	20 kV

3.3 MAJOR MAINTENANCE

The purpose of periodic major maintenance is to perform those tests, in addition to the aforementioned, which require lowering or opening the interrupting chamber or tank. Intervals are as specified in Section 3.0.

1. Check stationary and movable contacts for signs of abnormal wear, burning, pitting or galling. Dress and/or replace contacts as required. Examine alignment, travel and check for binding. Adjust as required to manufacturer's specifications.
2. Vacuum bottles - examine bottle carefully for any signs of damage. Check contacts for abnormal wear per manufacturer's specification.
3. Circuit Switcher – Confirm correct electrical operation of the motor operator per manufacturers instructions.
4. Arc chutes - check chutes for cracks, charring, carbon etc. Clean chutes removing charring and contaminants, replace cracked chutes.
5. Lift rod and assembly - check lift rod and guide assembly for damage and check all connections for tightness.
6. Interlock - Operate the external mechanical trip lever, check that the interlock has operated and verify that the device cannot be operated electrically in the LOCAL or SCADA positions.
7. Contact resistance - With the device closed, measure and record the contact resistance with a milli-ohm meter (ductor) or similar instrument designed to measure the extremely low resistance of breaker contacts. If a poor reading is obtained, determine which contact has the problem and dress and/or adjust contacts as required per manufacturer's instructions and recommendations.
8. Check all mechanical and electrical connections accessible within the control and mechanism cabinets.

3.4 Breaker Oil Analysis

The purpose of breaker oil analysis (BOA) is to assess the condition of the device by evaluating the quality of the oil. This is a condition based maintenace technique that classifies devices into one of three categories. These categories and remedial actions are listed below.

Condition Code 3 (Normal):
Continue normal operation and maintenance schedule.

Condition Code 2 (Caution):
Continue normal operation, re-test annually. Other actions may be necessary such as filtration depending on details of test result.

Condition Code 1 (Warning):
Schedule major maintenance as soon as practicable.

Oil samples for BOA will be taken according to the scheduled time interval or after the number of fault operations has been exceeded shown in Section 3.0. The tests performed are a diagnostic tool which can identify contact wear, interrupter wear, insulation breakdown, and arcing under oil conditions. Tests shall include dielectric breakdown, moisture content, color, dissolved gasses, metals and particulate count.

3.5 TESTING

1. Visual - give the device a thorough visual inspection. Check bushings, tank's and accessories for evidence of damage.
2. Breakers with condenser type bushing may be Doble tested to establish the condition of the bushing / provide a bench mark for future evaluation of the bushing. Any equipment over 34.5 kV is mandatory to be doble tested
3. A travel analyzer may be used to verify / adjust the opening and closing speed of the device.
4. A sample of oil shall be subjected to a standard battery of tests for dielectric breakdown voltage, color, PCB, etc.
5. Operating mechanism - Check for smooth operation of the latching mechanism. Check the electrical close and trip manually via LOCAL control and automatically via SCADA and with the relays.
6. Interlock - Operate the external mechanical trip lever, check that the interlock has operated and verify the device cannot be operated electrically in the LOCAL or SCADA positions.
7. Conductor connections - Clean contacts prior to reconnection.
8. Verify CT ratios are correct for the installation. This may require changing taps in the junction box mounted on the recloser hood (or in the mechanism cabinet).
9. High potential test, contact motion analysis, contact resistance tests can be performed on all media types of current interrupting devices.
10. Refer to Engineering Acceptance Test Recommendations

3.6 OPTIONAL TESTING

All equipment should be tested if service life or other questionable factors are noted during inspections.

Unitil

Operations Bulletin #OP3.05

SUBJECT: Isolating Devices
EFFECTIVE: 11/1/00

ISSUED BY: G. Appleton
CONTENT BY: S. Baker, T.Biklen, M Deschambeault, P.Stagno, A. Zogopoulos, R. Bisson

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1.0 PURPOSE

- To provide a uniform method for monitoring, maintaining and testing Isolating Devices in conjunction with manufacturers' recommendations.
- To ensure the integrity of the equipment
- To ensure the safe operation of the system
- To establish requirements for record keeping and performance measures to identify problems and analyze trends.

2.0 SCOPE

The maintenance procedures are for isolating devices rated 2.4 - 115kV.

3.0 MONTHLY MAINTENANCE

The purpose of monthly maintenance is to insure the isolation device and its ancillary equipment is functional and suitable to switch and/or de-energize. For pole mounted isolation devices, monthly maintenance will involve the visual inspections which may be performed from the ground.

1. Insulators - check visually for cracks, chips, crazing, burn marks, or glaze discoloration.
2. Indicating lamps – any associated lamps should be checked for burn out, replace as needed.
3. Interlock - check electrical/mechanical interlocks or stops, repair or replace as necessary.

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4.0 ANNUAL MAINTENANCE

The purpose of annual maintenance is to perform a thorough, in service examination of all isolation device components accessible. All checks done under monthly maintenance should be performed as well.

1. Insulators - examine the insulator for pits or small holes caused by arcing or lightning.
2. Conductor connections - Inspect to identify excessive heating via thermovision where available. Hot connections will require cleaning and reconnection; or may require transition plates or even replacement. Check connections for tightness and clean as necessary. Check that bus or conductor does not place excessive force (cantilever loading) on the bushing because this may crush gaskets and lead to leaks in the flange area.

5.0 MAJOR MAINTENANCE

The purpose of periodic major maintenance is to perform those tests, in addition to the aforementioned, which require removing the device from service. Intervals are as deemed necessary based on inspection results.

1. Check stationary and movable contacts for signs of abnormal wear, burning, pitting or galling. Dress and/or replace contacts as required. Examine alignment, travel and check for binding. Adjust as required to manufacturer's specifications.
2. Arc chutes - check chutes for cracks, charring, carbon etc. Clean chutes removing charring and contaminants, replace cracked chutes.
3. Interlock - check electrical/mechanical interlocks or stops, repair or replace as necessary.
4. Contact resistance - With the device closed, measure and record the contact resistance with a milli-ohm meter (ductor) or similar instrument designed to measure the extremely low resistance of contacts. If a poor reading is obtained, determine which contact has the problem and dress and/or adjust contacts as required per manufacturer's instructions and recommendations.
5. Slos close the knife blades and check for smooth movement both on the jaw side and the hindge side.
6. For Gang operated knife blades, look for all three blades closing/opening simultaneously.

6.0 TESTING

1. Visual - give the isolation device a thorough visual inspection. Check insulators and accessories for evidence of damage.

2. Depending on the voltage class, size and operation history, the isolation device may be Doble tested to establish the condition and/or provide a bench mark for future evaluation of the device.
3. Operating mechanism - Check for smooth operation of the latching mechanism.
4. Interlock - check electrical/mechanical interlocks or stops, repair or replace as necessary.
5. Conductor connections - Clean contacts prior to reconnection.
6. Refer to Engineering Acceptance Test Recommendations.

Unitil

Operations Bulletin #OP3.06

SUBJECT: Supervisory Control and Data
EFFECTIVE: 11/1/00

ISSUED BY: G. Appleton
CONTENT BY: S. Baker, T.Biklen, M Deschambeault, P.Stagno, A. Zogopoulos, R. Bisson

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1.0 PURPOSE

To outline procedures to follow for testing/verifying all SCADA functions in the substation and distribution environment to include control, status and telemetry. SCADA functions are relied upon greatly for everyday and emergency control and status/telemetry feedback. All functions should be tested on a routine basis as needed and when situations arise when the testing can be accomplished. Cycles for testing will depend on other factors such as the maintenance schedule of other station equipment. All testing/verification of SCADA functions shall be done in conjunction with the proper Control Authority at the Master station (ie., station attendant dispatcher, etc.) and to:

- To ensure the integrity of the equipment
- To ensure the safe operation of the system
- To establish requirements for record keeping and performance measures to identify problems and analyze trends.

2.0 SCOPE

The maintenance procedures are for all SCADA functions in a station or field device that is connected to a SCADA remote. The following are basic guidelines:

Control: All SCADA controls over a device (breaker, recloser, switch, etc.) should be tested when that device is taken out of service for regular or unscheduled maintenance. This should include tripping, closing, non-reclose, ground trip block and any other control feature that SCADA has over the device. Status of the device as well as the status of all control functions should be tested/verified at the same time. Other status feed back that have no control associated with the device should also be verified (ie., remote/local switch, etc.).

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All other controls and their associated status feedback **not** associated with a piece of equipment that has a regular maintenance cycle (ie, light controls, alarm controls, etc.) should be tested/ verified on a regular basis.

SCADA voltage reduction control/status feedback should be tested/verified on a yearly basis.

Status: Status feed back not associated with a control function should be tested on a routine basis. These include such alarms as transformer temperature, fans on/off, door open/shut, etc. If possible, these status points should be tested/verified by actually changing the state of the device they are monitoring. If this is not possible, then shorting or opening the status path up at the farthest point from the remote should suffice.

Telemetry: Telemetry feedback (kw, kva, kwh, volts, amps, temperature, pressure, etc.) should be verified on a routine basis. This could be as simple as doing an instantaneous check with the proper measuring device (ie, volt meter to check voltage feedback) and comparing readings to the Master Station, or remote display or laptop display. If the telemetry information is being used for billing purposes, a more routine check should be preformed, as well as an accuracy test of the traducers. Another acceptable way to verify telemetry data is to compare the information to another source (ie, MV90 information, etc.).

Misc. : The remote should be looked at during the monthly checks for any obvious signs of problems. Any battery in a remote should be checked routinely per the manufacture guidelines, and Unitil practices.

Initial Compliance Testing: All new SCADA installations should be thoroughly tested for control, status and analog, at the completed time of installation. Care should be taken so as not to inadvertently change the state of a device that has not been taken out of service or bypassed, during the testing process. Anytime new equipment (or added SCADA functions to an existing piece of equipment) that is placed in service shall have all SCADA functions (if any) tested prior to completion of the project.

Unitil

Operations Bulletin #OP3.07

SUBJECT: Protective Relays
EFFECTIVE: 11/1/00

ISSUED BY: G. Appleton
CONTENT BY: S. Baker, T.Biklen, M Deschambeault, P.Stagno, A. Zogopoulos, R. Bisson

1.0 PURPOSE

- To provide a uniform method for inspecting, maintaining and testing relays within the Unitil system
- To ensure the integrity of the equipment
- To ensure the safe operation of the system
- To establish requirements for record keeping and performance measures to identify problems and analyze trends.

2.0 SCOPE

2.10 RELAY SETTINGS

At all new protective relay installations, the relays should be adjusted in accordance with the settings given in the relay data sheets furnished by engineering, after which, tests should be made to determine if the actual operating characteristics check with the adjustments made. When the new settings are applied and tested the relay setting sheet should be completed with the testing information and returned to engineering. Relays and relay settings are not to be changed from what is indicated on current issues of relay data sheets unless authorized engineering.

2.20 APPLYING REVISED RELAY SETTINGS

It is necessary to revise relay settings from time to time. At such times it may also be necessary to make corresponding changes in backup protective equipment in order to maintain coordination. Under these conditions, the changes in the backup relays should be made first so that coordination will not be lost during the period between the beginning and the

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completion of the tests. This would apply whenever increased backup relay settings accompany changes in first-line protective equipment.

2.30 NEW INSTALLATIONS

Before placing a new installation into operation, the polarity of instrument transformers and the wiring to the relays should be checked. In some cases, the manufacturer's polarity marking has been found to be incorrect. New relays should be inspected carefully and all blocking put in by the manufacturer removed. The tester should read the instruction books furnished by the manufacturer to become familiar with the construction and operating principle of the relays.

2.40 TESTING EQUIPMENT REQUIRED

A good set of testing equipment and a set of relay tools are important. Several manufacturers produce portable relay test sets that will provide excellent results.

2.50 TESTING PRECAUTIONS

Before starting to test any relay on equipment in service, the person testing should become familiar with the relays and the circuits involved. Where test blocks are used, the person testing must make sure that in removing or inserting the plugs that a current transformer circuit will not be opened, resulting in a voltage being built up which may be dangerous to personnel, property, or equipment, or cause an important circuit to trip out. In old installations where test blocks are not available, the current transformer circuits must be short circuited by jumpers having reliable clamping devices which will not come loose, before the relay current circuit is opened.

2.60 FREQUENCY OF TESTING

It is recommended that protective and auxiliary relays be given a complete calibration test and inspection per the following schedule.

Relay Function	Construction Type	Test interval
Generator Relaying	All	1 Year
Transformer Differential	Electromechanical	2 Years
Transmission relays (69kV or 34.5kV)	Electromechanical	2 Years
Distribution Circuit relays/reclosers	Electromechanical	3 Years
Transformer Differential	Microprocessor	5 Years
Transmission relays (69kV or 34.5kV)	Microprocessor	5 Years
Distribution Circuit relays	Microprocessor	5 Years

This schedule is a guideline and may need to be revised due to available manpower or specific conditions of the particular relay scheme. The test frequency for each particular relay should be included in the relay setting and testing database. Factors to be considered if changes to the test schedule are needed, are shown in table 1.

Table 1. - *Criteria to determine possible alteration of the test period for relays*

Relay System Variables	Factor Reducing Test Interval	Factors Lengthening Test Interval
Type of Relays	Complex (distance, differential).	Simple (hinged armature plunger).
Age of Relays	New Installations with little operating history. Systems 20 years or older where insulation aging, etc., can be a problem	5-10 years old with a good operating history
Environment	Dusty area, contaminated atmosphere, temperature extremes.	Clean and/or air conditioned area.
History and Experience	Subjected to severe or frequent faults. Often required adjustments when tested.	Subjected to moderate or few faults.
Current Rating	Relays rated 5 amperes which are called upon to carry 7 or 8 amperes due to load requirements.	Relays operated at or below their 5 ampere rating
Control Voltage	Relays operated in battery circuit more than 5 percent above nominal relay rated voltage	Relays operated in battery circuit within ± 5 percent of nominal relay rated voltage
Station Service	Station service voltage supplied is more than 5 percent above nominal relay rated voltage.	Station service Voltage supply operated within + 5 percent of nominal relay rated voltage.

2.70 TEST PROCEDURES

The tests to be performed during routine maintenance are determined by the type of relay to be tested However, the test procedure of all relay schemes should include the following.

1. A **visual inspection** should be made of all relays on a terminal including the tripping auxiliaries and accessories. Any drawout type of relay should be withdrawn from its case for a close up examination. All other, including auxiliaries, should at least have the covers removed. Included in this visual inspection should be a check for loose connections, broken studs,

burned insulation, and dirty contacts. Each relay should be checked to be in agreement with its setting sheet. On some distance relays it may have been necessary to set the taps on something other than the specified values in order to get the proper calibration. Because of this, it may also be necessary to check the taps against the last calibration test report.

2. A **test trip** should be made of all relay systems. All relay elements, which may initiate some protective function, should be checked. This includes reclosing, carrier starting, or any similar type function. After proving that the tripping relays will successfully trip the circuit breaker and that all reclosing schemes work, continuity checks should be used, where applicable, to complete the checkout of the circuit breaker trip circuits.

a. AUXILIARY RELAYS

In addition to the tests described in paragraph 7, auxiliary relays employing devices for time delay (for example, capacitors) should have an operating time test performed (either pickup or dropout, whichever is applicable).

b. TIME OVERCURRENT AND TIME OVERVOLTAGE RELAYS

All the tests described in paragraph 9 should be performed for time-overcurrent and time-overvoltage relays where applicable. These types of relays should always be tested in the case, when able, in order to duplicate "in-service" conditions or to match published curves since the relay case normally acts as a shunt for the flux that the electromagnetic iron circuit cannot handle due to saturation. Testing the relay out of the case will also produce results that would not check previous tests or future tests since changes in test conditions, such as being near a steel cabinet, will change the results obtained if the relay is tested out of the case. The first electrical test made on the relay should be a pickup test. Pickup is defined as that value of current or voltage which will just close the relay contacts from the 0.5 time-dial position. Allowing for such things as meter differences and interpretations of readings, this value should be within ± 5 percent of the previous data.

One or two points on the time-current curve are generally sufficient for maintenance purposes. Reset the relay to the original time-dial setting and check at two points Such as 3 and 5 times pickup. Always use the same points for comparison with previous tests.

The instantaneous unit should be checked for pickup using gradually applied current. Whenever possible, current should be applied only to the instantaneous unit to avoid overheating the time unit. The target seal-in unit should also be tested using gradually applied current. The main unit contacts must be blocked closed for this test.

c. DIRECTIONAL OVERCURRENT RELAYS

In addition to the tests recommended for the overcurrent relay, the directional unit of the directional overcurrent relay should be tested for minimum pickup, angle of maximum

torque, contact gap, and clutch pressure. A test should also be made to check that the overcurrent unit operates only when the directional unit contacts are closed.

d. DISTANCE RELAYS

When testing distance relays, tests should be made of pickup, angle of maximum torque, contact gap, and clutch pressure, in addition to the tests described in paragraph 9.

e. DIFFERENTIAL RELAYS

A test of minimum pickup should be performed for differential relays. The differential characteristic (slope) should be checked, and where applicable, the harmonic restraint should be tested. Differential relays using ultrasensitive polarized units as sensing devices are slightly affected by previous history, such as heavy internal or external fault currents. It is therefore recommended that for this type of relay two pickup readings be taken and the second reading be the one that is used for comparison with previous and future tests.

f. ELECTRO-MECHANICAL

The following tests should be included for all electromechanical relays.

1. A **visual inspection** of the relay cover can reveal valuable information. Any excessive dust, dirt, or metallic material deposited on the cover should be noted and removed, thus preventing such material from entering the relay when the cover is removed. A cover glass, which is fogged, should be cleaned. The fogging is in most cases a normal condition due to volatile materials being driven out of coils and insulating materials, and is not an indication of a problem. However if the fogging appears excessive, since most relays are designed to operate in ambient temperatures not exceeding 40 ºC (104 ºF), a further check of the ambient temperature would be in order. The voltage and current supplied to the relay should be checked and compared with the name plate or instruction book ratings. Should evidence of overheating be found, the insulation should be checked for embrittlement and, where necessary, replaced. The removal of the connection plug in drawout relays may reveal evidence of severe fault currents or contaminated atmospheres, either of which may indicate the advisability of a change in the maintenance schedule. The condition of the relay contacts can be equally revealing.

2. **Mechanical adjustments and inspection** should be made according to the following instructions:

    a. Check to see that all connections are tight. Several loose connections could indicate excessive vibration, which should be corrected.

b. All gaps should be checked that they are free of foreign material. If foreign material is found in the relay, the case gasket should be checked and replaced if necessary.

c. All contact or armature gaps should be measured and the values compared with previous measurements. Large variations in these measurements may indicate excessive wear, and the worn parts should be replaced. Also an adjusting screw could have worked loose and must be tightened. All of this information should be noted on the test record.

d. All contacts except those not recommended for maintenance should be burnished, and measured for alignment and wipe.

e. Since checking the bearings or pivots usually involves dismantling the relay, it is recommended that such a test be made only when the relay appears to be extremely dirty, or when subsequent electrical tests indicate undue friction.

3. **Electrical tests and adjustments** should be made according to the following instructions:

a. Contact function. - Manually close or open the contacts, and observe that they perform their required function; such as trip, reclose, or block.

b. Pickup.-Gradually apply current or voltage to see that pickup is within limits. The current or voltage should be applied gradually in order to yield data, which can be compared with previous or future tests, and not be clouded by such effects as transient overreach.

c. Dropout or reset.-To test for excess friction, reduce the current until the relay drops out or resets. Should the relay be sluggish in resetting or fail to reset, then the jewel bearing and pivot should be examined. A four-power magnification is adequate for examining the pivot, and the jewel bearing can be examined with the aid of a needle, which will reveal any cracks in it. If dirt is the problem, the jewel can be cleaned with an orange stick and the pivot can be wiped clean with a soft, lint free cloth. No lubricant should be used on either the jewel or the pivot.

g. STATIC (SOLID STATE) RELAYS

Static relays should be tested in accordance with the manufacturer's recommendations given in the relay instruction books. As there are no moving parts in static relays, there is no physical wear due to usage and no need for lubricants. The prime causes of failure in electronic components are heat, vibration, and moisture. Overheating can be caused by voltage transients, current surges, excessive power, or high ambient temperature. Vibration can loosen or break leads

and connections and can crack component casings or insulations resulting in equipment failure. Moisture can result in corrosion of metallic elements which can result in circuit discontinuities, poor contact, or shorts. Preventive maintenance of static relays should be directed toward removing the causes of failure listed above by doing the following:

1. Keep the equipment clean by periodic vacuuming or blowing out of dirt, dust, and other surface contaminants.

2. Keep the equipment dry and protected against moisture and corrosion.

3. Inspect to see that all connections, leads, and contacts are tight and free as possible from the effects of vibrations.

4. Check to see that there is adequate ventilation to conduct the heat away efficiently.

5. Preventive measures should not be applied unnecessarily as this may contribute to failures. For example, printed circuit cards should not be pulled from their rocks to be inspected if there is no real need. Operating test switches unnecessarily may induce damaging voltage transients.

h. MICROPROCESSOR BASED RELAYS

1. Microprocessor based relays should be tested in accordance with the manufacturer's recommendations given in the relay instruction books. As there are no moving parts in microprocessor based relays, there is no physical wear due to usage and no need for lubricants. The prime causes of failure in electronic components are heat, vibration, and moisture. Overheating can be caused by voltage transients, current surges, excessive power, or high ambient temperature. Vibration can loosen or break leads and connections and can crack component casings or insulations resulting in equipment failure. Moisture can result in corrosion of metallic elements which can result in circuit discontinuities, poor contact, or shorts. Preventive maintenance of microprocessor based relays should be directed toward removing the causes of failure listed above by doing the following:

    a. Keep the equipment clean by periodic vacuuming or blowing out of dirt, dust, and other surface contaminants.

    b. Keep the equipment dry and protected against moisture and corrosion.

    c. Inspect to see that all connections, leads, and contacts are tight and free as possible from the effects of vibrations.

    d. Check to see that there is adequate ventilation to conduct the heat away efficiently.

    e. Preventive measures should not be applied unnecessarily as this may contribute to failures. For example, printed circuit cards should not be pulled

from their rocks to be inspected if there is no real need. Operating test switches unnecessarily may induce damaging voltage transients.

2. **Electrical tests and adjustments** should be made according to the following instructions:
    a. Contact function: - Manually close or open the contacts, and observe that they perform their required function; such as trip, reclose, or block.
    b. Pickup: - Gradually apply current or voltage to see that pickup is within limits. The current or voltage should be applied gradually in order to yield data, which can be compared with previous or future tests, and not be clouded by such effects as transient overreach.

i. HYDRAULIC CONTROLLED RECLOSERS

a. PORTABLE RELAY PANELS

Particular attention should be given to relays mounted on portable relay panels as these relays are subjected to more rough handling than those permanently installed on a switchboard. Therefore, whenever a portable panel of relays is installed, they should be thoroughly checked physically as well as electrically. If they are in bad condition, they should be repaired, or new relays installed before they are placed in service.

j. OPEN-SECONDARY CIRCUITS

WARNING: Secondary circuits of CT's must not be open while primary current flows. Extreme care should be taken to avoid breaking the secondary circuit while primary current is flowing. If the secondary is open-circuited the primary current raises the core flux density to saturation and induces a high voltage in the secondary which can endanger human life, and can damage connected apparatus and leads. If it is necessary to change secondary conditions while primary current is flowing, the secondary terminals must be short-circuited while the change is being made. **Caution should be exercised when working with differential circuits as shorting a current transformer in an energized differential relaying circuit could result in a relay operation.** It is recommended that the secondaries of all current transformers be kept short-circuited at all times when not installed in a circuit such as being held in stock or being transported.

Appendix A

ELECTRICAL DEVICE NUMBERS AND FUNCTIONS

The devices in control and switching equipment are referred to by numbers, with appropriate suffix letters when necessary, according to the functions they perform. These numbers are based on the IEEE standard for automatic switchgear and are incorporated in American National Standard C37.2-1970.

Device No.	Definition and Function
1	**Master Element** is the initiating device, such as a control switch, voltage relay, or float switch, which serves either directly or through such permissive devices as protective and time-delay relays to place an equipment in or out of operation.
2	**Time-Delay Starting or Closing Relay** is a device that functions to give a desired amount of time delay before or after any point of operation in a switching sequence or protective relay system, except as specifically provided by device functions 48, 62, and 79.
3	**Checking or Interlocking Relay** is a relay that operates in response to the position of a number of other devices (or to a number of predetermined conditions) in an equipment, to allow an operating sequence to proceed, or to stop, or to provide a check of the position of these devices or of these conditions for any purpose.
4	**Master Contactor** is a device, generally controlled by device function 1 or the equivalent and the required permissive and protective devices, that serves to make and break the necessary control circuits to place an equipment into operation under the desired conditions and to take it out of operation under other or abnormal conditions.
5	**Stopping Device** is a control device used primarily to shut down an equipment and hold it out of operation. (This device may be manually or electrically actuated, but excludes the function of electrical lockout [see device function 86] on abnormal conditions.)
6	**Starting Circuit Breaker** is a device whose principal function is to connect a machine to e of starting voltage.
7	**Anode Circuit Breaker** is a device used in the anode circuits of a power rectifier for the primary purpose of interrupting the rectifier circuit if an arc-back should occur.
8	**Control Power Disconnecting Device** is a disconnecting device, such as a knife switch, circuit breaker, or pull-out fuse block, used for the purpose of respectively connecting and disconnecting the source of control power to and from the control bus or equipment. NOTE: Control power is considered to include auxiliary power which supplies such apparatus as small motors and heaters.
9	**Reversing Device** is a device that is used for the purpose of reversing a machine field or for performing any other reversing functions.
10	**Unit Sequence Switch** is a switch that is used to change the sequence in which units may be placed in and out of service in multiple-unit equipments.
11	Reserved for future application.
12	**Over-speed Device** is usually a direct-connected speed switch which functions on machine overspeed.
13	**Synchronous-speed Device** is a device such as a centrifugal-speed switch, a slip-

	frequency relay, a voltage relay, an undercurrent relay, or any type of device that operates at approximately the synchronous speed of a machine.
14	**Under-speed Device** is a device that functions when the speed of a machine falls below a predetermined value.
15	**Speed or Frequency Matching Device** is device that functions to match and hold the speed or the frequency of a machine or of a system equal to, or approximately equal to, that of another machine, source, or system.
16	Reserved for future application.
17	**Shunting or Discharge Switch** is a switch that serves to open or to close a shunting circuit around any piece of apparatus (except a resistor), such as a machine field, a machine armature, a capacitor, or a reactor. **NOTE:** This excludes devices that perform such shunting operations as may be necessary in the process of starting a machine by devices 6 or 42, or their equivalent, and also excludes device function 73 that serves for the switching of resistors.
18	**Accelerating or Decelerating Device** is a device that is used to close or to cause the closing of circuits which are used to increase or decrease the speed of a machine.
19	**Starting-to-Running Transition Contactor** is a device that operates to initiate or cause the automatic transfer of a machine from the starting to the running power connection.
20	**Electrically Operated Valve** is an electrically operated, controlled, or monitored valve used in a fluid line.
21	**Distance Relay** is a relay that functions when the circuit admittance, impedance, or reactance increases or decreases beyond predetermined limits.
22	**Equalizer Circuit Breaker** is a breaker that serves to control or to make and break the equalizer or the current-balancing connections for a machine field, or for regulating equipment, in a multiple-unit installation
23	**Temperature Control Device** is a device that functions to raise or lower the temperature of a machine or other apparatus, or of any medium, when its temperature falls below, or rises above, a predetermined value. NOTE: An example is a thermostat that switches on a space heater in a switchgear assembly when the temperature falls to a desired value as distinguished from a device that is used to provide automatic temperature regulation between close limits and would be designated as device function 90T
24	Reserved for future application.
25	**Synchronizing or Synchronism-Check Device** is a device that operates when two a-c circuits are within the desired limits of frequency, phase angle, or voltage to permit or to cause the paralleling of these two circuits.
26	**Apparatus Thermal Device** is a device that functions when the temperature of the shunt field or the amortisseur winding of a machine, or that of a load limiting or load shifting resistor or of a liquid or other medium, exceeds a predetermined value; or if the temperature of the protected apparatus, such as a power rectifier, or of any medium, decreases below a predetermined value.
27	**Undervoltage Relay** is a relay that functions on a given value of undervoltage.
28	**Flame Detector** is a device that monitors the presence of the pilot or main flame in such

	apparatus as a gas turbine or a steam boiler.
29	**Isolating Contactor** is a device that is used expressly for disconnecting one circuit from another for the purposes of emergency operation, maintenance, or test.
30	**Annunciator Relay** is a nonautomatically reset device that gives a number of separate visual indications upon the functioning of protective devices, and which may also be arranged to perform a lockout function
31	**Separate Excitation Device** is a device that connects a circuit, such as the shunt field of a synchronous converter, to a source of separate excitation during the starting sequence, or one that energizes the excitation and ignition circuits of a power rectifier.
32	**Directional Power Relay** is a device that functions on a desired value of power flow in a given direction or upon reverse power resulting from arc-back in the anode or cathode circuits of a power rectifier
33	**Position Switch** is a switch that makes or breaks contact when the main device or piece of apparatus which has no device function number reaches a given position.
34	**Master Sequence Device** is a device such as a motor-operated multi-contact switch, or the equivalent, or a programming device, such as a computer, that establishes or determines the operating sequence of the major devices in an equipment during starting and stopping or during other sequential switching operations.
35	**Brush-operating or Slip-ring Short-circuiting Device** is a device for raising, lowering, or shifting the brushes of a machine, or for short- circuiting its slip rings, or for engaging or disengaging the contacts of a mechanical rectifier.
36	**Polarity or Polarizing Voltage Device** is a device that operates, or permits the operation of, another device on a predetermined polarity only, or verifies the presence of a polarizing voltage in an equipment.
37	**Undercurrent or Underpower Relay** is a relay that functions when the current or power flow decreases below a predetermined value.
38	**Bearing Protective Device** is a device that functions on excessive bearing temperature, or on other abnormal mechanical conditions associated with the bearing, such as undue wear, which may eventually result in excessive bearing temperature or failure.
39	**Mechanical Condition** Monitor is a device that functions upon the occurrence of an abnormal mechanical condition (except that associated with bearings as covered under device function 38), such as excessive vibration, eccentricity, expansion, shock, tilting, or seal failure.
40	**Field Relay** is a relay that functions on a given or abnormally low value or failure of machine field current, or on an excessive value of the reactive component of armature current in an a-c machine indicating abnormally low field excitation.
41	**Field Circuit Breaker** is a device that functions to apply or remove the field excitation of a machine.
42	**Running Circuit Breaker** is a device whose principal function is to connect a machine to its source of running or operating voltage. This function may also be used for a device, such as a contactor, that is used in series with a circuit breaker or other fault protecting means, primarily for frequent opening and closing of the circuit.
43	**Manual Transfer or Selector Device** is a manually operated device that transfers control

	circuits in order to modify the plan of operation of the switching equipment or of some of the devices.
44	**Unit Sequence Starting Relay** is a relay that functions to start the next available unit in a multiple-unit equipment upon the failure or nonavailability of the normally preceding unit.
45	**Atmospheric Condition Monitor** is a device that functions upon the occurrence of an abnormal atmospheric condition, such as damaging fumes, explosive mixtures, smoke, or fire.
46	**Reverse-phase or Phase-balance Current Relay** is a relay that functions when the polyphase currents are of reverse-phase sequence, or when the polyphase currents are unbalanced or contain negative phase-sequence components above a given amount.
47	**Phase-Sequence Voltage Relay** is a relay that functions upon a predetermined value of polyphase voltage in the desired phase sequence.
48	**Incomplete Sequence Relay** is a relay that generally returns the equipment to the normal, or off, position and locks it out if the normal starting, operating, or stopping sequence is not properly completed within a predetermined time. If the device is used for alarm purposes only, it should preferably be designated as 48A (alarm)
49	**Machine or Transformer Thermal Relay** is a relay that functions when the temperature of a machine armature or other load-carrying winding or element of a machine or the temperature of a power rectifier or power transformer (including a power rectifier transformer) exceeds a predetermined value.
50	**Instantaneous overcurrent or Rate-of-rise Relay** is a relay that functions instantaneously on an excessive value of current or on an excessive rate of current rise, thus indicating a fault in the apparatus or circuit being protected.
51	**A-C Time Overcurrent Relay** is a relay with either a definite or inverse time characteristic that functions when the current in an ac-circuit exceeds a predetermined value.
52	**A-C Circuit Breaker** is a device that is used to close and interrupt an a-c power circuit under normal conditions or to interrupt this circuit under fault or emergency conditions.
53	**Exciter or D-C Generator Relay** is a relay that forces the d-c machine field excitation to build up during the starting or which functions when the machine voltage has built up to a given value.
54	Reserved for future application.
55	**Power Factor Relay** is a relay that operates when the power factor in an a-c circuit rises above or falls below a predetermined value.
56	**Field Application Relay** is a relay that automatically controls the application of the field excitation to an a-c motor at some predetermined point in the slip cycle.
57	**Short-circuiting or Grounding Device** is a primary circuit switching device that functions to short-circuit or to ground a circuit in response to automatic or manual means.
58	**Rectification Failure Relay** is a device that functions if one or more anodes of a power rectifier fail to fire, or to detect an arc-back, or on failure of a diode to conduct or block properly.
59	**Overvoltage Relay** is a relay that functions on a given value of overvoltage.
60	**Voltage or Current Balance Relay** is a relay that operates on a given difference in voltage, or current input or output, of two circuits.

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61	Reserved for future application.
62	**Time-delay Stopping or Opening Relay** is a time-delay relay that serves in conjunction with the device that initiates the shutdown, stopping, or opening operation in an automatic sequence or protective relay system.
63	**Pressure Switch** is a switch which operates on given values, or on a given rate of change, of pressure.
64	**Ground Protective Relay** is a relay that functions on failure of the insulation of a machine, transformer, or of other apparatus to ground, or on flashover of a d-c machine to ground. NOTE: This function is assigned only to a relay that detects the flow of current from the frame of a machine or enclosing case or structure of a piece of apparatus to ground, or detects a ground on a normally ungrounded winding or circuit. it is not applied to a device connected in the secondary circuit of a current transformer, or in the secondary neutral of current transformers, connected in the power circuit of a normally grounded system.
65	**Governor** is the assembly of fluid, electrical, or mechanical control equipment used for regulating the flow of water, steam, or other medium to the prime mover for such purposes as starting, holding speed or load, or stopping.
66	**Notching or Jogging Device** is a device that functions to allow only a specified number of operations of a given device, or equipment, or a specified number of successive operations within a give time of each other. It is also a device that functions to energize a circuit periodically or for fractions of specified time intervals, or that is used to permit intermittent acceleration or jogging of a machine at low speeds for mechanical positioning.
67	**A-C Directional Overcurrent Relay** is a relay that functions on a desired value of , a-c overcurrent flowing in a predetermined direction.
68	**Blocking Relay** is a relay that initiates a pilot signal for blocking of tripping on external faults in a transmission line or in other apparatus under predetermined conditions, or cooperates with other devices to block tripping or to block reclosing on an out-of-step condition or on power swings.
69	**Permissive Control Device** is generally a two-position, manually operated switch that, in one position, permits the closing of a circuit breaker, or the placing of an equipment into operation, and in the other position prevents the circuit breaker or the equipment from being operated.
70	**Rheostat** is variable resistance device used in an electric circuit, which is electrically operated or has other electrical accessories, such as auxiliary, position, or limit switches.
71	**Level Switch** is a switch which operates on given values or on a given rate of change, of level
72	**D-C Circuit Breaker** is a circuit breaker that is used to close and interrupt a d-c power circuit under normal conditions or to interrupt this circuit under fault or emergency conditions.
73	**Load-resistor Contactor** is a contactor that is used to shunt or insert a step of loading limiting, shifting, or indicating resistance in a power circuit, or to switch a space heater in circuit, or to switch a light or regenerative load resistor of a power rectifier or other

	machine in and out of circuit.
74	**Alarm Relay** is a relay other than an annunciator, as covered under device function 30, that is used to operate, or to operate in connection with, a visual or audible alarm.
75	**Position Changing Mechanism** is a mechanism that is used for moving a main device from one position to another in an equipment: as for example, shifting a removable circuit breaker unit to and from the connected, disconnected, and test positions.
76	**D-C Overcurrent Relay** is a relay that functions when the current in a d-c circuit exceeds a given value.
77	**Pulse Transmitter** is used to generate and transmit pulses over a telemetering or pilot-wire circuit to the remote indicating or receiving device.
78	**Phase-angle Measuring or Out-of-step Protective Relay** is a relay that functions at a predetermined phase angle between two voltages or between two currents or between voltage and current.
79	**A-C Reclosing Relay** is a relay that controls the automatic reclosing and locking out of an a-c circuit interrupter.
80	**Flow Switch** is a switch which operates on given values, or on a given rate of change of flow.
81	**Frequency Relay** is a relay that functions on a predetermined value of frequency (either under or over or on normal system frequency) or rate of change of frequency.
82	**D-C Reclosing Relay** is a relay that controls the automatic closing and reclosing of a d-c circuit interrupter, generally in response to load circuit conditions.
83	**Automatic Selective Control or Transfer Relay** is a relay that operates to select automatically between certain sources or conditions in an equipment, or performs a transfer operation automatically.
84	**Operating Mechanism** is the complete electrical mechanism or servomechanism, including the operating motor, solenoids, position switches, etc., for a tap changer, induction regulator, or any similar piece of apparatus which otherwise has no device function number.
85	**Carrier or Pilot-wire Receiver Relay** is a relay that is operated or restrained by a signal used in connection with carrier-current or d-c pilot-wire fault directional relaying.
86	**Locking-out Relay** is an electrically operated hand, or electrically, reset relay or device that functions to shut down or hold an equipment out of service, or both, upon the occurrence of abnormal conditions.
87	**Differential Protective Relay** is a protective relay that functions on a percentage or phase angle or other quantitative difference of two currents or of some other electrical quantities.
88	**Auxiliary Motor or Motor Generator** is one used for operating auxiliary equipment, such as pumps, blowers, exciters, rotating magnetic amplifiers, etc.
89	**Line Switch** is a switch used as a disconnecting, load-interrupter, or isolating switch in an a-c or d-c power circuit, when this device is electrically operated or has electrical accessories, such as an auxiliary switch, magnetic lock, etc.
90	**Regulating Device** is a device that functions to regulate a quantity, or quantities, such as voltage, current, power, speed, frequency, temperature, and load, at a certain value or

	between certain (generally close) limits for machines, tie lines or other apparatus.
91	**Voltage Directional Relay** is a relay that operates when the voltage across an open circuit breaker or contactor exceeds a given value in a given direction.
92	**Voltage and Power Directional Relay** is a relay that permits or causes the connection of two circuits when the voltage difference between them exceeds a given value in a predetermined direction and causes these two circuits to be disconnected from each other when the power flowing between them exceeds a given value in the opposite direction.
93	**Field-changing Contactor** is a contactor that functions to increase or decrease, in one step, the value of field excitation on a machine.
94	**Tripping or Trip-free Relay** is a relay that functions to trip a circuit breaker, contactor, or equipment, or to permit immediate tripping by other device, or to prevent immediate reclosure of a circuit interrupter if it should open automatically even though its closing circuit is maintained closed.
95 96 97 98	Numbers from 95 to 99 should be assigned only for those functions in specific cases where none of the assigned standard device function numbers are applicable. Numbers which are "reserved for future application" should not be used.

Appendix B

Definitions of Relay Terms

The following definitions include terminology and nomenclature in common use in the relay industry. They have been compiled using information from the IEEE and the National Association of Relay Manufacturers. In instances where different terms are used synonymously, one has been defined and others have been cross-referenced to it. When the phrase "sometimes used for" is employed, a preference is implied for the terminology following the phrase, when "same as" is used; no strong preference is inferred.

Air Gap.-Sometimes used for Contact Separation or for Magnetic Air Gap.
Ampere-turns. -The product of the number of turns in a magnetic coil and the rms current in amperes passing through the coil.
Armature.-The hinged or pivoted moving part of the magnetic circuit of an electromagnetic relay. Sometimes used in a general sense to means any moving part which actuates contacts in response to a change in coil current.
Armature Contact.-Sometimes used for Movable Contact.
Armature Relay.-A relay operated by an electromagnet which, when energized, causes an armature to be attracted to a fixed pole (or poles).
Auxiliary Relay. -A relay which operates in response to the opening and closing of its operating circuit to assist another relay or device in the performance of a function. Back Contacts.-Sometimes used for the stationary contact of single-pole normally closed contacts.
Back Contacts.-Same as Normally Closed Contacts.
Backstop.-The part of a relay which limits the movement of the armature away from the pole piece or core.
Backup Relaying. -Supplementary relaying designed to operate if a primary relay should malfunction or a circuit breaker fail to operate. Back-up relaying usually disconnects more of the power system than just the part with the faulty element as this is necessary in order to remove the abnormal condition and to minimize the effect on the remainder of the system.
Bar Relay.-A relay so designed that a bar actuates several contacts simultaneously.
Break-before-make Contacts.-Contacts which interrupt one circuit before establishing another.
Break Contact.-Same as Back Contact.
Break Delay.-Sometimes used for Release Time.
Bridging.-Bridging is-a term used to describe a contact transfer in which the movable contact touches the normally open contact before leaving the normally closed contact during the transfer action, thus never completely opening the circuit of the movable contact.
Brush.-Sometimes used for Wiper.
Chatter.-A sustained rapid opening and closing of contacts caused by variations in the coil current, mechanical vibration and shock or other causes.
Clapper Relay.-Sometimes used for Armature Relay.
Close-differential Relay.-Sometimes used for Marginal Relay.
Coil.-A magnetic or thermal winding to which energy is supplied to activate the relay

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Contact Arrangement.-Contact arrangement refers to the combination of the different basic contact forms to make up the entire relay switching structure.
Contact Bounce. -The uncontrolled making and breaking of contact when relay contacts are moved to the closed position.
Contact follow.-The distance two contacts travel together after just touching.
Contact Gap.-Same as Contact Separation.
Contact Nomenclature.-Each of the movable contacts of a relay constitutes a pole of the relay.
A combination of a stationary contact and a movable contact which are engaged when the coil is unenergized is referred to as back, break, form B, or normally closed contacts and is abbreviated NC. A combination of a stationary contact and movable contact, which are engaged when the coil is energized is referred to as front, make, form A, or normally open contacts and is abbreviated NO.
A combination of two stationary contacts and a movable contact which engages one of them when the coil is energized and engages the other when the coil is unenergized is called transfer, form C, or double-throw contacts and is abbreviated DT
Contrasted with double-throw contacts, NO and NC contacts are called single-throw contacts, abbreviated ST
A combination in which a movable contact simultaneously makes and simultaneously breaks connection between two stationary contacts is called double-break contacts and is abbreviated DB. For normally open contacts, this combination may be called double-make contacts.
Relay contact notations are given in the following order:

1. Poles
2. Throws
3. Normal Position
4. DB, if double-break or double-make contacts

Examples: SPST NO DB designates single-pole, single-throw, normally open, double-break contacts.

All contacts are single break except when noted as double-break (DB). Relays having several sets of differently functioning contacts will have the contact forms listed in alphabetical order of their letter symbols.

Example: IA2B refers to SPST NO contacts and DPST NC contacts.

For a relay on which the moving contact engages more than two stationary contacts during its cycle of operation, the contact arrangement is described as MPNT, where M is the number of poles and N is the number of throws, e,g., 8P 20T
Contact Overtravel.-Sometimes used for Contact Follow.
Contact Separation.-The maximum distance between mating relay contacts when the contacts are in the open position.
Contact Spring.-A current-carrying spring to which the contacts are fastened.
Contacts.-Current-carrying parts of a relay which engage or disengage to make or break electrical circuits.
Contactor.-Sometimes used for a relay with heavy-duty contacts.
Continuity-transfer Contacts.-Same as Make-before-break Contacts.

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Continuous-duty Relay.-A relay which may be energized with its rated coil voltage or current at rated contact load for a period of 3 hours or more without failure and without exceeding its specified temperature requirements.
Current Balance Relay.-Relay that allows tripping whenever there is an abnormal change in the division of current between two circuits. Current Rating.-See Rated Coil Current and Rated Contact Current.
Current Relay.-A relay which is designed to operate at a particular rated coil current rather than at a given rated coil voltage.
Cycle Timer.-A controlling mechanism which opens or closes contacts according to a preset cycle.
Deenergize.-To deenergize a relay is to disconnected the relay coil from its power source.
Definite-purpose Relay.-A readily available relay which has some electrical or mechanical feature which distinguishes it from a general-purpose relay. Types of definite purpose relays are interlock, selector, stepping, sequence, latch-in and time-delay.
Delay Relay.-A relay that is intentionally designed for a time delay between the energizing or deenergizing instant and the time that the relay contacts open or close.
Differential relay.-A relay having multiple windings which functions when the voltage, current, or power difference between the windings reaches a predetermined value.
Directional Relay.-A relay that allows tripping for current flow in one direction only.
Double-break Contacts.-See Contact Nomenclature.
Double-make Contacts.-See Contact Nomenclature.
Double-Throw Contacts.-See Contact Nomenclature.
Double-wound Coil.-A double-wound coil is a winding consisting of two parts wound on the same core.
Drop-out Values.-The drop-out current, voltage, or power is the maximum value for which the contacts of a previously energized relay will always assume their unenergized positions.
Duty Cycle.-The rated working time of a device compared to its idle time.
Electric Reset.-A qualify term applied to a relay indicating that following an operation its contacts must be reset electrically to their original positions.
Electromagnetic Relay.-A relay whose operation involves the use of a magnetic field which is produced by an electromagnet.
Electrostatic Spring Shields.-Metallic shields between two relay springs to minimize capacitance between them.
Enclosed Relay.-A relay which has both coil and contacts protected from the surrounding medium by a cover that is not airtight.
Energize.-To energize a relay is to apply rated voltage to its coil.
Extension Spring.-Same as Restoring Spring.
Fast-operate Relay.-A high-speed relay specifically designed for short operate time but not short release time.
Fast-operate, Fast-release Relay.-A high-speed relay specifically designed for both short operate time and short release time.
Fast-operate, Slow-release Relay.-A relay specifically designed for short release time but not short operate time.

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Fast-release Relay.-A high-speed relay specifically designed for short release time but not short long release time.
Fixed Contacts.-The stationary contacts of a relay which are engaged and disengaged by moving contacts to make or break circuits.
Flight Time. -Sometimes used for Transfer Time.
Follow-through Contacts.-Contacts which have contact follow.
Frame.-The structure on which the coil and contact assembly are mounted.
Front Contacts.-Sometimes used for the stationary contact of single-pole normally open contacts. (See Contact Nomenclature).
Front Contacts. -Same as Normally Open Contacts.
Gasket-sealed Relay.-An airtight relay, the sealing of which involves the use of a gasket which is not bonded to the other sealing material.
General-purpose Relay.-A readily available relay which has design. construction, operational characteristics, and ratings such that it is adaptable to a wide variety of uses.
Hand-reset.-A qualifying term applied to a relay indicating that following an operation the contacts must be reset manually to their original positions.
Header.-The part of a hermetically sealed relay through which the electrical terminals pass.
Hermetically Sealed Relay.-An airtight relay the sealing of which involves fusing or soldering but does not use a gasket.
High-speed Relay.-A relay specifically designed for short operate time, release time, or both.
Hold Values.-The hold current, voltage, or power is the minimum value for which the contacts of a previously energized relay will always maintain their energized positions.
Homing.-Homing is a qualifying term applied to a stepping relay indicating that the wipers, upon completion of an operational cycle, are stepped around or back to the start position.
Hum.-Hum, as applied to relays, is the sound caused by mechanical vibration resulting from alternating current flowing in the coil.
Impregnated Coils.-Coils which have been permeated with a phenolic or similar varnish to protect the coils from mechanical vibration, handling, fungus, and moisture.
Inductive Winding.-An inductive winding, as contrasted with a noninductive winding, is a coil having an inductance.
Instrument Relay.-A relay, the operation of which depends upon principles employed in electrical measuring instruments such as the electrodynamometer, iron-vane and D'Arsonval.
Interlock relay.-A relay composed of two or more coils with their armatures and associated contacts so arranged that the freedom of one armature to move or its coil to be energized is dependent upon the position of the armature.
Intermittent-duty Relay.-A relay which must be deenergized at occasional or periodic intervals to avoid excessive temperature.
Latch-in Relay.-A relay having contacts which lock in either the energized or deenergized position until reset either manually or electrically
Level.-As applied to a stepping relay, the term level is used to denote one bank or series of contacts.

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Level Contact.-Sometimes used for Movable Contact.
Looking Relay.-Sometimes used for Latch-in Relay
Low-capacitance Contacts.-A type of contact construction providing low intercontact capacitance.
Make Contact.-Same as Front Contact.
Magnetic Air Gap.-A magnetic air gap is a nonmagnetic portion of a magnetic circuit.
Magnetic Freezing.-The sticking of a relay armature to the core, after deenergization, due to the residual magnetism of the core.
Magnetic Switch.-Sometimes used for Relay.
Make-before-break Contacts.-Double-throw contacts so arranged that the moving contact establishes a new circuit before disrupting the old one.
Make Delay.-Sometimes used for operate time.
Marginal Relay.-A relay which functions in response to predetermined changes in the value of coil current or voltage.
Mercury-contact Relay.-A relay in which the contacting medium is mercury.
Motor-driven Relay.-A relay which is actuated by the rotation of the shaft of some type of motor, for example, a shaded-pole, induction-disk, or hysteresis motor.
Movable Contact.-A contact which, when the relay is energized or deenergized, is mechanically displaced to engage or disengage one or more stationary contacts.
Multiple-break Contacts.-contacts so arranged that, when they open, the circuit is interrupted in two or more places.
Multiple Pile-up.-An arrangement of contact springs which is composed of two or more separate Pile-ups.
Multiple Stack.-Same as Multiple Pile-up.
Neutral Relay.-A neutral relay, in contrast to a polarized relay, is a relay in which the movement of the armature is independent of the direction of flow of current through the relay coil.
Non-bridging.-A term used to describe to a contact transfer in which the movable contact leaves one contact before touching the next.
Non-homing.-A qualifying term applied to a stepping relay indicating that wipers, upon completion of an operational cycle, do not return to the home position, but are at rest on the last used set of contacts.
Non-inductive Windings.-A type of winding in which the magnetic fields produced by two parts of the winding cancel each other and provide a non-inductive resistance.
Non-magnetic Shim.-A non-magnetic material attached to the armature or core of a relay to prevent iron-to-iron contact in an energized relay.
Non-operate Value. -The non-operate voltage, current, or power is the maximum value for which the contacts of a previously deenergized relay will always maintain their deenergized positions.
Normal Position. -The usual deenergized position, open or closed, of contacts due to spring tension or gravity
Normal Sequence of Operation.-The sequence in which all the normally closed contacts open before closure of the normally open contacts of the assembly.
Normal-speed Relay.-A relay in the design of which no attempt has been made either to increase or decrease the operate time or the release time.

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Normally Closed Contacts.-A combination of a stationary contact and movable contact which are engaged when the coil is unenergized.
Normally Open Contacts.-A combination of a stationary contact and a movable contact which are not engaged when the coil is unenergized.
Off-limit Contacts.-Contacts on a stepping relay used to indicated when the wiper has reached the limiting position on its arc and must be returned to normal before the circuit can function again.
Off-normal Contacts.-Stationary contacts on a homing stepping relay used to indicate when the wiper is not in the starting position.
Operate Time.-If a relay has only normally closed contacts, its operate time is the longest time interval given by definition (a) below. If a relay has normally open contacts (regardless of whether or not it has normally closed contacts) its operate time is the longest time interval given by definition (b).

(a) **Operate Time for Normally closed Contacts. -**Operate time for normally closed contacts is the total elapsed time from the instant the coil is energized until the contacts have operated; i.e., the contact current is zero.

(b) **Operate Time for Normally Open Contacts**.-Operate time for normally open contacts is the total elapsed time from the instant the coil is energized until the contacts are closed and all contact bounce has ceased.

Operate Values.-Same as Pick-up Values.
Operating Frequency.-The rated a-c frequency of the supply voltage at which the relay coil is designed to operated.
Overload Relay.-A relay which is specifically designed to operate when its coil current reaches a predetermined value above normal.
Overvoltage Relay.-A relay which is specifically designed to operate when its coil voltage reaches a predetermined value above normal.
Partially Enclosed Relay.-A relay which has either contacts or coil (but not both) protected from the surrounding medium by a cover that is not airtight.
Partially Sealed Relay.-A relay which has either contacts or coil (but not both) sealed.
Pick-up Values.-The pick-up voltage, current, or power is the minimum value for which the contacts of a previously deenergized relay will always assume their energized position.
Pile-up.-A set of contact arms, assemblies, or springs placed one on top of the other with insulation between them.
Plunger Relay.-A relay operated by energizing an electromagnetic coil which in turn operates a movable core or plunger by solenoid action.
Polarized Relay.-A relay the operation of which is dependent upon the polarity of the energizing current.
Pole.-See Contact Nomenclature.
Pole Face.-The pole face is the part of the magnetic structure on the end of the core nearest the armature.
Pull-in Values.-Same as Pick-up Values.
Pull-on Values.-Sometimes used for Pick-up Values.
Ratchet Relay.-A stepping relay actuated by an armature-driven ratchet.

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Rated Coil Current.-The steady-state coil current at which the relay is designed to operate.
Rated Coil Voltage.-The coil voltage at which the relay is designed to operate.
Rated Contact Current. -The current which the contacts are designed to carry for their rated life.
Relay.-A device which is operated by variation in the conditions of one electric circuit to affect the operation of other devices in the same or other electric circuits by either opening circuits or closing circuits or both.
Release Factor. -The ratio, expressed in percent, of drop-out current to rated current or the analogous voltage ratio.
Release Time.-If a relay has only normally open contacts, its release time is the longest time interval given by definition (a) below. If a relay has normally closed contacts (regardless of whether or not it has normally open contacts) its operate time is the longest time interval given by definition (b).

(a) **Release Time for Normally Open Contacts.-**Release time for normally open contacts is the total elapsed time from the instant the coil current starts to drop from its rated value until the contacts have opened, i.e., the contact current is zero.

(b) **Release Time for Normally closed Contacts**.-Release time for normally closed contacts is the total time from the instant the coil current starts to drop from its rated value until the contacts are closed and all contact bounce has ceased.

Release Values.-Same as Drop-out Values.
Repeating Timer.-A timing device which upon completion of one operating cycle continues to repeat automatically until excitation is removed.
Residual Gap.-The length of the magnetic air gap between the pole-face center and the nearest point on the armature when the armature is in the energized position.
Residual Pins or Screws.-Nonmagnetic pins or screws attached to either the armature or the core of a relay to prevent the armature from directly contacting the magnetic core.
Residual Setting.-The value of the residual gap obtained by the use of an adjustable residual screw.
Residual Shim.-Same as Non-magnetic Shim.
Restoring Spring.-A spring which, when the relay is deenergized, moves the armature to and holds it in the normal position.
Retractile Spring.-Sometimes used for Restoring Spring.
Rotary Relay.-Sometimes used for Motor-driven Relay.
Rotary Stepping Relay.-Same as Stepping Relay.
Rotary Stepping Switch.-Same as Stepping Relay.
Sealed Relay.-A relay which has both coil and contacts enclosed in an airtight cover.
Self-cleaning Contacts.-Sometimes used for Wiping Contacts.
Selector Relay.-A relay capable or automatically selecting one or more circuits from a number of circuits.
Sequence Control.-The automatic control of a series of operations in a predetermined order.

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Sequence Relay.-A relay which controls two or more sets of contacts in a definite predetermined sequence.
Shading Coil.-Sometimes used for Shading Ring.
Shading Ring.-A shorted turn surrounding a portion of the pole of an alternating current magnet, causing a delay of the change of the magnetic flux in that part, thereby preventing contact chatter.
Slave Relay.-Sometimes used for Auxiliary Relay.
Slow-operate, Fast-release Relay.-A relay specifically designed for long operate time and short release time.
Slow-operate Relay. -A slow-speed relay which has been specifically designed for long operate time but not for long release time.
Slow-operate, Slow-release Relay.-A slow-speed relay specifically designed for both long operate time and long release time.
Slow-release Relay.-A slow-speed relay specifically designed for long release time, but not for long operate time.
Slow-speed Relay.-A relay specifically designed for long operate time, release time, or both.
Slug.-In a relay a slug is a highly conductive sleeve placed over the core to aid in retarding the established or decay of flux within the magnetic path.
Solenoid Relay.-Sometimes used for a Plunger Relay.
Solid State Relays.-Relays that use various low-power components - diodes, transistors, and thyristors, and associated resistor and capacitors. These components are designed into logic units used in many ways.
Special-purpose Relay.-A relay which has an application that requires special features which are not characteristic of the conventional general-purpose or definite-purpose relay.
Specified duty Relay.-A relay which is designed to function with a specified duty cycle but which might not be suitable for other duty cycles.
Spring Buffer.-A bearing member made of insulating material which transmits the motion of the armature to the movable contact and from one movable contact to another in the same pile-up.
Spring Pile-up.-Same as Pile-up.
Spring Stud.-Same as Spring Buffer
Stack.-Same as Pile-up.
Stationary Contact.-A contact member which is rigidly fastened to the relay frame and which is not moved as a direct result of energizing or deenergizing the relay.
Stepping Relay.-A relay the contacts of which are stepped to successive positions as the coil is energized in pulses. Some stepping relays may be stepped in either direction. (The Stepping Relay is also called a Rotary Stepping Switch or a Rotary Stepping Relay.)
Telephone-type Relay.-Sometimes used for an armature relay with an end-mounted coil and spring pile-up contacts mounted parallel to the long axis of the relay coil.
Tension Spring.-Sometimes used for Restoring Spring.
Thermal Relay.-A relay which is operated by the heating effect caused by electric current flow.
Throw.-See Contact Nomenclature.

Appendix B

Time-delay Relay.-A relay in which a delayed action is purposely introduced.
Timing Relay.-A motor-driven time-delay relay.
Transfer Time.-The total elapsed time between the breaking of one set of contacts and the making of another set of contacts.

(a) **Transfer Time on Operate.-**The transfer time on operate is the total elapsed time from the instant the normally closed contacts start to open until the normally open contacts are closed and all contact bounce has ceased.

(b) **Transfer Time on Release.-**The transfer time on release is the total elapsed time from the instant the normally open contacts start to open until the normally closed contacts are closed and all contact bounce has ceased.

Transit Time.-Same as Transfer Time.
Trip Values.-The trip voltage, current, or power is the rated value at which a bistable polarized relay will transfer from one contact to another.
Undercurrent Relay.-A relay specifically designed to function when its coil current falls below a predetermined value.
Undervoltage Relay.-A relay specifically designed to function when its coil voltage falls below a predetermined value.
Unenclosed Relay.-A relay which does not have its contacts or coil protected from the surrounding medium by a cover.
Winding.-Same as Coil.
Wiper.-A moving contact on a stepping relay.
Wiping Contacts. - Contacts designed to have some relative motion during the interval from the instant of touching until completion of the closing motion.

Unitil
System Policy

Substation Maintenance Policy - **Infrared Survey**

Policy Number: 3.08

To: **UES, Unitil-MA** as follows:
Engineering Management, Operations Management ,and Supervisory Personnel

From: **John J. Bonazoli**

Effective: 11/1/00
Revision: 4/27/04

PURPOSE

The purpose of this policy is to provide a guideline for infrared surveying of electrical substations. Regularly scheduled infrared surveys of electrical connections can eliminate failures by detecting potential problems, and allowing time for repair before these problems become failures.

SCOPE

The scope of this policy is to provide recommended frequency intervals for surveying, and to provide a recommended time frame for the resolution of problems found during the survey.

SURVEY SCHEDULE

Infrared surveying has proven to be a safe, fast, and reliable method of non-contact inspection that can be performed any time without shutdown of the electrical facilities. Experience has proven the technical worth and economic justification of infrared survey as a preventative maintenance tool.

It is recommended that infrared surveys be performed by experienced personnel during periods of heavy loading, preferably during the summer peak load demand period between July 1st and September 1st, to reveal existing or potential connection problems, and transformer problems such as blocked radiators, low oil levels, etc.

A qualified company representative shall accompany the infrared surveyor during the survey. The company representative shall be familiar with substation equipment.

The recommended survey schedule is as follows:

- Major Substations - Survey every two years.
  Examples of major substations are system supply point stations, transmission switching stations, and large distribution stations.

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- Minor Substations - Survey every four years.
  Examples of minor substations are small distribution substations.

- New Substations - Survey after energization and with load.

- Repaired or Modified Substations - Survey within one year after significant repairs or modifications were made.

REPAIR SCHEDULE

The criteria listed below have been determined by past field experience throughout the industry for scheduling repairs of identified problems. The final decision for priorities and order of maintenance should be determined by the degree of temperature rise and critical nature of the equipment or system involved.

Temp above reference, deg C (see note below)	Temp above reference, deg F	Priority Level	Degree of Severity	Repair Schedule (Failure probability)
> 70	>126	1	Critical	Immediate (Failure imminent)
31 – 70	55 - 126	2	Serious	Within 1 week (Failure certain)
11 – 30	19 - 54	3	Moderate	Within 1 month (Failure probable)
1 – 10	1 - 18	4	Advisory	During regular maintenance (Failure improbable)

Notes:
"Temperature above reference" is the temperature of the higher temperature connection in question compared to the temperature of the same device of an adjacent phase.

Example - Phase A and B connections are measured as 40 degrees C, and phase C is measured as 80 degrees C.
Phase C is 40 degrees C above reference (Phases A & B), making the phase C connection a priority 2, or serious problem with failure certain.

Problems found in the serious and critical ranges shall be reported immediately.

REQUIRED REPORTS

The following documentation for each problem device shall be included in a final report following the infrared survey:

- Company name, substation name, device and phase designation;
- Photographs of the problem device as viewed by the infrared camera (infrared spectrum), and as viewed by a normal camera (visible spectrum);
- Device, reference, and ambient temperatures in degrees C;
- Time and date.

The final report shall be received within two weeks after the field survey has been completed.

Problems found in the serious and critical ranges shall be reported immediately.

Unitil

Operations Bulletin #OP3.12

SUBJECT: Substation Batteries
EFFECTIVE: 12/1/00

ISSUED BY: G. Appleton
CONTENT BY: S. Baker, T.Biklen, M Deschambeault, P.Stagno, A. Zogopoulos, R. Bisson

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1.0 PURPOSE

- To provide a uniform method for inspecting, maintaining and testing substation Batteries within the Unitil system
- To ensure the integrity of the equipment
- To ensure the safe operation of the system
- To establish requirements for record keeping and performance measures to identify problems and analyze trends.

2.0 SCOPE

These maintenance guidelines apply to all substation Batteries, refer **to Unitil Substation Maintenance/Testing Policy (USM/TP) 3.12 Storage Battery Maintenance & Principles** for specific and additional information. Where battery waste needs to be handled or processed consult Engineering for additional instructions.

3.0 MAINTENANCE/TEST CATEGORY and FREQUENCY

3.10 Monthly Maintenance - Routine inspections and readings to be performed monthly.
3.20 Annual Maintenance - Extensive inspections and testing to be performed annually.
3.30 Five Year Maintenace – Additional extensive tests performed once every five years.
3.40 Optional Maintenance/Tests - Additional maintenance/tests useful in identifying problem conditions. Refer to Policy 3.12
3.50 New Battery Tests - Testing and inspection of a new Battery when it arrives, after installation, and during the warranty period. Refer to Engineering Acceptance Procedures

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4.0 MONTHLY MAINTENANCE

The purpose of monthly maintenance is to make sure the batteries are operating within its design limits, tabulate readings, and inspect for damage or leaks. All values should be recorded, not just looked at, to see if they are out of limits. Limits should be set for all readings where practical. Refer to Unitil Substation Maintenance/Testing Policy (USM/TP) 3.12

4.10 Visual inspections are made to assess the general condition of the battery, battery room, and safety equipment.

a. Check for general cleanliness of the battery, mounting rack, and battery room. Check for electrolyte leaks and cracks in cells, and take corrective action if any are found.
b. Check for corrosion at terminals, connectors, racks, and cabinets.
c. Check the ambient temperature and make sure ventilation devices (fans & vents) are operable.
d. Check the electrolyte levels and correct if necessary.
e. Check for availability and condition of all safety equipment, gloves, aprons, facceshields, etc.
f. Check for a full gallon of labeled neutralizing solution, operability of eyewash stations or portable eyewash equipment.
g. Check for a class C Fire extinguisher and check that it has been inspected and tested according to schedule.
h. Check for availability of insulated tools and utensils so short circuits can be avoided.
i. Check the hydrometer for ceanliness and cracking of rubber parts.

4.20 Check the Battery Voltage. Take the voltage across the overall battery terminals with an accurate digital meter and compare this reading with the charger and the bus voltmeters. If needed, adjust the charger float voltage based on the digital meter. Adjust the charger and/or bus voltmeters to agree with the digital meter if needed. The voltmeter used must be very accurate. An inaccurate meter can result in either over or undercharge and resulting problems, which reduce life and service of the battery.

a. Check the pilot cell float voltage with digital voltmeter and record
b. Take the Specific Gravity reading of the pilot cell and record
c. Record the pilot cell temperatures.

5.0 ANNUAL MAINTENANCE

The purpose of annual maintenance is to do a thorough inspection and testing of all critical equipment. This should include a review of data since the last annual maintenance to look for trends or potential problems. In addition to the following the monthly maintenance is also required.

1. Check all cells with a digital voltmeter.
2. Check Specific Gravity readings for all cells.
3. Check Connection Resistance on all connections.
4. Capacity Discharge Test if prior testing results were less than 90%.

6.0 5 YEAR MAINTENANCE

The purpose of this maintenance is to do a thorough inspection and testing of all critical equipment. This should include a review of data since the last monthly and annual maintenance to look for trends or potential problems. In addition to the following the monthly and annual maintenance is also required.

1. Capacity Discharge Test

7.0 OPTIONAL MAINTENANCE/TESTS

There are many different types of batteries and battery systems. Each require specific maintenance and testing to ensure full optimum life expentancy. USM/TP 3.12 Storage Battery Maintnenace and Principals shall be referenced and followed if any questions should arise.

8.0 NEW BATTERY TESTS

Testing of a new Battery installation is to be performed during the warranty period to verify it will operate as guaranteed.

1. Visual - A very extensive visual inspection should be performed when the Batteries are received to verify no damage in transit and that no leaks have developed.
2. Electrical - Verify and test, where possible, all electrical control, monitoring and alarm circuitry.
3. Refer to Engineering Acceptance Test Recommendations

Operations Bulletin #OP3.13

SUBJECT: Insulation Oil Analysis
EFFECTIVE: 8/10/2001

ISSUED BY: G. Appleton
CONTENT BY: R. Bisson, T.Biklen, M Deschambeault, P.Stagno, S.Shepard

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1.0 PURPOSE

This bulletin is written to establish procedures for periodic testing of electrical insulating mineral oils. Specifically, this bulletin establishes the tests to be performed, the equipment to be tested, the intervals and time frames that tests are to be performed, the testing and reporting format, the methods for taking oil samples, and the technical standard.

2.0 TESTS TO BE PERFORMED

When performing dissolved gas-in-oil analysis, gas levels are to be determined in parts-per-million (ppm). When performing dissolved gas-in-oil analysis the following tests shall be included:

- Acetylene (C_2H_2) content (combustible)
- Carbon Dioxide (CO_2) content
- Carbon Monoxide (CO) content (combustible)
- Ethane (C_2H_6) content (combustible)
- Ethylene (C_2H_4) content (combustible)
- Hydrogen (H_2) content (combustible)
- Methane (CH_4) content (combustible)
- Nitrogen (N_2) content
- Oxygen (O_2) content
- Total Gas content (calculated)
- Total Combustible Gas content (calculated)

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When performing fluid quality tests the following tests shall be included:

- ASTM D1500 Color
- ASTM D877 Dielectric Strength
- ASTM D971 Interfacial Tension
- ASTM D974 Neutralization Number
- ASTM D4059 Polychlorinated Biphenyl (PCB) content (optional as appropriate)
- ASTM D924 Power Factor @ 25°C (optional)
- ASTM D924 Power Factor @ 100°C (optional)
- ASTM D1298 Specific Gravity (optional)
- ASTM D1524 Visual (optional)
- ASTM D1533 Water

3.0 EQUIPMENT and TIME INTERVALS TESTING

- **Annual Testing and Interval Maintenance**

  Dissolved gas-in-oil analysis tests and fluid quality tests shall be scheduled and performed on equipment containing insulation oil as specified in the equipment specific Operations Bulletin. Additionally, fluid quality tests shall be performed on all substation and line equipment, containing insulation oil, whenever overhaul maintenance is scheduled to be performed on such equipment. The below listed process shall be followed when performing insulation oil analysis.

  Process

  1. Operations personnel shall draw oil samples for annual testings during the year.

  2. All scheduled annual oil samples are to be obtained and sent to a certified testing laboratory by November 1st of each calendar year. (applies to scheduled testing only).

  3. The certified laboratory shall send the tests results to Operations for processing.

  4. Samples analyzed for visual color and dielectric strength may be performed, analyzed and recorded by Operations personnel.

  5. Operations will forward one copy of the tests results to Engineering.

  6. Engineering shall review the results and submit a written report to Operations with recommendations. Engineering shall submit the written report by March 1st of the following year. (applies to scheduled testing only).

  7. Operations shall review all the test results and shall review the recommendations as submitted by Engineering.

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8. Operations shall schedule and priortize all work required to correct equipment conditions identified during oil analysis.

9. Operations shall be responsible to insure that all annual and scheduled maintenance oil sampling and testing is completed.

10. Operations shall be responsible for maintaining a permanent record of all insulation oil testing, analysis and reports.

4.0 TESTING and REPORTING FORMAT

Oil samples, except for tests that may be performed by Operations personnel, are to be sent to a certified testing laboratories for analysis. The laboratory is to perform all tests in accordance with the ASTM testing procedures as specified for each test. A written report is to be submitted to the company defining the results of the tests. A separate test sheet shall be prepared for each piece of equipment tested. Separate test sheets shall be prepared for the main tank oil analysis and for the LTC compartment oil analysis for transformers equipped with Load Tap Changers. The laboratory report shall include previous years tests results (as available) with the current oil sample test results. Data and test results are to be presented both numerically and in graphical form. Operations shall be responsible for maintaining a permanent record of all insulation oil testing, analysis and reports.

5.0 OIL SAMPLING PROCEDURES

- **General**

  This section of the bulletin is written to specify the procedure obtaining oils samples from electrical equipment for electrical insulating oil analysis.

- **Considerations**

1. The sample collected must be protected from all possible contamination. Samples which are exposed to ambient air should be collected only when the oil is at least as warm as the outside air and when the relative humidity is less than 70%. Cold oil will condense moisture from the outside air which will contaminate the sample. When collecting samples outdoors, it is important to prevent contamination from wind blown dust and other airborne particles.

2. Unrepresentative samples are often obtained when sampling electrical apparatus using the sample ports mounted on drain valves without appropriate preparation. The flow allowed by these small ports is not adequate to properly flush the drain valve and drain valve extension of the electrical apparatus. The fluid in the drain

valve and extension remains quite dormant during normal operation of the equipment and can be contaminated with stem packing and moisture. Obtaining a sample using these ports can result in the sample not being a true representation of the insulating fluid contained in the electrical apparatus.

3. The desired location of sample outlets on electrical apparatus for various types of insulating fluid may differ due to the specific gravity of the fluid. In fluids with a specific gravity greater than 1.0, such as askarels or other heavy oils, free water will separate out on top of the oil thus top sampling is desirable. In mineral oils with a specific gravity of less than 1.0, free water separate out below the oil thus bottom sampling is desirable.

4. When equipment and oil temperature is below freezing, samples drawn should not be tested for water content or tested for properties which are affected by water content such as dielectric breakdown voltage and power factor. Samples taken when the liquid temperature is below freezing can not be accurately tested for moisture content.

5. Electrical insulating oils may contain polychlorinated biphenyls (PCB's) which are regulated substances. All appropriate federal, state and local regulations that apply should be followed when handling these fluids.

6. Caution must be taken when samples are drawn from electrical apparatus having small volumes of insulating fluid. The insulating fluid within the electrical apparatus being sampled must be maintained at a level that will not reduce the dielectric strength of the insulation system.

7. Electrical apparatus, when sampled, must have a positive pressure at the sample outlet so as not to admit an air bubble into the electrical apparatus during the sampling process. Electrical apparatus must not be sampled if a negative pressure exists at the sample outlet.

- **Electric Apparatus Preparation**

1. Electrical apparatus, when sampled, must have a positive pressure at the sample outlet. Positive pressure will prevent any air bubble from entering the electrical apparatus during the sampling process. Energized electrical apparatus must not be sampled if a negative pressure exists at the sample outlet.

2. Electrical apparatus should not be sampled if only a drain plug is provided as an adequate control of liquid flow could result.

3. Verify positive pressure at a sample outlet by using a pressure gauge or by placing a slug of insulating fluid in a piece of clear plastic tubing and attaching it to the sample outlet. When using a slug of insulating fluid observe the direction that the slug of insulating fluid moves as the sample outlet valve is slightly opened. If the slug moves towards the electrical apparatus, a negative pressure exists. Sampling should be

discontinued. If the slug moves away from the electrical apparatus, a positive pressure exists. Care should be used in performing this procedure. A small quantity of air may be present in the valve. Alternately raising and lowing the plastic tubing should allow the oil to displace the air. The small internal diameter of the plastic tubing greatly amplifies the movement of the insulating fluid and permits fine control over the fluid's movement. Air intake into the transformer is prevented. Reducing the internal diameter of the plastic tubing will result in greater control of the process.

4. Place a flush oil container under the main drain valve and remove the security pipe plug from the valve outlet port. Wipe the inside of the valve and threads with a clean lint free cloth. Drain at least two quarts of fluid into the flush oil container to flush the drain valve and drain valve extension. One of two procedures may then be used to prepare the sample outlet.

    1. Procedure A – Install a sample adapter on the drain valve (suitable thread size bushing adapter IPS to 3/8" bayonet) with a piece of oil resistant tubing attached. Flush the valve and installed sample adapter by allowing at least one more quart of fluid to flow into the flush oil container before collecting sample.

    2. Procedure B – Install the drain valve security plug. Attach oil resistant tubing to the sample port on the drain valve and flush at least one more quart of fluid into the flush oil container before collecting the fluid in the sample container.

- **Dissolved Gas-In-Oil and Water Content Analysis**

1. Glass syringes shall be used for collecting samples to be analyzed for dissolved gases or moisture content of insulating fluid. The glass syringe shall be of good quality precision ground piston-to-barrel fit with dependable three way stopcock are mandatory. Glass syringes with interchangeable pistons and barrels are not acceptable for use. The glass syringe should be sized for the volume of insulating fluid required for the proposed tests. The amount of insulating fluid required can be obtained by consulting the laboratory performing the analysis.

2. Sample glass syringes must be thoroughly cleaned. Only glass syringes received in sealed packaging shall be used for obtaining oil samples. Non-sealed packaged syringes or unclean syringes shall not be used to obtain oil samples.

3. Glass containers or glass bottles shall ***NOT*** be used to obtain oil samples that are to be used to determine dissolved gas content or water content.

4. Positive identification of the samples to be collected is essential. Accepted methods of identification are:

    - Prepare numbered labels and securely attach labels to the sample syringes and record the pertinent sample information.

- Fasten tags that contain complete sample identification securely to the sample containers. Labels should, at a minimum, identify the manufacturer of the equipment, the serial number, temperature of oil sampled, and the date sampled.

- **Sampling Electrical Apparatus Using Glass Syringe (dissolved gas-in-oil analysis and water content analysis):**

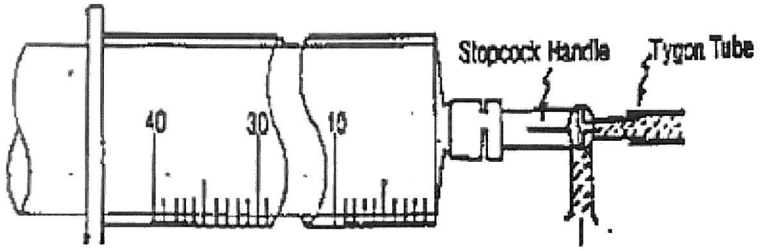
1. Obtain a clean glass syringe and complete top section insulating oil screen test form including the syringe number.

2. Make sure apparatus to be sampled is under positive pressure.

3. Connect the Tygon tubing to the sample valve and drain at least one quart of oil to flush the valve.

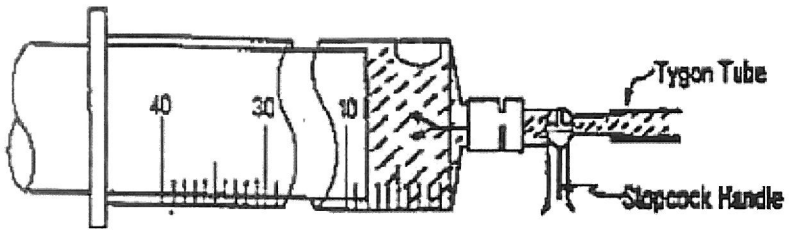
4. Connect the syringe to the tubing with the syringe stopcock handle pointing toward the syringe (Figure 1). Note: The handle of the plastic stopcock always points to the closed port leaving the other two ports open.

   Figure 1



5. Turn the stop cock slowiy to the open position (Figure 2. Handle in line with the flushing port) and allow 50cc of oil to enter the syringe. Immediately close the stopcock (Figure 1, handle toward the syringe).

   Figure 2



6. With the syringe held vertical, turn the stopcock up (Figure 3, handle away from the syringe), carefully depress the syringe piston to leave 1-2cc of oil in the syringe. This step is to flush the syringe and to eject any air bubbles.

   Figure 3

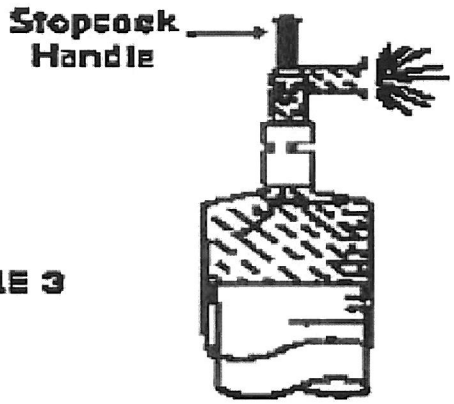


FIGURE 3

7. Open the stopcock (Figure 2) and allow oil pressure to push the piston back until the syringe is filled to approximately the 40cc mark.

8. Close the stopcock (Figure 1) and separate it from the tubing. Inspect the sample for air bubbles. If any are present, discharge oil and repeat steps 4-8.

NOTES: Care should be taken to shield the filled syringe from light, and adequate precaution should be taken to avoid breakage in transit.

Bubbles may form after sampling but, provided the sample was bubble-free initially, this will not affect subsequent analysis. Don't remove these bubbles.

- **Fluid Quality Tests**

1. Glass containers or glass syringes shall be used for collecting samples to be analyzed for fluid quality testing of insulating fluid.

2. Glass containers are the preferred container for obtaining oils samples used in fluid quality testing. The glass container shall be clear glass with glassed stopper or fitted with screw type caps having a pulp-board liner faced with tin or aluminum foil or with a suitable oil-resistant plastic liner. The glass container shall be amber colored glass if the sample is to be subjected to light or if the sample is to be stored for a period of time.

3. Only clean, uncontaiminted glass containers shall be used for obtaining oil samples. Do not re-use screw type glass container covers.

4. Glass syringes shall be of the same type and quality used to obtain oil samples for dissolved gas-in-oil analysis and water content analysis. Sample glass syringes must be thoroughly cleaned. Only glass syringes received in sealed packaging shall be used for obtaining oil samples. Non-sealed packaged syringes or unclean syringes shall not be used to obtain oil samples.

5. Positive identification of the samples to be collected is essential. Accepted methods of identification are:

    - Prepare numbered labels and securely attach labels to the sample syringes and record the pertinent sample information.

    - Fasten tags that contain complete sample identification securely to the sample containers. Labels should, at a minimum, identify the manufacturer of the equipment, the serial number, temperature of oil sampled, and the date sampled.

- **Sampling Electrical Apparatus Using Glass Container (fluid quality test):**

1. Perform the steps in preparation for sampling.

2. When collecting the sample in a glass container, hold the container so that the sample will run down the side to limit aeration of the fluid.

3. Partially fill the container several times with oil and slosh the fluid around to warm and rinse the container. Discard the fluid after each rinse.

4. Obtain the sample for evaluation by allowing the fluid to flow down the sides of the container. Once the container is full, install the cover immediately. A free space of one inch should be left in the container when samples are obtained in cold weather.

5. Close the drain valve, remove the sampling adapter and install the drainvalve security plug with a non-hardening sealant.

- **Sampling Electrical Apparatus Using Glass Syringe (fluid quality test):**

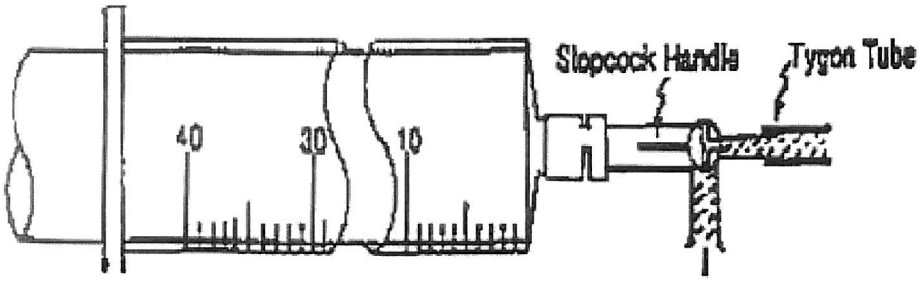
1. Perform the steps in preparation for sampling.

2. When collecting samples with glass syringes for the determination of dissolved gases and/or water content, the glass syringe should be filled to the 40-cc mark. The filled syringe should contain no air. However, gas saturated samples will begin to release gases soon after sampling. Do not release any evolved gases since these

gases must be included in the dissolved gas analysis. The filled syringe should be packaged as soon as possible to protect the sample from light.

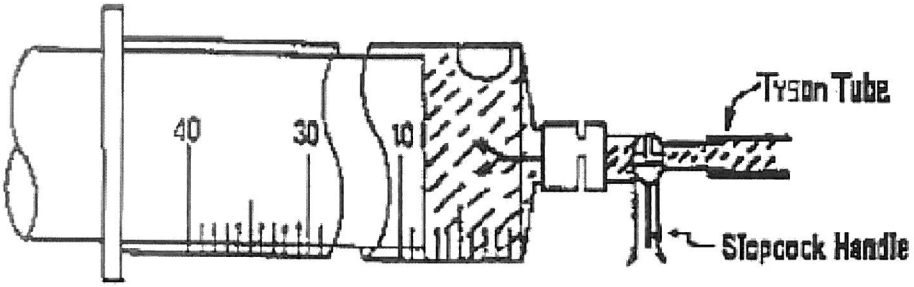
3. Adjust the equipment drain valve or the sample port valve for a gentle flow of fluid through the tubing with the syringe stopcock open (Figure 1) to permit flushing of the stopcock (handle toward the syringe). (Note: The handle of the plastic stopcock always points to the closed port leaving the other two ports in open communication.)

Figure 1:



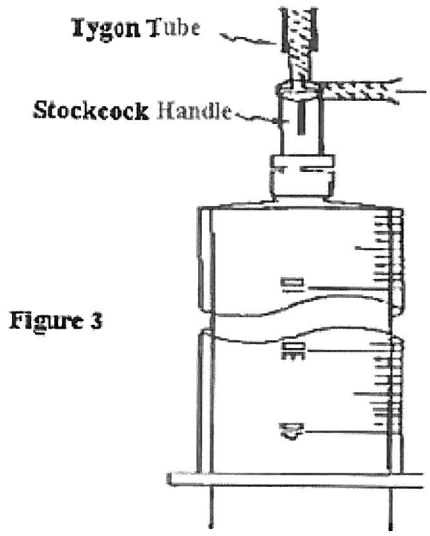
4. Turn the stopcock slowly to the open position (Figure 2, handle in line with the flushing port) and allow 5 to 10 cc of fluid to enter the syringe. Immediately close the stopcock (handle toward the syringe) and separate from the tubing. Allow the fluid to continue to flow from the tubing (or hole).

Figure 2:



5. With the syringe vertical (Figure 3, stopcock up, handle away from the syringe), eject any air bubles and carefully depress the syringe piston far enough to leave 1-2 cc of fluid in the syringe. (If all of the fluid is evacuated from the syringe, there is a greater chance of an air leak.) Close the stopcock (handle toward the syringe).

Figure 3:



6. The syringe, bubble-free, and with its dead volume filled with fluid, is now reconnected to the tubing (Figure 4). To eliminate any possibility that air may be entrapped in the valve, let the fluid flow through the flushing port before the valve is turned to allow the syringe to be filled.

7. Open the stopcock (Figure 2, handle in line with flushing port) and allow fluid pressure to push the piston back until the syringe is filled to approximately the 40 cc mark. Do not pull the piston manually since this can result in bubble formation.

8. Close the stopcock (Figure 3, handle toward syringe) and separate it from the tubing and inspect for air bubbles. If air is present, discharge oil with syringe vertical (stopcock up) and obtain another sample.

9. Remove the sample adapter if used, and install the security plug with a non-hardening sealant.

6.0 TEST RESULTS STANDARDS

Insulation oil analysis of electric equipment is performed utilizing different criteria and analysis techniques. Historically, the most reliable analysis uses a comparison of the current oil test results with previous year test results for a given piece of equipment. This trending of insulation oil performance facilitates the evaluation of equipment oil quality of and insulation system integrity over a period of time. Degradation of oil and insulation within the equipment can be monitored and tracked over time.

Currently two technical analysis criteria for insulation oil evaluation: IEEE limits and rules and the most recently adopted new rules associated with IEC limits are being used. Both sets of limits provide appropriate guidelines and are accepted as industry standards. Other methods including Rogers Ratio Method or specific equipment manufacturer's method have also be used when performing oil analysis on specific pieces of equipment.

It is realized that no one set of industry or published guidelines can provide a completely accurate and comprehensive method of analysis. The use of these criteria and standards in addition to experience and trending analysis will continue to be used when evaluating insulation oil analysis results for specific equipment.

Unitil

Operations Bulletin #OP3A.14

SUBJECT: Substation Monthly V&O Inspection
EFFECTIVE: 11/1/00

ISSUED BY: G. Appleton
CONTENT BY: S. Baker, T.Biklen, M Deschambeault, P.Stagno, A. Zogopoulos, R.Bisson

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1.0 PURPOSE

- To provide a uniform method for maintaining and inspecting substations within the Unitil system
- To ensure the integrity of the equipment
- To ensure the safe operation of the system
- To establish requirements for record keeping and performance measures

The following procedure describes how to properly complete a Monthly Substation - V&O Inspection, using a Substation - V&O Inspection Report form.

V&O (Visual and Operational) Inspection of each Substation and Switchyard is a key element in the Unitil preventive maintenance program. V&O Inspections are performed with the apparatus in service and are designed to detect abnormal conditions before the apparatus is damaged or a customer outage occurs. Data collected during the V&O Inspection is one of the items used to prioritize individual apparatus for further investigation.

This procedure is based on the philosophy that a "qualified employee" will be utilized to perform the V&O Inspection and in conjunction with the inspection minor problems will be repaired as they are found. One person may perform this procedure alone. In some instances, certain criteria may not be applicable due to operational or staffing differences between operating companies.

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C. Substation - V&O Inspection Report.....Example A

D. Substation - V&O Inspection Checklist.....Example B

2.0 SCOPE

These inspection guidelines apply to substations with a primary voltage up to 69 kV.

PROCEDURE

1.0 Safety and Entering Property

1.1 Lower Antenna on Vehicle
Before entering a substation or switchyard, care shall be taken to see that the antenna is well clear of any conductors or equipment with which it may come in contact.

1.2 All Company Safety policies and Procedures should be reviewed and followed.

1.3 Check Yard –
Quick inspection for anything broken, vandalized, grounds cut or removed, noises, fence condition, gates, locks, warning signs, alarms.

1.4 Notify the Control Authority/Dispatcher –

Inform them of the V&O Inspection and of alarm testing. Check the station on-schedule and for abnormal conditions.

2.0 Report Heading

During the V&O Inspection all abnormal conditions should be marked in pen or pencil, this includes check blocks. Abnormal check blocks should also be explained under remarks.

2.1 Substation
Fill in the complete name and number of the substation being inspected.

2.2 Inspected by
Fill the names of the person or persons performing the inspection.

2.3 Sheet
Number each sheet used in the inspection and put the total pages used for the station on all sheets.

2.4 Date
Fill in date of V&O Inspection.

2.5 Time
Record starting time of inspection including am/pm. The time helps coordinate the information and its meaning.

2.6 Ambient Temperature
Record the general outside temperature. The temperature is required for gas circuit breakers and power transformers.

2.7 Control House Temperature
Record the inside control house temperature.

3.0 Control House

3.1 Station Log Book – (where applicable)

a) Enter the date, time and employee names that are performing the V&O Inspection.
b) Check the Station Log Book for abnormal conditions that can be corrected during the V&O Inspection.
c) After the V&O Inspection, record in the Log Book, all abnormal problems found, corrected or not.

Note: Record anything abnormal and notify supervisor of major problems.

3.2 Control Panels -

a) Indicating Lights - Check that the indicating lights are working on the Control Board. Check the available stock of spare bulbs; stock as necessary.
b) Inspect rear of Control boards for any signs of overheating, burned wiring, moisture, etc.
c) Noises - Listen for any unusual noises from relays, panels
d) Relay Targets - (for control panel mounted relays)

    1) Check for relay targets or alarms on the control boards.
    2) Record targets and alarms on the V&O Report with the apparatus effected and in LogBook. Be sure to indicate phase and type of relays or alarm descriptions.
    3) Reset and report relay targets and alarms to the Control Authority/Dispatcher and supervisor.

If relays are located in breaker cabinet, this should be done during the Breaker Inspection (7.3).

e) Reclosing Relay - Check that reclosing relay and/or switch is in the normal position and that the relay is in the start or zero position.

    1) If blocked with a DO NOT OPERATE tag, currently dated. Note, but leave blocked.
    2) If blocked without a tag or with an out dated tag, notify the Control Authority and/or supervisor.

f) Ground Trip - Check that ground trip switch is normal position.

    1) If locked with a DO NOT OPERATE tag, currently dated. Note, but leave blocked.
    2) If blocked without a tag or with an out dated tag, notify the Control Authority and/or supervisor.

3.3 Annunciator - (where applicable)

a) Annuciator panel

    1) Move toggle switches that are not tagged to the test position to check lights (this will send an alarm to dispatch).
    2) To clear trouble condition, turn the toggle switch to the reset position.
    3) Leave toggle switches in the on position.
    4) Any switches found in the off position or tagged, check with supervisor before testing.

3.4 Tags and Switching Order Pads - (where applicable)

a) Check the available stock of Operating Tags, stock as necessary.

ORANGE Tags
RED Tags
BLUE Tags
WHITE Information Tags

b) Check the stock of Switching Order Pads, stock as necessary.
c) Check that pens and pencils are available, stock as necessary.

3.5 Lighting
a) Inspect lighting in control house; replace any burned out bulbs. Note if not working.
b) Test emergency lighting.

3.6 Heaters
Inspect heaters and thermostats for proper operation. Make sure fans are not broken or bound up and they are in good working order.

3.7 Station Service and Transfer Switch
a) Transfer Switch - Check transfer switch to be on preferred supply and any signs of trouble or overheating.
b) AC and DC Panels - Check that switches or circuit breakers are in the proper position.

3.10 Switch Sticks
a) Inspect Switch Sticks for damage and proper operation.
b) Switch Sticks should be stored properly and cleaned if necessary.

3.11 Fire Equipment
a) Inspect fire extinguishers to be properly stored in their marked locations. Update inspection cards.
b) Note any out of date fire extinguishers on the V&O Report for future replacement.

3.12 Emergency Plan Posted - (if applicable)
a) Check that the notification list is posted.
b) Check that the Emergency Plan is available at the substation.

3.13 Emergency Equipment Checklist - (where applicable)

Check that oil spill clean-up equipment is available and in good condition.

3.14 Phone Lists Updates
Check that local area cards and Control Authority/Dispatcher cards are updated and posted to ensure that phone numbers are available for switching and trouble calls.

3.15 Clean and General Condition - (where applicable)
a) Clean control house floors, facilities, empty waste baskets and dust switchboard.
b) Inspect for water leaks in roof and walls.
c) Check for signs of animal entry into control house.
d) Report panel or cabinet covers, which may have been removed during maintenance, or trouble.
e) Put on yard lights, so they can be checked during the Yard Inspection.

4.0 Battery & Charger

All Company Safety policies and Procedures should be reviewed and followed.

Note: Do not smoke or introduce any flames or sparks near the battery area.

4.1 Reference Number or Designation
Check and record proper designation of battery, such as #1 Battery, Reference Number assigned. Some stations have more than one battery in the control house or other locations.

4.2 Voltage Rating
Record voltage rating of the battery bank. This is another way to determine which battery is being inspected.

4.3 Pilot Cell -
a) Cell Number - Check and record the cell number of the pilot cell.
b) Temperature - Check and record the temperature of pilot cell. This represents the battery temperature.
c) Specific Gravity - Check and record specific gravity of pilot cell. Never add water before taking specific gravity readings.
d) Volts - Check and record pilot cell voltage.

4.4 Charger -
a) Load Amps - Check and record constant load amps on charger ammeter.
b) Float Voltage - Check and record float voltage on charger voltmeter. If the float voltage is above or below the required value, it should be noted on the V&O Report.

4.5 Grounds

Check and record voltage to ground indicators on charger in positive and in negative direction. Any severe grounds should be investigated and recorded in red pen in the logbook and on the V&O Report.

4.6 Overall - (where applicable)

a) Volts -

1) Turn off charger's AC supply. Wait for 2 minutes.
2) Check and record the over-all battery voltage.
3) Turn on charger's AC supply and make check of it's operation.

b) Liquid level - Check each cell for proper electrolyte level. The proper amount is between high and low level mark on the battery. Add distilled water to each cell that is low. Record any abnormal amount of distilled water added to the battery.

4.7 Equalize charge

If water was added or specific gravity of pilot cell was low, the battery should be equalized in accordance with company policy.

Note: Charger should be checked the following day to see if cycle was completed and battery came up to proper voltage and charger return to float level.

4.8 Checklist -

a) No Smoking Sign - Check that a No Smoking sign is in the vicinity of battery area. If not, signs should be ordered.
b) Eye Wash Bottle - Check that an Eye wash bottle is located in the vicinity of batteries. Check that the bottle is unopened and that the expiration date is not expired. (three years from date on bottle) Replace if necessary.
c) Vent Caps/Arresters - Check that the vent caps or flame arresters and dust caps are properly installed and are clean and dry.
d) Connections - Check each terminal post for any corrosion, dirt, moisture or accumulation of power. Clean as necessary. Observe electrical connections of each cell, looking for discoloration, pitting, or burn marks. Gently tug on each connection to ensure tightness.
e) Plates Buckling - Check for excessive buckling or bending of the plates or separator material.
f) Sediment - Check for excessive sediment laying in the bottom of the battery container or wedged between the plates and walls of the container.
g) Rack and Paint Condition - Notice the general conditions of rack and nearby walls and floor. Look for dirt, moisture, and corrosive stains from battery. Also, check painted finish on both rack and floor.

h) Grounding - Inspect grounding of charger and battery rack.
i) Leakage - Check for any leakage of electrolyte on floors, batteries, rack or walls. Neutralize and wipe up area of floors and tops of batteries, if necessary.

4.9 Remarks - List remarks if any.

5.0 Security Inspection

5.1 Vandalism
Most switchyards and substations are enclosed by security fences and walls, which protect people and wildlife from the electrical hazards inside. For security purposes, walk the perimeter fence, inspecting for any signs of damage or signs of vandalism. Security problems will be corrected and reported immediately to supervisor.

5.2 Fence and Barbed Wire -
a) Barbed Wire - Inspect the barbed wire strands to be intact and tight. Report and record any abnormal condition.
b) Fabric - Inspect for holes or breaks in the chain link. Make the fence secure before leaving substation. Report and record any abnormal condition.
c) Ties - Inspect for loose or missing fence tie wires. Tighten or replace any ties found to have a problem.
d) Erosions - Inspect the area along the fence for signs of erosion or digging under the fence. Space below fence should be less than 3 inches.
e) Grounding - Inspect ground conductor and connection to be intact and connected to every other fence post. Posts on both sides of gates should be grounded also.
f) Posts - Inspect post to be sound and not rusted through at ground level. Check that the post has not been raised by frost.

5.3 Gates, Locks and Chains
Visually check for proper operation as necessary.

5.4 Warning Signs
Check for proper "Danger High Voltage" warning signs along perimeter of fence, on gates and on non-hinged side of gate.

5.5 Yard Lights
Check all yard light for proper operation. (Yard lights should have been turned on during control house inspection.) Report and/or replace broken bulbs, glass fixtures, spot light heads, or other lighting that needs attention.

5.6 Vegetation

Check for any growth of vegetation in fence and gate area. Record, so the Arborist can be notified to have it removed or sprayed minimally every two years or as needed.

6.0 Yard Inspection

These checks are to identify problems and initiate corrective procedures. This check actually begins at the entrance to the substation switchyard and is to verify that all equipment is in good order.

6.1 Checklist -

a) All Porcelain - Check visually for any broken or chipped skirts carbon traces or flashed over insulators and general deterioration, dirt accumulation on exterior surfaces of porcelain.

- Broken or damaged insulators should be recorded on V&O Report.
- Broken porcelain should be picked up off the ground.

b) Noises - Upon walking through yard, note any unusual noises in the substation. Record on V&O Report.

c) Ground Connections - Check visually throughout the V&O Inspections for any cut, broken or missing ground connections to structures or guy wires. Static wires are inspected at this time and any abnormalities should be noted.

d) Evidence of Heating - Check for any signs of damage to equipment, or heating of disconnects, bushing connections, bus supports, structures and any flashovers.

e) Disconnects, Switches, Fuses - Check visually for signs of overheating, discoloring, pitting, improper alignment, broken operating rods and linkage, ground connections, fuse indicators, cleanliness, carbon traces, support insulators and proper grounding of switch handle.

f) Station Service Transformers
   1) Oil Leaks - Check for oil leaks on transformer tank, bushings and the ground.
   2) Bushing - Check for broken, overheated or discolored bushings.
   3) Fuses - Check visually fuses on primary of transformers.

g) Clean and General Conditions - Clean up substation yard of trash or general debris left around. If area requires major clean up or crushed stone require leveling, note on V&O Report.

7.0 Circuit Breakers & Reclosers

7.1 Circuit Designation
Check circuit breaker to be labeled properly and record circuit designation on V&O Report.

7.2 Counter
Check and record operations counter on breaker mechanism. Update counter card assigned to breaker. List under remarks how many fault and routine operations since last V&O Inspection.

7.3 Relays and Targets - (for breaker cabinet mounted relays)

a) Relay Targets - Check and record breaker relay targets on the counter card and V&O Report. Reset targets. At completion of the V&O Inspection, record targets in LogBook and report them to control authority and supervision.

- Be sure to indicate Designation, phase and type of relays or alarm descriptions.
- If relays are located in control house, this should have been previously done during the Control House Inspection.

b) Reclosing Relay - Check that reclosing relay or switch is in the normal position and that the relay is in the start or zero position.

1) If blocked with a DO NOT OPERATE tag, currently dated. Note, but leave blocked.
2) If blocked without a tag or with an out dated tag, notify the control authority and/or supervisor.

c) Ground Trip - Check that ground trip switch is normal position.

1) If blocked with a DO NOT OPERATE tag, currently dated. Note, but leave blocked.
2) If blocked without a tag or with an out dated tag, notify the control authority and/or supervisor.

7.4 Indicating Lights
Check and record that the indicating lights are working in the Breaker Control Cabinet.

7.5 Reclosers Battery Check
Perform load test on recloser control battery. Record D.C. voltage before and during the test.

7.6 Air Compressor
Any oil or moisture should be wiped down inside cabinet at this time to check where leaks are coming from.

a) Cut-In - Drain down air receiver tank slowly to remove any accumulated moisture. Drain until compressor starts.

Note: If all of the moisture is not removed, before the compressor starts, let the compressor build pressure and stop before continuing to drain. This will prevent the possible tripping of some breakers or the sending of additional alarms.
Note: If the temperature is below 40°F do not perform blow down, because the valve may freeze.

b) Cut-Out - Record cut-out pressure when compressor stops.
c) Checklist - (Air Compressor)

1) V-Belts - Check for any broken, cracked or loose belts.
2) Compressor Motor - Make sure the motor frame is not loose. The motor should be checked for noises and over heating during the cut in and cut out pressure checks.
3) Gaskets - Check to see if any oil or air leaks when the compressor is running.
4) Valves - Listen for any leaks from valves.
5) Before leaving the station make sure all compressors have stopped

7.7 Hydraulic
Any oil or moisture should be wiped from inside cabinet at this time to check where the leaks are coming from.

a) Record hydraulic fluid from high pressure to receiver tank
b) Oil levels - Check and record the hydraulic fluid level in sight gauge. The fluid should be visible in the lower end of the sight gauge at all times.
c) Checklist - (Hydraulic)

1) Gaskets - Check to see if any oil is leaking out the gaskets.
2) Tubing/Fittings - Check for oil leaks in tubing and fittings.
3) Accumulator - Check for leaks and any indication of damage.

7.8 Oil (Oil Circuit Breaker/Recloser) -

a) Level - Check and record breaker oil levels and indicate which phase, if any are low.
b) Leaks - Check and record any leaks on the bushings, tanks, door covers or valves. Report any leak that can be done safely and report as described in the Leak Section.

7.9 Gas (Gas Circuit Breakers) -
a) Pressure - Check and record gas pressure.
b) Temperature - Check and record gas/ambient temperatures.
c) Normal - Check pressure versus temperature chart and record normal fill pressure for ambient temperature. Note if the breaker gas pressure is abnormal.

7.10 Checklist (Circuit Breaker) -
a) Bushing Damage - Check for any damage to bushings from ground level. Determine if any broken glass, pitting, flash over, overheating, chipping, or cracks need to be reported. If needed, inspect with binoculars.
b) Bushing Oil Level - Check each bushing oil level to be at normal levels.
c) Position Indicator - Check that position indicator agrees with breaker position (open or closed).
d) Spring charged - Check that the charging springs are charged for the operating mechanism of the breaker.
e) Noise - Check and report unusual noises from the mechanism, air compressor or miscellaneous equipment of breaker.
f) Moisture - Check for signs of moisture and animal entry in control cubicles. Inspect weatherproofing and cabinets for leaks.
g) Cabinet Vents (air) - Check vents in doors and cabinet is not blocked and air filters are clean.
h) Cabinet Heater - Check thermostats and heaters are in proper working order. Heater control switches are in the "ON" position during the required season.
i) Check interlocks/mechanical trip control positions are in the proper position.

Vacuum Breakers and Reclosers - Check the heat is on for primary cabinet. For VSA Reclosers the underside of the tank can be felt.

7.11 Remarks
List remarks if any.

8.0 Voltage Regulators & L.T.C.

8.1 Circuit Designation

Check regulators to be properly labeled and record circuit designation. If an LTC, describe as LTC of transformer. (i.e. LTC #1Trf)

8.2 Phase Designation
Record phase designation or note as LTC.

Note: Keep legal clearance from all energized parts.

8.3 Counter
Check and record operations counter.

8.4 Position Indicator -
a) Minimum, Present and Maximum - Check and record drag hand on the position indicator.
b) Record Load Bonus Hands (limit switch position)
c) Reset - Reset minimum and maximum drag hands.
d) Take at least one phase out of automatic voltage limit (band width) to see if it rebalances when placed back in automatic

8.5 Volts
Check and record voltage across terminals marked output voltage with multimeter.

8.6 Oil -
a) Oil Level - Check and record oil level in sight glass.
b) Oil Color - Check and record oil color in sight glass. This indicates signs of overheating, burning, high carbon content or internal problems.
c) Leaks - Check for any leaks from tank, valve or breather system. Report any leak that can be done safely and report as described in the Leak Section.

8.7 Checklist -
a) Bushing Damage - Inspect all bushings for cracks, breakage or chipping. Check connections for signs of overheating.

Note: Keep legal clearance from all energized parts.

b) Tank Grounds - Check that all ground connections are properly connected and are not cut or broken.
c) Noise - Check for abnormal noise in operation of voltage regulator during V&O Inspection checks.
d) Arresters - Check external by-pass arrester for discolor, signs of overheating or blown. If arrester is blown, regulator should be turned off in place. Notify Supervisor immediately.

9.0 Transformers

9.1 Circuit Designation
Check transformer to be labeled properly and record circuits and phase designation. LTC information is recorded with voltage regulators.

9.2 Nitrogen Pressures (gas checks) -
a) Cylinder (Blanketed System) - Check and record nitrogen cylinder pressure on transformer gas system. Cylinder should be changed if pressure is 200 lbs. or less.
b) Transformer - Check and record nitrogen pressure in transformer from gas pressure indicator gauge.

1) Blanketed System - Pressure should be between .5 and 5 lbs. in positive direction. This positive pressure is controlled by a combination of pressure regulator and relief devices.
2) Sealed Tank Systems - Pressure in this type of system can vary from positive 5 lbs. to negative 5 lbs. And is kept between those values by a vacuum/pressure device. If the pressure is below 1 lb., gas can be added to the system. If there is a leak in the system, lost gas will be made up by air and the leak will go undetected.
3) Gas/Oil Sealed Systems - Pressure should be 1.5 lbs. to 3 lbs. positive. The pressure is kept positive by a head of oil in a two-part expansion tank. If the pressure is below 1 lb., gas can be added to the system to raise the oil back into the upper compartment.
4) Atmoseal/COPS Conservator Systems - These systems protect the oil by using an air bag in a conservator tank, sealing the transformer. There is no nitrogen or nitrogen pressure.
5) Free Breathing Conservator Systems - This system has a conservator tank partially filled with oil. The tank is vented to atmosphere through a breather. There is no nitrogen or nitrogen pressure.

9.3 Fans and Pumps - (Cooling Equipment)
a) Fans - Check and operate fans. Switch controls from auto to manual and run for a couple of minutes do not turn off and on intermittently. Bad capacitors in capacitance-run motors result in excessive motor current causing trip off on thermal overload. When cooled, motor restarts. Note any unusual noises, leaking capacitors and slow or non-running fans. Inspect all external electrical connections to the fans. Check for fan blade clearance and fan guards to be secure.

b) Pumps - Check and operate oil pumps and verify that the oil flow indicators work properly. Clean any leak that can be done safely and report as described in the leak section (Appendix B).

Controls - Change selector switch from group 1 to group 2 or back, if so equipped.

9.4 Temp °C max/ind. - (Operating Temperatures)

a) Top Oil - Check and record top oil temperatures (maximum and indicating values) from the liquid temperature gauge.
b) H, X & Y Winding Temperature - Check and record winding temperature (maximum and indicating values) from the winding temperature indicators. Some transformers have a winding temperature gauges on each winding.
c) Reset - Reset maximum drag hands.

1) Unscrewing the cover knob and pulling the stem down resets the maximum temperature drag hands on instruments with a reset stem.
2) Placing a magnet against the glass directly opposite the indicator and moving the magnet in the desired direction reset the maximum temperature drag hands on instruments with a reset magnet. This can be done by taping a magnet to a switch stick for indicators near top of transformer.

9.5 Oil level

Check and record oil level on the oil level indicator. The 25°C mark indicates the correct oil level for the transformer, which is operating at 25°C.

9.6 Leaks

Check any leaks on the bushings, tanks, covers, flanges, pump or valves. Report any leak that can be done safely and report as described in the leak section (Appendix C).

9.7 Checklist -

a) Bushing Damage - using binoculars, if needed, examine for any cracks, porcelain chipping, damage, and surface leakage, loose connections.

Note: Keep legal clearance from all energized parts.

b) Bushing Oil level - Check bushing oil level sight glass for proper level. Unless mechanical damage, the fill level should be satisfactory for life of the bushing.
c) Tank Grounds - Check that all ground connections and pads are okay and have not been disturbed.
d) Cabinet Heater & Vents - The transformer cabinet is checked for signs of leaks, such as watermarks, moisture, etc. Verify that cabinet thermostats and heaters are in working order and all vents are free of any obstruction. It is good practice to clean and remove paper, leaves, mice nests, beehives or any foreign objects that might effect operation of the controls.
e) Silica Gel - Check for proper color (proper color is blue). If it is any other color it must be replaced or dried. Silica gel absorbs moisture before it enters the transformer.
f) Mechanical Relief - Mechanical relief device relieves excessive pressure (greater than 10 to 15 lbs.) by venting gas from transformer to atmosphere. Located on top of transformer most devices have a visual signal flag that pops up. If up, notify supervisor immediately.
g) Coolers - Examine for dirt, leaves, paper or anything else that may prevent airflow. If possible, obstructions are to be removed. If not obstructions are noted for future maintenance. Also, wiring to fans and pumps are checked for cracks, in insulation, fraying and other signs of deterioration.
h) Noise Level - Check and report unusual noises from the transformer, fans, pumps and other auxiliary equipment.

9.8 Remarks - List any remarks.

10.0 Capacitors

10.1 Circuit Designation
Check capacitor to be labeled properly and record circuit designation.

Note: Keep legal clearance from all energized parts.

10.2 Switch Position
Check and record the as found capacitor switch position. (open/closed)

10.3 Counters -
a) Controls - Check and record the control's operations counter.
b) Switch - Check and record operations counter on vacuum switch or breaker of capacitor bank.

10.4 Control Operation

Verify the automatic operation of capacitor bank control by comparing the previous counter reading.

10.5 Time Clock – (when applicable)
a) Indicating - Check and record the time on the time clock.
b) Actual - Check and record the actual time.
c) Corrected - If the time difference is more than one half hour, reset the time clock to proper time.

10.6 Bulges
Visually inspect each unit for any abnormal tank bulges, ruptures and corrosion. Record any abnormal conditions on V&O Report.

10.7 Leaks
Visually inspect each unit for any leaks. Record any leaks on V&O Report. Care should be taken to prevent any leakage from entering the environment.

10.8 Fuses -
a) Check and record blown individual capacitor fuses
b) Check and record blown capacitor bank fuses

10.9 Checklist -
a) Bushing Damage - Visually inspect for any cracks, porcelain chipping, damage, surface leakage, loose connections.

Note: Keep legal clearance from all energized parts.

b) Grounds - Visually inspect that all neutral/ground connections are made to each capacitor unit. Check that the rack base is connected to the system ground.

10.10 Remarks
List any remarks on V&O form.

11.0 Surge Arresters

V&O Inspections include a visual inspection of the arresters in the substation. No information need be recorded, except for abnormal conditions. Surge arresters are used to protect getaway cables and bus sections.

11.1 Circuit Designation
Record circuit designation in appropriate column for each transformer or bus surge arresters.

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11.2 Relief Diaphragm
Visually check for any signs of blow out at top and bottom of arrester. Check the 3 phases okay, if no visible signs of problems are found

11.3 Checklist -
a) Porcelain - Check porcelain for damage or flashed.
b) Connections - Visually check the primary and ground connections for heating or discoloration.

11.4 Remarks
List any remarks.

12.0 Motor Operated Disconnects and Circuit Switchers

12.1 Circuit Designation
Check the disconnect/airbreak to be labeled properly and record circuit designation in appropriate column.

12.2 Counters
Check and record operations counter located in motor operator.

12.3 Closed/Opened
Check and record airbreaks position, open or closed. Also, check open and close indicating lights on control panel. On Circuit Switchers, check that the interrupter is closed (yellow target located on the brain section of the Circuit Switcher indicates contacts open.)

12.4 Automatic/Manual
Check and record position of auto/manual switch. Contact control authority if not in proper position.

12.5 Gas Indicator (Circuit Switchers)
Record color of target on interrupter section of Circuit Switcher – (If target is red this indicated loss of gas notify supervisor immediately.)

12.6 Checklist -
a) Fully Open or Closed - Visually check that all switches are in proper operating position.
b) Locks - Check that all airbreaks are properly locked and that the lock is in good condition.
c) Interlocks - Check all key interlocks for any broken keys, cylinders, or any other broken parts. Verify visually that all are in good working order.

d) Handle Grounded - Check to be sure braided strap on airbreak rod is in good condition and connected to the ground grid.
e) Grounds - Check for proper ground connections from ground grid to motor mechanism and structure.
f) Motor operators with self contained batteries should be load tested with the voltage recorded before testing and during.

12.7 Remarks
List any remarks.

13.0 Miscellaneous Apparatus

13.1 Instrument/Metering Transformers - C.T. and P.T.
a) Noise - Check for any abnormal noises.
b) Level - Check for oil level on oil filled apparatus.
c) Leaks - Check for oil leaks. Report any leak that is safe and report as described in the leak section (Appendix B).
d) Porcelain - Check for cracks in porcelain or butyl rubber.
e) Overheating - Check for any signs of overheating.
f) Connections - Check primary and secondary connections visually.
g) Nitro System – Inspect tubing, regulators, alarms and gauges.

13.2 Line Traps/Reactors - Dry Type
a) Cleanliness - Check visually for cleanliness. Check for any foreign materials on coils. (i.e. bird nests)
b) Support Insulators - Check support insulators to be clean and intact.
c) Connections - Check primary and secondary connections visually. (over heating)
d) Concrete - Check concrete reactor frame for any cracks or breakage.
e) Winding Distortion - Visually check for any distortion on coils.

13.3 Cables and Terminations (Potheads)-
a) Tracking - Check for tracking along termination and base of pothead.
b) Overheating - Check for signs of overheating.
c) Leaks - Check for leaking compound from termination.

13.4 Busses
a) Noise - Check for any abnormal noises with bus in operation.
b) Overheating - Check for any signs of overheating.
c) Insulators - Visually check bus for distortion or broken, damaged or tracked insulators.

14.0 Final Checklist

a) Yard lights - Shut off yard lights.

b) Station LogBook - Observations should be entered in logbook such as: targets found, breaker operations, any defective or broken equipment.
c) Control Authority/Dispatcher - Call control authority to notify them that the V&O Inspection has been completed and you will be leaving the station. Report any abnormal conditions, alarms or relay targets.
d) Securing Station - Make sure control house lights are off and doors secured. Closed gate and locked securely with chain.
e) V&O Report - Turn in V&O Inspection Report to supervisor.

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Appendix A

TROUBLE REPORTING

Trouble - The term trouble is defined as any condition, which occurs on the equipment that, has or will terminate the ability of that equipment to perform its required function.

I. SEVERE TROUBLE - A severe trouble condition is a situation that is immediately hazardous to the system and/or personnel. These troubles are immediately reported to the Control Authority/Dispatcher and to the person in charge of the substation. The employee shall secure the area and warn unauthorized people to stay clear of the danger.

Examples

- Dead station battery
- Blown bushings or cable terminator
- Downed live lines
- Multiple broken support insulators
- Electrical fires
- Grounds cut in station
- Loss of station service power
- Broken pole or structure
- Blown by pass/shunt arresters on regulators

II. NOT IMMEDIATELY FIXABLE TROUBLE - These troubles are reported immediately to the Control Authority. The person in charge of the substation shall also be notified of the non-fixable items and it shall be noted on the V&O form, to be fixed at a later date.

Examples

- Surge Arrester Blown
- Broken operating rods on disconnects
- Broken bus support insulators
- Low oil levels

Appendix A

III. FIXABLE TROUBLE - Fixable items should be repaired as they are discovered during the V&O Inspection. This insures that the station is maintained in the best possible operating condition and prevents unnecessary return trips. The items fixed should be noted on the V&O Report.

Examples

- Battery electrolyte filling
- Replacing burnt indicating lamps
- Installing new locks

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Appendix B

OIL LEAK REPORTING

Oil filled apparatus must be inspected for any signs of leaks. The V&O Inspection Report now requires that the oil leak status be indicated for each piece of oil filled apparatus.

When inspecting the apparatus during a V&O Inspection, mark the appropriate column with the letter that indicates the leak status. The available status ratings are:

Repaired ® - If a leak is found and repaired during the V&O Inspection, use the repaired status and note the repairs made.

Leak (minor (**L**) - A Leak is defined by the PCB Manual as anytime the external surface of a piece of apparatus is wet with oil. Must write remark of what was leaking.

Moderate Leak (**M**) - By definition is any instance when oil is detected running off or about to run off the external surface of containers or electrical apparatus or any leak that is actively dripping.

No status letter is defined for an oil leak that is more severe than a moderate leak. Any leak considered being of a magnitude greater than a moderate leak shall be responded to as an oil spill. Notify the supervisor of the condition at once and begin repair and the clean up.

The repaired leak may then be reported on the V&O Inspection Report as an "R", with a description the repairs made and the clean up done for the leak.

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Appendix C

SUBSTATION - V&O INSPECTION REPORT

Note any abnormalities

Substation	Sheet ___of___	Date Time am/pm
Inspected By	Ambient Temp	Control House Temp

CONTROL HOUSE (3)

Log Book	_____	Heavy Duty Ground	_____	Vandalism	_____
Control Panels	_____	Sittch Sticks	_____	Fence & Barbed Wire	_____
Annunciator/Test Switches	_____	Fire Equipment	_____	Gates	_____
Station Alarms	_____	Emergency Plan Posted	_____	Gate Locks & Chains	_____
Tags & Switching Order Pads	_____	Emergency Equipment Checklist	_____	Warning Signs	_____
Lighting	_____	Phone Lists	_____	Yard Lights	_____
Heaters	_____	Clean & General Condition	_____	Vegetation	_____
Station Service and Transfer					
Preferred _____ Emer _____					

SECURITY (5)

YARD INSPECTION (6)

Checklist _____

Leaks * C = Clean L = Leaks R = Repaired M = Moderate Leaks

01 - CIRCUIT BREAKERS & RECLOSERS (7

Circuit Desig	Counter	Relay Targets	Ind Lts	Recloser Batt Chk	Air Compressor / Hydraulic				Checklist	Gas			Checklist	Remarks
					Cut In	Cut Out	Hours	Level		Pressure Level	Temp. Oil	Normal Leaks*		

04 - VOLTAGE REGULATORS & LTC (8)

Circuit Desig	Phase Design	Counter	Position Indicator				Volts	Load Mgt 2.50% Chk	Oil			Checklist	Remarks
			Min	Present	Max	Reset			Level	Color	Leaks*		

Appendix C

SUBSTATION - V&O INSPECTION REPORT			
Substation	Inspected By	Sheet _____of_____	Date _____

02 - TRANSFORMERS (9)

If Transformer is an LTC, Note LTC operation under V.R. section

Circuit Design	Nitro Press		Fans & Pumps	Temp °C (max/ind)					Oil		Checklist	Remarks
	Cyldr	Trans		Top Oil	WDG			Reset	Level	Leaks*		
					H	X	Y					

08 - CAPACITORS (10)

Circuit Design	Sw Pos	Counters		Control Operation				Buldges	Leaks*	Fuses	Checklist	Remarks
		Controls	Switch		Indicating	Actual	Correct					

19 - SURGE ARRESTERS (11)

Circuit Design	Relief Diaphragm			A phase		B phase		C phase		Checklist	Remarks
	A	B	C	Counter	Milliamps	Counter	Milliamps	Counter	Milliamps		

09 - MOTOR OPERATED DISCONNECTS AND CIRCUIT SWITCHERS (12)

Circuit Design	Counters	Live Line Ind	Time Reset	Preferred	Emer	Closed	Open	Auto	Manual	Gas Ind	Checklist	Remarks

06 - BATTERIES & CHARGERS (4)

Ref No / Desig	Voltage Rating	Pilot Cell				Charger		Grounds		Over All		Eql Chg	Checklist	Remarks
		Cell #	Temp	Sp gr	Volts	Load Amps	Float Voltage	P-G	N-G	Volts	Liq Lev			

REMARKS:

CHECKLIST

BUSSES _____

LINE TRAPS/REACTORS _____

CABLE & TERMINATIONS _____

INSTRUMENT TRANSFORMER (CT.PT.CCVT) _____

Appendix D

SUBSTATION - V&O INSPECTION CHECKLIST		
FILL IN AS FOLLOWS: IF SATISFACTORY OK IF DOES NOT APPLY -- IF UNSATISFACTORY WRITE COMMENT	SUBSTATION:	
	DATE:	INSP. BY

BATTERIES (4)

a) NO SMOKING SIGN _____
b) EYE WASH _____ (EXPIRATION DATE) _____
c) VENT CAPS ARRESTER _____
d) CONNECTIONS _____
e) PLATES BUCKLING _____
f) SEDIMENT _____
g) RACK & PAINT _____
CONDITION _____
h) GROUNDING _____
I) LEAKAGE _____

YARD INSPECTION (6)

a) ALL PORCELAIN _____
b) NOISE LEVEL _____
c) GROUND CONNECTION _____
d) EVIDENCE OF HEATING _____
e) DISCONNECTS. _____
SWITCHES & FUSES
f) STATION SERVICE TRF _____
g) PAINT CONDITION _____
h) CLEAN AND GENERAL _____
CONDITION

AIR COMPRESSOR (7)

a) V BELTS _____
b) COMPRESSOR MOTOR _____
c) AIR FILTERS _____
d) GASKETS _____
e) VALVES _____

HYDRAULIC SYSTEM (7)

a) GASKETS _____
b) TUBING/FITTINGS _____
c) ACCUMULATOR _____

CIRCUIT BREAKERS/ RECLOSERS (7)

a) BUSHING DAMAGE _____
b) BUSING OIL LEVEL _____
c) POSITION INDICATOR _____
d) SPRING CHARGED _____
e) PAINTED SURFACES _____
f) RECLOSING RELAY _____
g) NOISE LEVEL _____
h) CONTROL FUSES _____
i) MOISTURE _____
j) CABINET VENTS (AIR) _____
k) CABINET HEATER _____
l) FOUNDATION _____

REGULATOR OR LTC (8)

a) BUSHING DAMAGE _____
b) TANK GROUNDS _____
c) NOISE LEVEL _____
d) CABINET VENTS (AIR) _____
e) ARRESTERS _____
f) BREATHER _____

TRANSFORMER (9)

a) BUSHING DAMAGE _____
b) BUSHING OIL LEVEL _____
c) TANK GROUNDS _____
d) CABINET HEATER _____
e) CABINET VENTS _____
f) SILICA GEL _____
g) MECH RELIEF _____
h) COOLERS _____
i) NOISE LEVEL _____

CAPACITORS (10)

a) BUSHING DAMAGE _____
b) GROUNDS _____
c) BANK GUARD SYSTEM _____

ARRESTERS (11)

a) PORCELAIN _____
b) CONNECTIONS _____

SWITCHES (12)

a) FULLY OPEN OR CLOSE _____
b) LOCKS _____
c) INTERLOCKS _____
d) RODS & LINKAGE _____
e) HANDLE GROUNDED _____
f) GROUNDS _____
g) FUSES _____
h) HEATERS _____

INSTRUMENT TRANSFORMERS (13) (CT. PT. CCVT)

a) NOISE LEVEL _____
b) OIL LEVEL _____
c) LEAKS _____
d) PORCELAIN _____
e) OVERHEATING _____

LINE TRAPS/REACTORS (13)

a) CLEANLINESS _____
b) SUPPORT INSULATORS _____
c) CONNECTIONS _____
d) CONCRETE _____
e) WINDING DISTORTION _____

CABLE & TERMINATIONS (13)

a) TRACKING _____
b) OVERHEATING _____
c) LEAKS _____

BUSSES (13)

a) NOISE LEVEL _____
b) OVERHEATING _____

Operations Bulletin #OP3A.15

SUBJECT: Substation Annual Inspection
EFFECTIVE: 11/1/00

ISSUED BY: G. Appleton
CONTENT BY: S. Baker, T.Biklen, M Deschambeault, P.Stagno, A. Zogopoulos, R. Bisson

1.0 PURPOSE

- To provide a uniform method for maintaining and inspecting substations within the Unitil system
- To ensure the integrity of the equipment
- To ensure the safe operation of the system
- To establish requirements for record keeping and performance measures

The following procedure describes how to properly complete an Annual Substation - V&O Inspection, using a Substation - V&O Inspection Report.

V&O (Visual and Operational) Inspection of each Substation and Switchyard is a key element in the Unitil preventive maintenance program. V&O Inspections are performed with the apparatus in service and are designed to detect abnormal conditions before the apparatus is damaged or a customer outage occurs. Data collected during the V&O Inspection is one of the items used to prioritize individual apparatus for further investigation.

This procedure is based on the philosophy that a "qualified employee" will be utilized to perform the V&O Inspection and in conjunction with the inspection minor problems will be repaired as they are found. One person may perform this procedure alone. In some instances, certain criteria may not be applicable due to operational or staffing differences between operating companies.

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D.	Substation - V&O Inspection Checklist.....	Example B

PROCEDURE

1.0 Safety and Entering Property

1.1 Lower Antenna on Vehicle

Before entering a substation or switchyard, care shall be taken to see that the antenna is well clear of any conductors or equipment with which it may come in contact.

1.2 All Company Safety
Policies and Procedures should be reviewed and followed.

1.3 Check Yard
Quick inspection for anything broken, vandalized, grounds cut or removed, noises, fence condition, gates, locks, warning signs, alarms.

1.4 Notify the Control Authority/Dispatcher
Inform them of the V&O Inspection and of alarm testing. Check the station on-schedule and for abnormal conditions.

2.0 REPORT HEADING

During the V&O Inspection all abnormal conditions should be marked in pen or pencil, this includes check blocks. Abnormal check blocks should also be explained under remarks.

2.1 Substation
Fill in the complete name and number of the substation being inspected.

2.2 Inspected by
Fill the names of the person or persons performing the inspection.

2.3 Sheet
Number each sheet used in the inspection and put the total pages used for the station on all sheets.

2.4 Date
Fill in date of V&O Inspection.

2.5 Time
Record starting time of inspection including am/pm. The time helps coordinate the information and its meaning.

2.6 Ambient Temperature
Record the general outside temperature. The temperature is required for gas circuit breakers and power transformers.

2.7 Control House Temperature
Record the inside control house temperature.

3.0 CONTROL HOUSE

3.1 Station Log Book – (where applicable)

a) Enter the date, time and employee names that are performing the V&O Inspection.
b) Check the Station LogBook for abnormal conditions that can be corrected during the V&O Inspection.
c) After the V&O Inspection, record in the LogBook, all abnormal problems found, corrected or not.

Note: Record anything abnormal and notify supervisor of major problems.

3.2 Control Panels

a) Indicating Lights - Check that the indicating lights are working on the Control Board. Check the available stock of spare bulbs; stock as necessary.
b) Inspect rear of Control boards for any signs of overheating, burned wiring, moisture, etc.
c) Noises - Listen for any unusual noises from relays, panels
d) Relay Targets - (for control panel mounted relays)

    1) Check for relay targets or alarms on the control boards.
    2) Record targets and alarms on the V&O Report with the apparatus effected and in LogBook. Be sure to indicate phase and type of relays or alarm descriptions.
    3) Reset and report relay targets and alarms to the Control Authority/Dispatcher and supervisor.

If relays are located in breaker cabinet, this should be done during the Breaker Inspection (7.3).

e) Reclosing Relay - Check that reclosing relay and/or switch is in the normal position and that the relay is in the start or zero position.

    1) If blocked with a DO NOT OPERATE tag, currently dated. Note, but leave blocked.
    2) If blocked without a tag or with an out dated tag, notify the Control Authority and/or supervisor.

f) Ground Trip - Check that ground trip switch is normal position.

    1) If locked with a DO NOT OPERATE tag, currently dated. Note, but leave blocked.
    2) If blocked without a tag or with an out dated tag, notify the Control Authority and/or supervisor.

3.3 Annunciator – (where applicable)

a) Annuciator panel

1) Move toggle switches that are not tagged to the test position to check lights (this will send an alarm to dispatch).
2) To clear trouble condition, turn the toggle switch to the reset position.
3) Leave toggle switches in the on position.
4) Any switches found in the off position or tagged, check with supervisor before testing.

3.4 Tags and Switching Order Pads – (where applicable)

a) Check the available stock of Operating Tags, stock as necessary.

ORANGE Tags
RED Tags
BLUE Tags
WHITE Information Tags

b) Check the stock of Switching Order Pads, stock as necessary.
c) Check that pens and pencils are available, stock as necessary.

3.5 Lighting

a) Inspect lighting in control house; replace any burned out bulbs. Note if it's not working.
b) Test emergency lighting.

3.6 Heaters
Inspect heaters and thermostats for proper operation. Make sure fans are not broken or bound up and they are in good working order.

3.7 Station Service and Transfer Switch -

a) Transfer Switch - Check transfer switch to be on preferred supply and any signs of trouble or overheating.
b) AC and DC Panels - Check that switches or circuit breakers are in the proper position.

3.8 Switch Sticks

a) Inspect Switch Sticks for damage and proper operation.
b) Switch Sticks should be stored properly and cleaned if necessary.

3.9 Fire Equipment

a) Inspect fire extinguishers to be properly stored in their marked locations. Update inspection cards.
b) Note any out of date fire extinguishers on the V&O Report for future replacement.

3.10 Emergency Plan Posted - (where applicable)

a) Check that the notification list is posted.
b) Check that the Emergency Plan is available at the substation.

3.11 Emergency Equipment Checklist - (where applicable)
Check that oil spill clean-up equipment is available and in good condition.

3.12 Phone Lists Updates
Check that local area cards and Control Authority/Dispatcher cards are updated and posted to ensure that phone numbers are available for switching and trouble calls.

3.13 Clean and General Condition - (where applicable)

a) Clean control house floors, facilities, empty waste baskets and dust switchboard.
b) Inspect for water leaks in roof and walls.
c) Check for signs of animal entry into control house.
d) Report panel or cabinet covers, which may have been removed during maintenance, or trouble.
e) Put on yard lights, so they can be checked during the Yard Inspection.

4.0 BATTERY & CHARGER

All Company Safety policies and Procedures should be reviewed and followed.

Note: Do not smoke or introduce any flames or sparks near the battery area.

1. Reference Number or Designation
Check and record proper designation of battery, such as #1 Battery, Reference Number assigned. Some stations have more than one battery in the control house or other locations.

2. Voltage Rating - Record voltage rating of the battery bank. This is another way to determine which battery is being inspected.

3. Pilot Cell

a) Cell Number - Check and record the cell number of the pilot cell.

b) Temperature - Check and record the temperature of pilot cell. This represents the battery temperature.
c) Specific Gravity - Check and record specific gravity of pilot cell. Never add water before taking specific gravity readings.
d) Volts - Check and record pilot cell voltage.

4. Charger

a) Load Amps - Check and record constant load amps on charger ammeter.
b) Float Voltage - Check and record float voltage on charger voltmeter. If the float voltage is above or below the required value, it should be noted on the V&O Report.

5. Grounds
Check and record voltage to ground indicators on charger in positive and in negative direction. Any grounds should be investigated and recorded in the logbook and on the V&O Report.

6. Overall - (where applicable) rounds
a) Volts

1) Turn off charger's AC supply. Wait for 2 minutes.
2) Check and record the over-all battery voltage.
3) Turn on charger's AC supply and make check of it's operation.

b) Liquid level
Check each cell for proper electrolyte level. The proper amount is between high and low level mark on the battery. Add distilled water to each cell that is low. Record any abnormal amount of distilled water added to the battery.

7. Equalize Charge
If water was added or specific gravity of pilot cell was low, the battery should be equalized in accordance with company policy.

Note: Charger should be checked the following day to see if cycle was completed and battery came up to proper voltage and charger return to float level.

8. Checklist
a) No Smoking Sign - Check that a No Smoking sign is in the vicinity of battery area. If not, signs should be ordered.
b) Eye Wash Bottle - Check that an Eye wash bottle is located in the vicinity of batteries. Check that the bottle is unopened and that the

expiration date is not expired. (three years from date on bottle) Replace if necessary.

c) Vent Caps/Arresters - Check that the vent caps or flame arresters and dust caps are properly installed and are clean and dry.
d) Connections - Check each terminal post for any corrosion, dirt, moisture or accumulation of power. Clean as necessary. Observe electrical connections of each cell, looking for discoloration, pitting, or burn marks. Gently tug on each connection to ensure tightness.
e) Plates Buckling - Check for excessive buckling or bending of the plates or separator material.
f) Sediment - Check for excessive sediment laying in the bottom of the battery container or wedged between the plates and walls of the container.
g) Rack and Paint Condition - Notice the general conditions of rack and nearby walls and floor. Look for dirt, moisture, and corrosive stains from battery. Also, check painted finish on both rack and floor.
h) Grounding - Inspect grounding of charger and battery rack.
i) Leakage - Check for any leakage of electrolyte on floors, batteries, rack or walls. Neutralize and wipe up area of floors and tops of batteries, if necessary.

9. Remarks - List remarks if any.

5.0 SECURITY INSPECTION

5.1 Vandalism

Most switchyards and substations are enclosed by security fences and walls, which protect people and wildlife from the electrical hazards inside. For security purposes, walk the perimeter fence, inspecting for any signs of damage or signs of vandalism. Security problems will be corrected and reported immediately to supervisor.

5.2 Fence and Barbed Wire

a) Barbed Wire - Inspect the barbed wire strands to be intact and tight. Report and record any abnormal condition.
b) Fabric - Inspect for holes or breaks in the chain link. Make the fence secure before leaving substation. Report and record any abnormal condition.
c) Ties - Inspect for loose or missing fence tie wires. Tighten or replace any ties found to have a problem.
d) Erosions - Inspect the area along the fence for signs of erosion or digging under the fence. Space below fence should be less than 3 inches.

e) Grounding - Inspect ground conductor and connection to be intact and connected to fence post. Posts on both sides of gates should be grounded also.
f) Posts - Inspect post to be sound and not rusted through at ground level. Check that the post has not been raised by frost.

5.3 Gates
Check gates for proper operation. Gates should swing easily out of the way. When closed, the gates should meet in the middle with minimal space and should be secured with lock and chain. Gateposts should be grounded. Make required repairs or adjustments.

5.4 Gate Locks and Chains
Check to see that all gate locks operate properly. Chain should be made-up as tight as possible, not allowing entrance between gates. Report any poor operating lock with new lock. Check control house door locks to be operational.

5.5 Warning Signs
Check for proper "Danger High Voltage" warning signs along perimeter of fence, on gates and on non-hinged side of gate.

5.6 Yard Lights
Check all yard light for proper operation. (Yard lights should have been turned on during control house inspection.) Report and or Replace broken bulbs, glass fixtures, spot light heads, or other lighting that needs attention.

5.7 Vegetation
Check for any growth of vegetation in fence and gate area. Record, so the Arborist can be notified to have it removed or sprayed minimally every two years or as needed.

6.0 YARD INSPECTION

These checks are to identify problems and initiate corrective procedures. This check actually begins at the entrance to the substation switchyard and is to verify that all equipment is in good order.

6.1 Checklist
a) All Porcelain - Check visually for any broken or chipped skirts carbon traces or flashed over insulators and general deterioration, dirt accumulation on exterior surfaces of porcelain.

- Broken or damaged insulators should be recorded on V&O Report.
- Broken porcelain should be picked up off the ground.

b) Noises - Upon walking through yard, note any unusual noises in the substation. Record on V&O Report.
c) Ground Connections - Check visually throughout the V&O Inspections for any cut, broken or missing ground connections to structures or guy wires. Static wires are inspected at this time and any abnormalities should be noted.
d) Evidence of Heating - Check for any signs of damage to equipment, or heating of disconnects, bushing connections, bus supports, structures and any flashover.
e) Disconnects, Switches, Fuses - Check visually for signs of overheating, discoloring, pitting, improper alignment, broken operating rods and linkage, ground connections, fuse indicators, cleanliness, carbon traces, support insulators and proper grounding of switch handle.
f) Station Service Transformers

    1) Oil Leaks - Check for oil leaks on transformer tank, bushings and the ground.
    2) Bushing - Check for broken, overheated or discolored bushings.
    3) Fuses - Check visually fuses on primary of transformers.

g) Clean and General Conditions - Clean up substation yard of trash or general debris left around. If area requires major clean up or crushed stone require leveling, note on V&O Report.

7.0 CIRCUIT BREAKERS & RECLOSERS

7.1 Circuit Designation
Check circuit breaker to be labeled properly and record circuit designation on V&O Report.

7.2 Counter
Check and record operations counter on breaker mechanism. Update counter card assigned to breaker. List under remarks how many fault and routine operations since last V&O Inspection

7.3 Relays and Targets - (for breaker cabinet mounted relays)
a) Relay Targets - Check and record breaker relay targets on the counter card and V&O Report. Reset targets. At completion of the V&O Inspection, record targets in LogBook and reports them to control authority and supervision.

- Be sure to indicate Designation, phase and type of relays or alarm descriptions.
- If relays are located in control house, this should have been previously done during the Control House Inspection.

b) Reclosing Relay - Check that reclosing relay or switch is in the normal position and that the relay is in the start or zero position.

1) If blocked with a DO NOT OPERATE tag, currently dated. Note, but leave blocked.
2) If blocked without a tag or with an out dated tag, notify the control authority and/or supervisor.

c) Ground Trip - Check that ground trip switch is normal position.

1) If blocked with a DO NOT OPERATE tag, currently dated. Note, but leave blocked.
2) If blocked without a tag or with an out dated tag, notify the control authority and/or supervisor.

7.4 Indicating Lights
Check and record that the indicating lights are working in the Breaker Control Cabinet.

7.5 Reclosers Battery Check
Perform load test on recloser control battery. Record D.C. voltage before and during the test.

7.6 Air Compressor
Any oil or moisture should be wiped down inside cabinet at this time to check where leaks are coming from.

a) Cut-In - Drain down air receiver tank slowly to remove any accumulated moisture. Drain until compressor starts and record cut-in pressure.

Note: If all of the moisture is not removed, before the compressor starts, let the compressor build pressure and stop before continuing to drain. This will prevent the possible tripping of some breakers or the sending of additional alarms.
Note: If the temperature is below 40°F do not perform blow down, because the valve may freeze.

b) CutOut - Record cutout pressure when compressor stops.
c) Hours - Record compressor operating hours.
d) Oil Level - Check the compressor oil level with the compressor stopped.
e) Checklist - (Air Compressor)

1) V-Belts - Check for any broken, cracked or loose belts. If the belt needs to tighten, be sure not to over tighten because this will cause

excessive strain on the motor and compressor bearings. **(WARNING -deenergize motor before adjusting belts.)**

2) Compressor Motor - Make sure the motor frame is not loose. The motor should be checked for noises and over heating during the cut in and cut out pressure checks.
3) Air Filters - Check the condition of air filters associated with the air compressor system. Clean or replace as necessary.
4) Gaskets - Check to see if any gaskets are leaking oil or air when the compressor is running.
5) Valves - Listen for any leaks from valves.
6) Before leaving the station make sure all compressors are stopped.

7.7 Hydraulic

Any oil or moisture should be wiped from inside cabinet at this time to check where the leaks are coming from.

a) Cut-In - Transfer hydraulic fluid from high pressure to receiver tank slowly until pump starts and record cut in pressure.
b) CutOut - Record cutout pressure when pump stops.
c) Hours - Record the pumps operating hours.
d) Oil levels - Check and record the hydraulic fluid level in sight gauge. The fluid should be visible in the lower end of the sight gauge at all times.
e) Checklist - (Hydraulic)

1) Gaskets - Check to see if any oil is leaking out the gaskets.
2) Tubing/Fittings - Check for oil leaks in tubing and fittings.
3) Accumulator - Check for leaks and any indication of damage.

7.8 Oil (Oil Circuit Breaker/Recloser)

a) Level - Check and record breaker oil levels and indicates which phase, if any are low.
b) Leaks - Check and record any leaks on the bushings, tanks, door covers or valves. Clean any leak that can be done safely and report as described in the Leak Section.

7.9 Gas (Gas Circuit Breakers)

a) Pressure - Check and record gas pressure.
b) Temperature - Check and record gas/ambient temperatures.
c) Normal - Check pressure versus temperature chart and record normal fill pressure for ambient temperature. Note if the breaker gas pressure is abnormal.

7.10 Checklist (Circuit Breaker)

a) Bushing Damage - Check for any damage to bushings from ground level. Determine if any broken glass, pitting, flash over, overheating, chipping, or cracks need to be reported. If needed, inspect with binoculars.
b) Bushing Oil Level - Check each bushing oil level to be at normal levels.
c) Position Indicator - Check that position indicator agrees with breaker position (open or closed).
d) Spring charged - Check that the charging springs are charged for the operating mechanism of the breaker.
e) Painted Surfaces - Check conditions of painted areas. Note areas where there is rust or corrosion, which needs repair.
f) Noise - Check and report unusual noises from the mechanism, air compressor or miscellaneous equipment of breaker.
g) Control Fuses - Check control and heater circuits for voltage to prove fuses are not blown.
h) Moisture - Check for signs of moisture and animal entry in control cubicles. Inspect weatherproofing and cabinets for leaks.
i) Cabinet Vents (air) - Check vents in doors and cabinet is not blocked and air filters are clean.
j) Cabinet Heater - Check thermostats and heaters are in proper working order. Heater control switches are in the "ON" position during the required season.
k) Check interlocks/mechanical trip control positions are in the proper position.

Vacuum Breakers and Reclosers - Check the heat is on for primary cabinet. For VSA Reclosers the underside of the tank can be felt.

l) Foundation - Inspect for any erosion, cracking or cement broken away indicating weakness. Inspect breaker leads expansion joints for signs of over extension.

7.11 Remarks
List remarks if any.

8.0 VOLTAGE REGULATORS & L.T.C.

8.1 Circuit Designation
Check regulators to be properly labeled and record circuit designation. If an LTC, describe as LTC of transformer. (i.e. LTC #1Trf)

8.2 Phase Designation
Record phase designation or note as LTC.

Note: Keep legal clearance from all energized parts.

8.3 Counter
Check and record operations counter.

8.4 Position Indicator
a) Minimum, Present and Maximum - Check and record drag hand on the position indicator.
b) Reset - Reset minimum and maximum drag hands.
c) Record – Load Bonus Hands (limit switch positions)
d) Take at least one phase out of automatic voltage limit (band width) to see if it rebalances when placed back in automatic

8.5 Volts
Check and record voltage across terminals marked output voltage with multimeter.

8.6 Load Management 2.5% (5%) Check
Perform load management test by:

a) Placing the remote/local switch to local control.
b) Turn the selector switch to 2.5% (5%) position or position #1 on G.E. regulators.
c) Observe the regulators operation. Note if regulator does not step in the lower direction or the counter does not operate.
d) Place controls in normal operating position.
e) Observe the regulators operation in the raise direction.
f) Reset drag hands.

8.7 Oil
a) Oil Level - Check and record oil level in sight glass.
b) Oil Color - Check and record oil color in sight glass. This indicates signs of overheating, burning, high carbon content or internal problems.
c) Leaks - Check for any leaks from tank, valve or breather system. Clean any leak that can be done safely and report as described in the Leak Section.

8.8 Checklist

a) Bushing Damage - Inspect all bushings for cracks, breakage or chipping. Check connections for signs of overheating.

Note: Keep legal clearance from all energized parts.

b) Tank Grounds - Check that all ground connections are properly connected and are not cut or broken.

c) Noise - Check for abnormal noise in operation of voltage regulator during V&O Inspection checks.
d) Cabinet Vents (air) - Check and clean any cabinets vents that might be blocked by papers, duct seal, etc. and if needed order new screens to prevent bees from entering cabinets.
e) Arresters - Check external by-pass arrester for discolor, signs of overheating or blown. If arrester is blown, regulator should be turned off in place. Notify Supervisor immediately.
f) Breather - Breather at bottom of regulator tank should be checked to verify that it is not plugged so circulation of air will go through regulator and out upper breather to prevent condensation and keeps walls dry and free from rust.

8.9 LTC's with Vacuum bottles (GE LRT 200)
Test protective circuit as follows:

a) If red fault light on control panel is not lit (this is the normal condition).

1) Hold test switch on panel in the test position.
2) Place control switch to the raise position.
3) If the protective system is functioning properly. The drive motor will raise, then lower it self momentarily. At this point the red fault light will light and lock out the controls. Check by operating in the raise and lower directions, no movement should occur.
4) Press reset switch.
5) Repeat the test placing the control switch in the lower position. The protective system should function the same as in step 3.
6) Press reset switches and repeat test in lower direction.
7) If any steps fail contact supervisor.

b) If red fault light on control panel is lit.

1) Reset alarm light.
2) Place control switch in the raise position.

3) If mechanism successfully completes tap change leave control in the normal position.
4) If Red fault light comes on, place controls in the off position and contact supervisor.

8.10 Remarks
List remarks if any.

9.0 TRANSFORMERS

9.1 Circuit Designation

Check transformer to be labeled properly and record circuits and phase designation. LTC information is recorded with voltage regulators.

9.2 Nitrogen Pressures(gas checks)

a) Cylinder (Blanketed System) - Check and record nitrogen cylinder pressure on transformer gas system. Cylinder should be changed if pressure is 200 lbs. or less.
b) Transformer - Check and record nitrogen pressure in transformer from gas pressure indicator gauge.

1) Blanketed System - Pressure should be between .5 and 5 lbs. in positive direction. This positive pressure is controlled by a combination of pressure regulator and relief devices.
2) Sealed Tank Systems - Pressure in this type of system can vary from positive 5 lbs. to negative 5 lbs. And is kept between those values by a vacuum/pressure device. If the pressure is below 1 lb., gas can be added to the system. If there is a leak in the system, lost gas will be made up by air and the leak will go undetected.
3) Gas/Oil Sealed Systems - Pressure should be 1.5 lbs. to 3 lbs. positive. The pressure is kept positive by a head of oil in a two-part expansion tank. If the pressure is below 1 lb., gas can be added to the system to raise the oil back into the upper compartment.
4) Atmoseal/COPS Conservator Systems - These systems protect the oil by using an air bag in a conservator tank, sealing the transformer. There is no nitrogen or nitrogen pressure.
5) Free Breathing Conservator Systems - This system has a conservator tank partially filled with oil. The tank is vented to atmosphere through a breather. There is no nitrogen or nitrogen pressure.

9.3 Fans and Pumps - (Cooling Equipment)

a) Fans - Check and operate fans. Switch control from auto to manual and run for a few minutes do not turn off and on intermittently. Bad capacitors in capacitance-run motors result in excessive motor current causing trip off on thermal overload. When cooled, motor restarts. Note any unusual noises, leaking capacitors and slow or non-running fans. Inspect all external electrical connections to the fans. Check for fan blade clearance and fan guards to be secure.
b) Pumps - Check and operate oil pumps and verify that the oil flow indicators work properly. Clean any leak that can be done safely and report as described in the leak section (Appendix C).

Controls - Change selector switch from group 1 to group 2 or back, if so equipped.

9.4 Temp °C max/ind. - (Operating Temperatures)

a) Top Oil - Check and record top oil temperatures (maximum and indicating values) from the liquid temperature gauge.
b) H, X & Y Winding Temperature - Check and record winding temperature (maximum and indicating values) from the winding temperature indicators. Some transformers have a winding temperature gauges on each winding.
c) Reset - Reset maximum drag hands.

1) Unscrewing the cover knob and pulling the stem down resets the maximum temperature drag hands on instruments with a reset stem.
2) Placing a magnet against the glass directly opposite the indicator and moving the magnet in the desired direction reset the maximum temperature drag hands on instruments with a reset magnet. This can be done by taping a magnet to a switch stick for indicators near top of transformer.

9.5 Oil level
Check and record oil level on the oil level indicator. The 25°C mark indicates the correct oil level for the transformer, which is operating at 25°C.

9.6 Leaks - Check any leaks on the bushings, tanks, covers, flanges, pump or valves. Clean any leak that can be done safely and report as described in the leak section (Appendix C).

9.7 Checklist

a) Bushing Damage - using binoculars, if needed, examine for any cracks, porcelain chipping, damage, and surface leakage, loose connections.

Note: Keep legal clearance from all energized parts.

b) Bushing Oil level - Check bushing oil level sight glass for proper level. Unless mechanical damage, the fill level should be satisfactory for life of the bushing.
c) Tank Grounds - Check that all ground connections and pads are okay and have not been disturbed.
d) Cabinet Heater & Vents - The transformer cabinet is checked for signs of leaks, such as watermarks, moisture, etc. Verify that cabinet

thermostats and heaters are in working order and all vents are free of any obstruction. It is good practice to clean and remove paper, leaves, mice nests, beehives or any foreign objects that might effect operation of the controls.

e) Silica Gel - Check for proper color (proper color is blue). If it is any other color it must be replaced. Silica gel absorbs moisture before it enters the transformer.
f) Mechanical Relief - Mechanical relief device relieves excessive pressure (greater than 10 to 15 lbs.) by venting gas from transformer to atmosphere. Located on top of transformer most devices have a visual signal flag that pops up. If up, notify supervisor immediately.
g) Coolers - Examine for dirt, leaves, paper or anything else that may prevent airflow. If possible, obstructions are to be removed. If not obstructions are noted for future maintenance. Also, wiring to fans and pumps are checked for cracks, in insulation, fraying and other signs of deterioration.
h) Noise Level - Check and report unusual noises from the transformer, fans, pumps and other auxiliary equipment.

9.8 Remarks
List any remarks.

10.0 CAPACITORS

10.1 Circuit Designation
Check capacitor to be labeled properly and record circuit designation.

Note: Keep legal clearance from all energized parts.

10.2 Switch Position
Check and record the as found capacitor switch position. (open/closed)

10.3 Counters

a) Controls - Check and record the control's operations counter.
b) Switch - Check and record operations counter on vacuum switch or breaker of capacitor bank.

10.4 Control Operation
Verify the automatic operation of capacitor bank control by comparing the previous counter reading. If operation can not be verified, test capacitor controls.

Note: Capacitor should be operated, if possible, by automatic control. Capacitors must not be re-energized for **five minutes**.

10.5 Time Clock - (where applicable)

a) Indicating - Check and record the time on the time clock.
b) Actual - Check and record the actual time.
c) Corrected - If the time difference is more than one half hour, reset the time clock to proper time.

10.6 Bulges
Visually inspect each unit for any abnormal tank bulges, ruptures and corrosion. Record any abnormal conditions on V&O Report.

10.7 Leaks
Visually inspect each unit for any leaks. Record any leaks on V&O Report. Care should be taken to prevent any leakage from entering the environment.

10.8 Fuses

a) Check and record blown individual capacitor fuses.
b) Check and record blown capacitor bank fuses

10.9 Checklist

a) Bushing Damage - Visually inspect for any cracks, porcelain chipping, damage, surface leakage, loose connections.

Note: Keep legal clearance from all energized parts.

b) Grounds - Visually inspect that all neutral/ground connections are made to each capacitor unit. Check that the rack base is connected to the system ground.

10.10 Remarks - List any remarks on V&O form.

11.0 SURGE ARRESTERS

V&O Inspections include a visual inspection of the arresters in the substation. No information need be recorded, except for abnormal conditions. Distribution class surge arresters are used to protect getaway cables and bus sections.

11.1 Circuit Designation
Record circuit designation in appropriate column for each transformer or bus surge arresters.

11.2 Relief Diaphragm

Visually check for any signs of blow out at top and bottom of arrester. Check the 3 phases okay, if no visible signs of problems are found.

11.3 Checklist

a) Porcelain - Check porcelain for damage or flashed.
b) Connections - Visually check the primary and ground connections for heating or discoloration.

11.4 Remarks - List any remarks.

12.0 MOTOR OPERATED DISCONNECTS AND CIRCUIT SWITCHERS

12.1 Circuit Designation
Check the disconnect/airbreak to be labeled properly and record circuit designation in appropriate column.

12.2 Counters
Check and record operations counter located in motor operator.

12.3 Closed/Opened
Check and record airbreaks position, open or closed. Also, check open and close indicating lights on control panel. On Circuit Switchers, check that the interrupter is closed (yellow target located on the brain section of the Circuit Switcher indicates contacts open.)

12.4 Automatic/Manual
Check and record position of auto/manual switch. Contact control authority if not in proper position.

12.5 Gas Indicator (Circuit Switchers)
Record color of target on interrupter section of Circuit Switcher – (If target is red this indicated loss of gas notify supervisor immediately.)

12.6 Checklist

a) Fully Open or Closed - Visually check that all switches are in proper operating position.
b) Locks - Check that all airbreaks are properly locked and that the lock is in good condition.
c) Interlocks - Check all key interlocks for any broken keys, cylinders, or any other broken parts. Verify visually that all are in good working order.
d) Rods and Linkage - Check and verify that all rods and linkage are in good condition. Note anything broken or loose parts, or any signs of wear.

e) Handle Grounded - Check to be sure braided strap on airbreak rod is in good condition and connected to the ground grid.
f) Grounds - Check for proper ground connections from ground grid to motor mechanism and structure.
g) Fuses - Check control and heater circuits for voltage to prove fuses are not blown.
h) Heaters and Vents - Check thermostats and heaters are in proper working order. Heater control switches are in the "ON" position during the required season. Check vents in mechanism are not blocked
i) Motor operators with self contained batteries should be load tested. Record voltage before and during testing.

12.7 Remarks
List any remarks.

13.0 MISCELLANEOUS APPARATUS

13.1 Instrument/Metering Transformers - C.T. and P.T.

a) Noise - Check for any abnormal noises.
b) Level - Check for oil level on oil filled apparatus.
c) Leaks - Check for oil leaks. Clean any leak that is safe and report as described in the leak section (Appendix B).
d) Porcelain - Check for cracks in porcelain or butal.
e) Overheating - Check for any signs of overheating.
f) Connections - Check primary and secondary connections visually.
g) Nitro System – Check tubing, regulators, alarms, gauges using the soap test.

13.2 Line Traps/Reactors - Dry Type

a) Cleanliness - Check visually for cleanliness. Check for any foreign materials on coils. (i.e. bird nests)
b) Support Insulators - Check support insulators to be clean and intact.
c) Connections - Check primary and secondary connections visually. (over heating)
d) Concrete - Check concrete reactor frame for any cracks or breakage.
e) Winding Distortion - Visually check for any distortion on coils.

13.3 Cables and Terminations (Potheads)

a) Tracking - Check for tracking along termination and base of pothead.
b) Overheating - Check for signs of overheating.
c) Leaks - Check for leaking compound from termination.

13.4 Busses

a) Noise - Check for any abnormal noises with bus in operation.
b) Overheating - Check for any signs of overheating.
c) Insulators - Visually check bus for distortion or broken, damaged or tracked insulators.

14.0 FINAL CHECKLIST

a) Yard lights - Shut off yard lights.
b) Station LogBook - Observations should be entered in logbook such as: targets found, breaker operations, any defective or broken equipment.
c) Control Authority/Dispatcher - Call control authority to notify them that the V&O Inspection has been completed and you will be leaving the station. Report any abnormal conditions, alarms or relay targets.
d) Securing Station - Make sure control house lights are off and doors secured. Closed gate and locked securely with chain.
e) V&O Report - Turn in V&O Inspection Report to supervisor.

Appendix A

TROUBLE REPORTING

Trouble - The term trouble is defined as any condition, which occurs on the equipment that, has or will terminate the ability of that equipment to perform its required function.

I. SEVERE TROUBLE - A severe trouble condition is a situation that is immediately hazardous to the system and/or personnel. These troubles are immediately reported to the Control Authority/Dispatcher and to the person in charge of the substation. The employee shall secure the area and warn unauthorized people to stay clear of the danger.

Examples

- Dead station battery
- Blown bushings or cable terminator
- Downed live lines
- Multiple broken support insulators
- Electrical fires
- Grounds cut in station
- Loss of station service power
- Broken pole or structure
- Blown by pass/shunt arresters on regulators

II. NOT IMMEDIATELY FIXABLE TROUBLE - These troubles are reported immediately to the Control Authority. The person in charge of the substation shall also be notified of the non-fixable items and it shall be noted on the V&O form, to be fixed at a later date.

Examples

- Surge Arrester Blown
- Broken operating rods on disconnects
- Broken bus support insulators
- Low oil levels

III. FIXABLE TROUBLE - Fixable items should be repaired as they are discovered during the V&O Inspection. This insures that the station is

maintained in the best possible operating condition and prevents unnecessary return trips. The items fixed should be noted on the V&O Report.

Examples

- Battery electrolyte filling
- Replacing broken lamps
- Changing filters
- Installing missing covers
- Installing signs (if missing)
- Repairing holes in fence
- Installing new locks
- Cleaning and repairing oil leaks
- Tightening compressor belts
- Changing recloser batteries
- Replacing control fuses
- Changing nitrogen bottles
- Changing Silica Gel turned pink or white (desiccant)
- Cleaning and repairing leaks

Appendix B

OIL LEAK REPORTING

Oil filled apparatus must be inspected for any signs of leaks. The V&O Inspection Report now requires that the oil leak status be indicated for each piece of oil filled apparatus.

When inspecting the apparatus during a V&O Inspection, mark the appropriate column with the letter that indicates the leak status. The available status ratings are:

Repaired ® - If a leak is found and repaired during the V&O Inspection, use the repaired status and note the repairs made.

Leak (minor (**L**) - A Leak is defined by the PCB Manual as anytime the external surface of a piece of apparatus is wet with oil. Must write remark of what was leaking.

Moderate Leak (**M**) - By definition is any instance when oil is detected running off or about to run off the external surface of containers or electrical apparatus and any leak is actively dripping.

No status letter is defined for an oil leak that is more severe than a moderate leak. Any leak considered being of a magnitude greater than a moderate leak shall be responded to as an oil spill. Notify the supervisor of the condition at once and begin repair and the clean up.

The repaired leak may then be reported on the V&O Inspection Report as an "R", with a description the repairs made and the clean up done for the leak.

Appendix C

SUBSTATION - V&O INSPECTION REPORT

Note any abnormalities

Substation	Sheet ___of___	Date	Time	am/pm
Inspected By	Ambient Temp	Control House Temp		

CONTROL HOUSE (3)

Log Book	_____	Heavy Duty Ground	_____	Vandalism	_____
Control Panels	_____	Sittch Sticks	_____	Fence & Barbed Wire	_____
Annunciator/Test Switches	_____	Fire Equipment	_____	Gates	_____
Station Alarms	_____	Emergency Plan Posted	_____	Gate Locks & Chains	_____
Tags & Switching Order Pads	_____	Emergency Equipment Checklist	_____	Warning Signs	_____
Lighting	_____	Phone Lists	_____	Yard Lights	_____
Heaters	_____	Clean & General Condition	_____	Vegetation	_____

Station Service and Transfer

Preferred _____ Emer _____

YARD INSPECTION (6)

Checklist _____

SECURITY (5)

Leaks * C = Clean L = Leaks

R = Repaired M = Moderate Leaks

01 - CIRCUIT BREAKERS & RECLOSERS (7

Circuit Desig	Counter	Relay Targets	Ind Lts	Recloser Batt Chk	Air Compressor / Hydraulic				Checklist	Gas			Checklist	Remarks
					Cut In	Cut Out	Hours	Level		Pressure Level	Temp. Oil	Normal Leaks*		

04 - VOLTAGE REGULATORS & LTC (8)

Circuit Desig	Phase Design	Counter	Position Indicator				Volts	Load Mgt 2.50% Chk	Oil			Checklist	Remarks
			Min	Present	Max	Reset			Level	Color	Leaks*		

Appendix C

SUBSTATION - V&O INSPECTION REPORT			
Substation	Inspected By	Sheet _____of_____	Date _____

02 - TRANSFORMERS (9)

If Transformer is an LTC, Note LTC operation under V.R. section

Circuit Design	Nitro Press		Fans	Temp ° C (max/ind)					Oil		Checklist	Remarks
	Cyldr	Trans	& Pumps	Top Oil	WDG			Reset	Level	Leaks*		
					H	X	Y					

08 - CAPACITORS (10)

Circuit Design	Sw Pos	Counters		Control Operation				Buldges	Leaks*	Fuses	Checklist	Remarks
		Controls	Switch		Indicating	Actual	Correct					

19 - SURGE ARRESTERS (11)

Circuit Design	Relief Diaphragm			A phase		B phase		C phase		Checklist	Remarks
	A	B	C	Counter	Milliamps	Counter	Milliamps	Counter	Milliamps		

09 - MOTOR OPERATED DISCONNECTS AND CIRCUIT SWITCHERS (12)

Circuit Design	Counters	Live Line Ind	Time Reset	Preferred	Emer	Closed	Open	Auto	Manual	Gas Ind	Checklist	Remarks

06 - BATTERIES & CHARGERS (4)

Ref No / Desig	Voltage Rating	Pilot Cell				Charger		Grounds		Over All		Eql Chg	Checklist	Remarks
		Cell #	Temp	Sp gr	Volts	Load Amps	Float Voltage	P-G	N-G	Volts	Liq Lev			

REMARKS:

CHECKLIST

BUSSES _____

LINE TRAPS/REACTORS _____

CABLE & TERMINATIONS _____

INSTRUMENT TRANSFORMER (CT.PT.CCVT) _____

Appendix D

SUBSTATION - V&O INSPECTION CHECKLIST		
FILL IN AS FOLLOWS: IF SATISFACTORY OK IF DOES NOT APPLY -- IF UNSATISFACTORY WRITE COMMENT	SUBSTATION:	
	DATE:	INSP. BY

BATTERIES (4)

a) NO SMOKING SIGN _____
b) EYE WASH _____ _____
EXPIRATION DATE
c) VENT CAPS ARRESTER _____
d) CONNECTIONS _____
e) PLATES BUCKLING _____
f) SEDIMENT _____
g) RACK & PAINT _____
CONDITION _____
h) GROUNDING _____
I) LEAKAGE _____

YARD INSPECTION (6)

a) ALL PORCELAIN _____
b) NOISE LEVEL _____
c) GROUND CONNECTION _____
d) EVIDENCE OF HEATING _____
e) DISCONNECTS, _____
SWITCHES & FUSES
f) STATION SERVICE TRF _____
g) PAINT CONDITION _____
h) CLEAN AND GENERAL _____
CONDITION

AIR COMPRESSOR (7)

a) V BELTS _____
b) COMPRESSOR MOTOR _____
c) AIR FILTERS _____
d) GASKETS _____
e) VALVES _____

HYDRAULIC SYSTEM (7)

a) GASKETS _____
b) TUBING/FITTINGS _____
c) ACCUMULATOR _____

CIRCUIT BREAKERS/ RECLOSERS (7)

a) BUSHING DAMAGE _____
b) BUSING OIL LEVEL _____
c) POSITION INDICATOR _____
d) SPRING CHARGED _____
e) PAINTED SURFACES _____
f) RECLOSING RELAY _____
g) NOISE LEVEL _____
h) CONTROL FUSES _____
i) MOISTURE _____
j) CABINET VENTS (AIR) _____
k) CABINET HEATER _____
l) FOUNDATION _____

REGULATOR OR LTC (8)

a) BUSHING DAMAGE _____
b) TANK GROUNDS _____
c) NOISE LEVEL _____
d) CABINET VENTS (AIR) _____
e) ARRESTERS _____
f) BREATHER _____

TRANSFORMER (9)

a) BUSHING DAMAGE _____
b) BUSHING OIL LEVEL _____
c) TANK GROUNDS _____
d) CABINET HEATER _____
e) CABINET VENTS _____
f) SILICA GEL _____
g) MECH RELIEF _____
h) COOLERS _____
i) NOISE LEVEL _____

CAPACITORS (10)

a) BUSHING DAMAGE _____
b) GROUNDS _____
c) BANK GUARD SYSTEM _____

ARRESTERS (11)

a) PORCELAIN _____
b) CONNECTIONS _____

SWITCHES (12)

a) FULLY OPEN OR CLOSE _____
b) LOCKS _____
c) INTERLOCKS _____
d) RODS & LINKAGE _____
e) HANDLE GROUNDED _____
f) GROUNDS _____
g) FUSES _____
h) HEATERS _____

INSTRUMENT TRANSFORMERS (13) (CT, PT, CCVT)

a) NOISE LEVEL _____
b) OIL LEVEL _____
c) LEAKS _____
d) PORCELAIN _____
e) OVERHEATING _____

LINE TRAPS/REACTORS (13)

a) CLEANLINESS _____
b) SUPPORT INSULATORS _____
c) CONNECTIONS _____
d) CONCRETE _____
e) WINDING DISTORTION _____

CABLE & TERMINATIONS (13)

a) TRACKING _____
b) OVERHEATING _____
c) LEAKS _____

BUSSES (13)

a) NOISE LEVEL _____
b) OVERHEATING _____

Unitil

Operations Bulletin #OP8.00

SUBJECT: Critical Spares Policy
EFFECTIVE: 01/01/2002

ISSUED BY: G. Appleton
CONTENT BY: R Bisson, T. Biklen, M. Deschambeault, P.Stagno, S. Shepard

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1.0 PURPOSE

This bulletin establishes the requirements for inventorying critical spare parts and components for in-service energy delivery equipment. Specifically, this bulletin establishes the criteria and conditions for carrying an inventory of spare parts that would be deemed critical.

2.0 SPARE PARTS CLASSIFICATION & DEFINITION

Spare parts are classified as either Critical Spares or Non-Critical Spares.

Critical Spares

Critical spares are defined as inventoried parts that are immediately available as replacements for failed components. Critical spares are inventoried for only those components that if failed would result in service interruption to customers or diminished use or availability of the energy distribution system. Specifically, the component failure would cause the loss of service to customers, the loss of equipment use, the loss of a system's availability, or result in the energy delivery system to be operated in a sub-optimal first contingency basis until the component or affected equipment is replaced or repaired.

A sub-optimal first contingency basis means operating the energy delivery system:

- When there is an increased outage exposure to a significant number of additional customers

FG&E327

- When protection may not be fully coordinated or may result in not isolating faulted portions of the system prior to the occurrence of significant damage.
- When a mobile substation would be installed for a period of time greater than 2 weeks.
- When an automatic transfer scheme may require disabling.
- When conditions prevent full compliance with ISO-NE / NEPOOL operating requirements.

It is the company's intention to minimize the time that the energy delivery system is operated in such a configured manner. Accordingly parts and components that require inventorying in order to minimize this manner of operation are classified as critical spares.

Non-Critical Spares

Non-critical spares are defined as inventoried parts that are available as replacements for in-service components. Non-critical spares, if failed would result in operating the system on a first contingency basis where the affected equipment or system is not available but does not significantly increase outage exposure to additional customers. Additionally, the loss of the equipment or the system availability would be for a short period of time and does not result in operating the system on a sub-optimal basis. Included in this classification are consumable supplies used to perform periodic, routine maintenance, and are generally not returned to the stockroom. Such items include cleaning solvents, lubricants, and temperature control and actuating fluids and general use hardware.

It is not the intent of this policy to establish guidelines for identifying and inventorying non-critical spare parts.

3.0 REQUIREMENTS FOR CRITICAL SPARES

All critical spares, regardless of cost, shall meet the following requirements:

- The spare part shall meet the classification definition in Sec 2.0, above.
- The spare part shall be used to replace a component that is unique to the equipment and essential to the equipment operation.
- The failure of the essential component must render the equipment or system inoperable and force its removal from service.

- No other part, component or subsystem exists as a functional or economically viable substitute for the part.

Certain spare parts may be multi-functional or may be viable replacement components for a large number and variety of equipment or systems. Critical spares that meet component replacement requirements for multiple systems and equipment shall be stocked in preference to sole function critical spare parts.

It is recognized that items used in the course of routine or planned construction may be used to replace parts that have failed and rendered equipment or a system inoperable. Such items are usually stocked in quantities sufficient to meet both emergency and planned work requirements. These items shall not be classified as critical spares. In the event that emergency use of such items exceeds planned use, a re-evaluation of the stock classification for the item will be made.

Critical spares will only be used when a component failure occurs. Critical spares shall not be used for planned maintenance or planned construction work. In most instances, there is a high probability that a critical spare will not be needed or used during the operational lifetime of the equipment or the system. In the relatively rare event that a piece of equipment or system experiences a failed component resulting in the permanent use of a critical spare, an order shall be issued to obtain a replacement critical spare part to be placed in inventory.

3.0 CRITICAL SPARE STOCKING METHODOLOGY

The decision to stock at least one unit of a given type of a critical spare shall be determined using an equipment and service availability criteria and a system impact criteria. The on-hand quantity for a specific critical spare component shall be determined using an inventory control model criteria. The inventory control model establishes the critical spare stocking levels assuming an exponential distribution of failure free operating time, an exponential distribution of re-supply lead time, the quantity of in-service parts deemed to be classified as critical and an inventoried part availability service level of 95%.

Equipment Availability Impact Criteria

The reliability of the energy delivery system is dependent upon the availability of the equipment, systems and components that make up the system. Equipment, lines and systems are not available for service when a component or part has failed. Determining a component failure rate is necessary for determining stocking levels for critical spares.

Failure Rate:

The identification of critical spares and inventoried quantities for in-service components is based upon the premise of equipment reliability or a very high failure free operating time. Such equipment and systems must be supported with sound preventative maintenance and spare parts availability. Accurately predicting a component failure rate is required to establish a cost efficient and effective critical spare parts inventory.

The failure rate of the part can be determined from the historical reliability data for the component. Analysis of equipment component failures, equipment maintenance history, equipment in-service duty and equipment in-service performance can be used to estimate a failure rate. Where equipment is new or no historical operational data is available, information regarding the component availability should be obtained from the equipment manufacturer, from other utilities, utility associations or sources. Experience with similar equipment placed into service under similar operating conditions may provide information regarding component rate failure predictability.

A failure rate must be determined and established for any in-service component or part that is to be supported by a critical spare. The failure rate is measured and quantified as a mean failure free operating time of the component or spare part. Operational performance records that include hours of failure free operating time shall be recorded for in-service components that are supported by a critical spare.

System Impact Criteria

The failure of critical spare parts could adversely impact system operating conditions causing service interruption to customers or diminished use or availability of the energy distribution system. Prolonged operation of the system in such a manner creates conditions that put customers at a high risk of having service interrupted. These operating conditions must be limited to minimum amounts of time. Accordingly critical spare inventories shall be established and maintained for components that may fail in service and result in the following conditions:

- loss of service to customers
- operating conditions that prevents compliance with ISO-NE / NEPOOL operating requirements
- energy delivery system being operated in a sub-optimal first contingency basis
- a mobile substation placed into service for a period of time greater than two weeks

Inventory Control Model

The on-hand quantity for a specific critical spare component shall be determined using an inventory control model criteria. The inventory control model establishes the critical

spare stocking levels assuming an exponential distribution of failure free operating time, an exponential distribution of re-supply lead time, the quantity of in-service parts deemed to be classified as critical and an inventoried part availability service level of 95%.

The chart shown in FIGURE 1 establishes the inventoried quantity for a specified critical spare for the designated service level of 95%. The horizontal axis indicates the calculated ratio of the mean lead-time for re-supply or acquisition of a critical spare to the failure free operating time of an in-service critical component. The mean lead-time is the duration of time between the spare part order time and spare part receipt time. The Mean failure free operating time is the period of time between failures of a specific in-service component. The vertical axis indicates the number of critical components in-service.

The inventory model calculates and graphs a stepped boundary that separates the quantity of critical spares to be inventoried based upon a calculated spare part mean lead-time to mean failure free operating time ratio for a given number of in-service components.

The graph further indicates that the quantity of inventoried spares changes very little over a wide range of operating parameters such as part lead-time, component failure rates and in-service component quantities. A single graph can be used to establishing stocking quantities for many critical spares.

The graph depicts a simplified way in which to determine spare part quantities. The inventory model used to create the graph employs a complex set of calculations based upon exponential distributions around calculated means and probabilities that considered several occurring conditions. Several assumptions that were made when establishing this inventory control model. Most of the assumptions were conservative and were made to simplify the model. Assumptions

- A unit of in-service equipment utilizes critical spares in quantities of one. It is recognized that certain in-service equipment utilizes critical spares in quantities greater than one. The inventoried quantity for these critical spares must be adjusted to account for multiple component use by a single unit of equipment.

- All critical spares are acquired from a single supplier. No alternative supply of the part was considered such as an alternate supplier or borrowing the part from another utility.

- All failed components are to be discarded. No failed components were assumed to be refurbished and placed into inventory

- The model is based upon an in-service of equipment availability premise not a total down time cost premise that include transaction charges and inventory carrying charges.

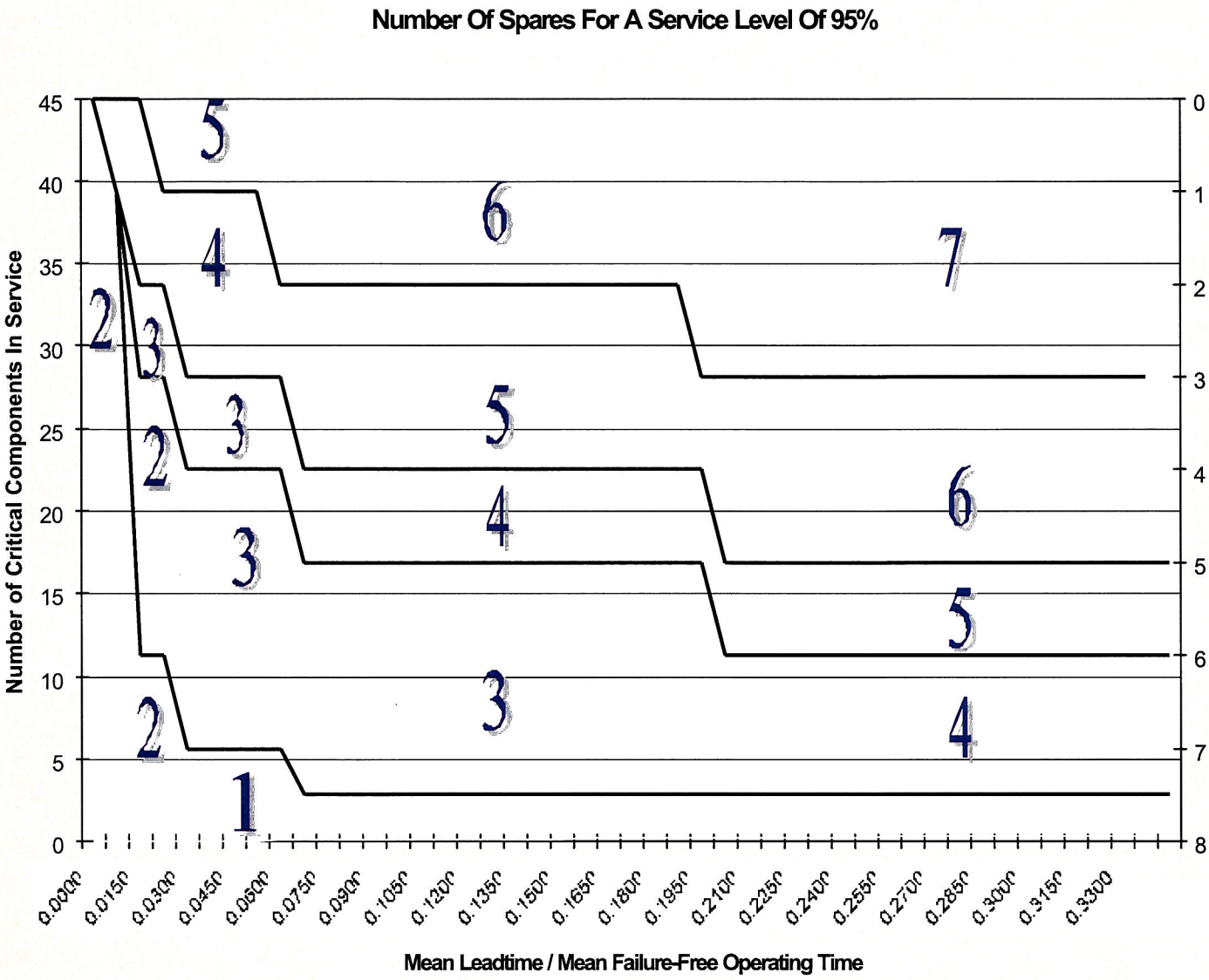
Number Of Spares For A Service Level Of 95%
Number of Critical Components In Service
Mean Leadtime / Mean Failure-Free Operating Time
45
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
0.000
0.015
0.030
0.045
0.060
0.075
0.090
0.105
0.120
0.135
0.150
0.165
0.180
0.195
0.210
0.225
0.240
0.255
0.270
0.285
0.300
0.315
0.330
5
4
2
3
3
2
3
2
1
6
5
4
3
7
6
5
4

FIGURE 1

Unitil

Operations Bulletin #OP10.00

SUBJECT: Electric Test Equipment Policy
EFFECTIVE: 12/2/02

ISSUED BY: G. Appleton
CONTENT BY: R. Bisson, T.Biklen, M. Deschambeault, J. Bonazoli, S. Baker, R. Abel

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1.0 PURPOSE

This bulletin is written to establish a policy that specifies the electric test equipment that will be used when testing electric substation control and protection systems, electric substation equipment, underground cables and underground electric equipment.

Test equipment purchased and utilized shall be maintained and calibrated in accordance with the equipment manufacturer's recommendations.

Storage / housing locations for test equipment designated for sharing among the Distribution Operations Centers (DOC`s) operating centers are specified in the test equipment description. Each DOC shall be responsible for the acquisition of test equipment. The DOC responsible for housing shared test equipment shall be responsible for the acquisition and maintenance of the equipment. Test equipment purchases shall be included in the annual capital budget.

This policy shall be reviewed on a periodic basis for inclusion of new test equipment

2.0 EQUIPMENT

2.1 Insulation Resistance Tester (Megger)

Insulation resistance tester is used to measure the insulation resistance of a cable or equipment. The test may be conducted at applied voltages of 100 volts – 15,000 volts. The instrument indicates the insulation resistance in megohms. It may be hand cranked, motor driven or electronic. Two insulation resistance meters, based upon applied test voltage requirements, are acceptable for use.

FG&E333

15 kV Insulation Resistance Tester (Megger)

- Input = 115 volts, single phase or hand driven
- Output = 15Kv (incremented in 500 volt steps)Scale = up to 500,000MΩ (multi-range)
- Line, guard and ground leads
- Motor driven recommended for 15Kv test set
- Number of units: One for system @ Fitchburg.

1 kV Insulation Resistance Tester (Megger)

- Input = 115 volts, single phase or hand driven
- Output = 1Kv (variable output)
- Scale = up to 100,000MΩ (multi-range)
- Line, guard and ground leads
- Number of units: One at each DOC

2.2 Protective Relay Test Set

Protective relay test set to test both in-service and spare protective relays. Test set shall be capable of testing the following relay types: Three winding transformer differential, over / under current (DC & AC), over / under voltage (DC & AC), directional, Single phase and three-phase distance, frequency, directional power, reclosing, timing, current or voltage balance, current or voltage restrained, synchronism, single phase and three phase. The test set shall be capable of testing all operational features of both electromechanical and solid state relays.

- Test set is to be portable and operated with 120 volt AC or 240 volt AC supply
- Input = 0 – 250 volts, 0 – 75 A (multiple ranges)
- Output = current range 0.5 A – 75 A, voltage range 1.3V – 300V, frequency (increment adjustable)
- Test set to be capable of testing, with auxiliary current source, up to 150 A
- DC Meters = current, voltage (full range of input and output)
- AC Meters = current, voltage (full range of input and output)
- Frequency Meter = 0 Hz – 100 Hz continuous
- Multiple Timers for measuring multiple events
- Auxiliary discrete inputs
- Auxiliary outputs contacts
- Auxiliary DC voltage output
- PC and software capabilities: store and download relay test results, relay test history and relay test method to PC, operator able to program test procedures, automatic operation of programmed procedures
- Number of units: One unit at Fitchburg and one unit shared by Seacoast and Capital.

2.3 Recloser Control Test Set

The recloser control test set is used to test the electronic protective relaying and electronic controls for types ME Form electronic reclosers. Specifically, the test set will check battery function, phase and ground trip setting, operating sequence, reclosing time, reset time and electrical operation of the recloser and ancillary equipment functions.

- Input: 120 volt AC
- Output: 0 ma – 3,000 ma
- DC meters: 0 ma – 4 / 40 ma, 0 volts – 40 volts (multi-range)
- AC meters: 0 ma – 30 / 100 / 300 / 1,000 / 3,000 ma (multi-range)
- Timer: 0 – 60 seconds in 0.01 sec increments
- Number of units: One unit at each DOC
  Note: Recloser control test sets will not be replaced if they fail. Use protective relay test set if a failure occurs.

2.4 Automatic Oil Circuit Recloser Test Set

The automatic oil circuit recloser test set provides a variable high current output to test the minimum trip current and time-current characteristics of circuit reclosers and sectionalizers. The current, trip time and reclose time for each operation as well as the total clearing time are all automatically measured by the test set.

- Input: 220 volts single phase
- Output: 25 to 2000 amperes at 600 to 7.5 volts respectively
- Timer: 0 to 9999 cycles (999.9 s)
- Solid state digital display ammeter 0 to 19.99 kA maximum range
- Number of Units: One for the system @ Fitchburg

2.5 Contact Resistance Test Set

The contact resistance test set is used to measure contact resistance in circuit breakers, reclosers and sectionalizers. Additionally, the test set is used to measure winding resistance in high voltage power transformers. The actual measured resistance is determined by the DC current flowing through the conductor and the DC voltage drop across the specimen. It recommended that contact resistance measurements on medium and high voltage breakers and high voltage transformers be conducted with a test set having at least a 100 amp direct current output.

- Input = 115 volts AC, .single phase or DC power supply, 100 A
- Output = 100 A DC current output
- Measurement: 1,000$\mu\Omega$ (multi-range)
- Number of units: One at each DOC

2.6 Portable AC Hipot for Vacuum Bottle Testing

Lightweight AC hipot test set to provide continuously adjustable output voltages for GO/NO-GO testing of high voltage insulation, switchgear and vacuum devices. Test are performed in accordance with the manufacturer's instructions, generally AC testing is required.

- Input: 120 volts single phase
- Output: 0 – 30 kv AC, 1kVA resistive load
- Kilovolt meter: 0 –30 kV AC RMS
- Shielded output cables
- Number of Units: One for the system @ Fitchburg

2.7 Primary Cable Fault Location Test Set

The impulse generator with both proof test and burn capabilities is used to locate faults in primary voltage rated cables. The impulse generator (thumper) transmits a pulse between the faulted conductor and ground creating an audible arc at the location of the fault. The fault is located by using an audible detector or by tracing the magnetic field generated by the arc with a magnetic detector

Impulse Generator (thumper)

- Input = 115 volts AC, single phase
- Output = 30kV / 60kV, 50ma / 100ma burn capacity, 12μf, 3,500watt-sec thumping
- Portable unit
- Number of units: One at each DOC

Magnetic Detector (primary cables in duct)

- Battery powered, portable, with detector and sheath coil pickup
- Number of units: One at each DOC

Acoustic Detector (primary cables direct buried)

- Battery powered, portable, with amplifier, headset and surface tracing coil.
- Number of units: One at each DOC

2.8 Secondary Cable Fault Locator

- Input: 115 volts AC, single phase or battery powered
- Output: 1,000 volts DC, 0 – 100 ma
- Acoustic detector is usually required
- Number of units: One at Fitchburg, one shared by Seacoast and Capital

2.9 DC High potential test set

The test set is used to check the quality of insulation systems in high voltage equipment, cables, transformers, capacitors and aerial booms and lifts. The insulation quality is determined by measuring the DC current flowing through the insulation with a known DC voltage applied across the specimen.

- Input = 115 volts AC, single phase
- Output = 0 - 120kV, 5 ma for 20 minutes, 2 ma continuous
- Measurement = 100μA (multi-range) 0.1 μA (increments)
- Number of units: One at Fitchburg, one shared by Seacoast and Capital

2.10 Power Factor Test Set

AC power factor tests measure insulation capacitance, AC dielectric loss and the ratio of the measured quantities. Insulation power factor measurements are taken on medium and high voltage transformers, circuit breakers, cables, surge arresters, insulators, insulation fluids and equipment in both the transmission and distribution systems.

- Input = 115 volts AC, single phase
- Output = 10kV AC, 100 ma
- Measurements: 0 – 1,000 watts (multi-range), 0 - 10kV continuous, 0 – 100 ma (multi-range), 0 – 100 % power factor
- Automatic balancing of both capacitance and power factor
- Automatic temperature correction
- Insulation fluid specimen test
- PC and software capabilities: store and download test results, and test method to PC, operator able to program test procedures, automatic operation of programmed procedures. Test history stored on PC.
- Number of units: One for the system @ Fitchburg
  Note: Annual lease.

2.11 Transformer Turns Ratio Tester

The Transformer Turns Ratio Test set is used to determine the additive and subtractive polarity, open or short-circuited windings and the turns ration of single phase and three phase transformers. If a single-phase transformer turns ratio test set is used it is not necessary to have or acquire a three-phase transformer turns ration test set.

Transformer Turns Ratio Tester (three phase)

- Three phase, motor driven
- Input = 120 volt
- Ratio = 0 – 130 range (+/- 0.1%)
- Features to include: Null check, zero ratio check, unity check
- Number of units: One at each DOC

Transformer Turns Ratio Tester (single phase)

- single phase, hand powered
- Ratio = 0 – 130 range (+/- 0.1%)
- Features to include: Null check, zero ratio check, unity check
- Number of units: One at each DOC

2.12 Liquid Dielectric Test Set

Liquid dielectric test set is used to determine the breakdown voltage of liquid dielectrics in accordance with ASTM D877 and ASTM D1816.

- Input = 115 volts AC, minimum 5 A
- Output = 60kV
- Rate of rise 500 volts per second through 3,000 volts per second (multi-range)
- Test cups to allow both D877 and D1816 tests
- Number of units: One at each DOC

2.13 Percent Total Combustible Gas Analyzer

The tester will measure the percent of total combustible gas in the inert gas space located of a transformer. The tester will draw a sample from the transformer gas space and automatically express the total combustible gas content as a percent of total gas sampled.

- Input: battery powered (portable)
- Measures and displays the percent of total combustible gas sampled 0% - 100% range (+/- 0.1%).
- The unit shall be self calibrating with measurement display
- The gas sample shall be drawn into the test unit for measurement.
- Number of units: One at each DOC

2.14 Battery Impedance Tester

This test set is use to measure the internal impedance of the entire battery bank and / or an individual cell. The battery impedance is measured by passing a low frequency current through the battery while measuring the voltage across each individual cell. The impedance is calculated by dividing the cell voltage by the current passing through the cell or battery.

- Input: 0 – 10 amps (variable), 0 – 240 volt (variable)
- Maximum total voltage at current source leads: 275 vdc
- Measures: Cell and battery impedance up to 7,000 amp-hour battery size (lead acid and nickel cadmium)
- PC and software capabilities: store and download test results to PC, operator able to program test procedures, automatic operation of programmed procedures
- Number of units: One for the system @ Fitchburg.

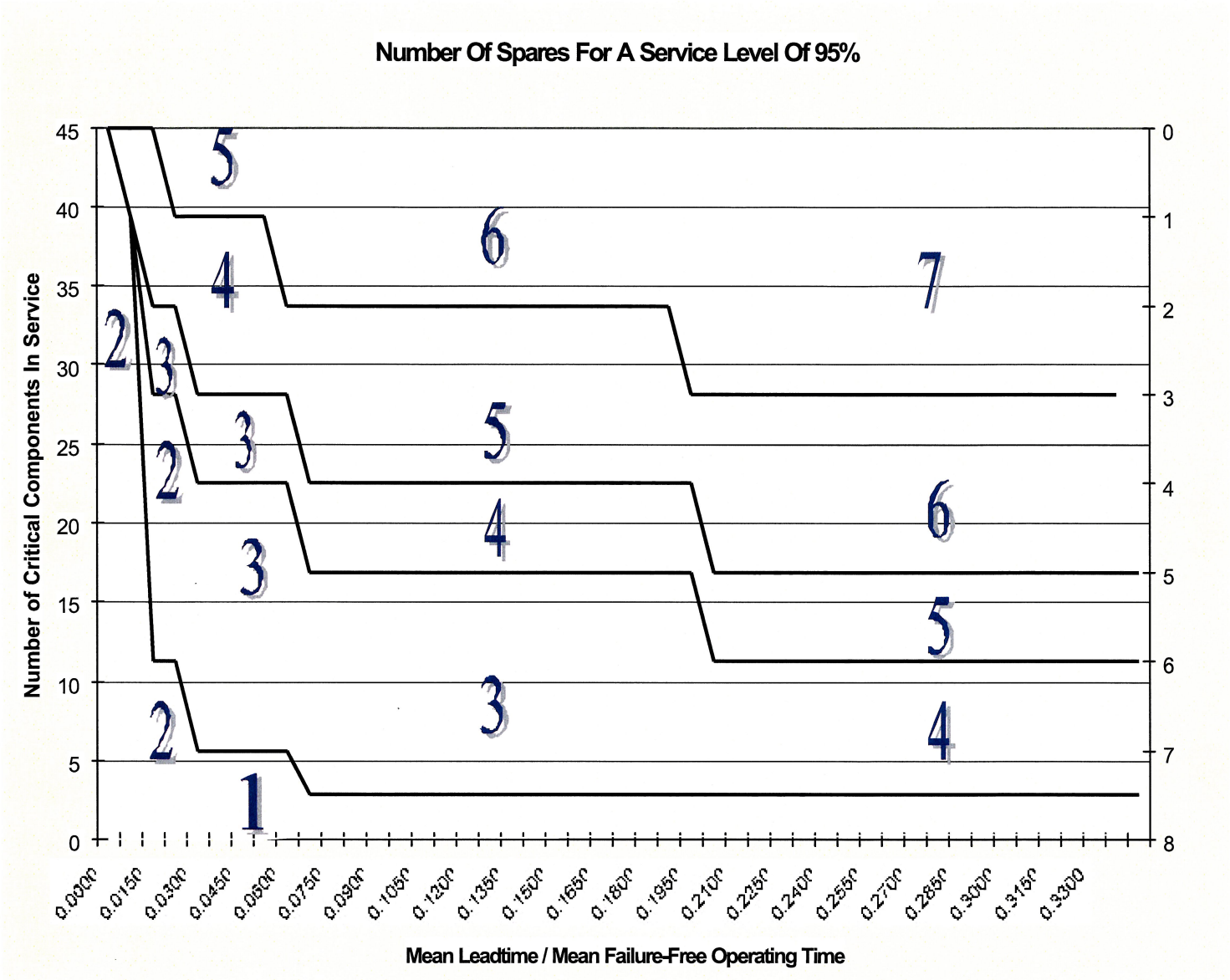
Number Of Spares For A Service Level Of 95%
Number of Critical Components In Service
Mean Leadtime / Mean Failure-Free Operating Time
45
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
0.000
0.015
0.030
0.045
0.060
0.075
0.090
0.105
0.120
0.135
0.150
0.165
0.180
0.195
0.210
0.225
0.240
0.255
0.270
0.285
0.300
0.315
0.330

FIGURE 1

Unitil

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EFFECTIVE: 12/2/02

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FG&E333

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- Input = 0 – 250 volts, 0 – 75 A (multiple ranges)
- Output = current range 0.5 A – 75 A, voltage range 1.3V – 300V, frequency (increment adjustable)
- Test set to be capable of testing, with auxiliary current source, up to 150 A
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- Input = 115 volts AC, .single phase or DC power supply, 100 A
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- Measurement: 1,000$\mu\Omega$ (multi-range)
- Number of units: One at each DOC

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- Input: 120 volts single phase
- Output: 0 – 30 kv AC, 1kVA resistive load
- Kilovolt meter: 0 –30 kV AC RMS
- Shielded output cables
- Number of Units: One for the system @ Fitchburg

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The impulse generator with both proof test and burn capabilities is used to locate faults in primary voltage rated cables. The impulse generator (thumper) transmits a pulse between the faulted conductor and ground creating an audible arc at the location of the fault. The fault is located by using an audible detector or by tracing the magnetic field generated by the arc with a magnetic detector

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- Battery powered, portable, with detector and sheath coil pickup
- Number of units: One at each DOC

Acoustic Detector (primary cables direct buried)

- Battery powered, portable, with amplifier, headset and surface tracing coil.
- Number of units: One at each DOC

2.8 Secondary Cable Fault Locator

- Input: 115 volts AC, single phase or battery powered
- Output: 1,000 volts DC, 0 – 100 ma
- Acoustic detector is usually required
- Number of units: One at Fitchburg, one shared by Seacoast and Capital

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Transformer Turns Ratio Tester (three phase)

- Three phase, motor driven
- Input = 120 volt
- Ratio = 0 – 130 range (+/- 0.1%)
- Features to include: Null check, zero ratio check, unity check
- Number of units: One at each DOC

Transformer Turns Ratio Tester (single phase)

- single phase, hand powered
- Ratio = 0 – 130 range (+/- 0.1%)
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