Accelerated Weathering of Overhead Loadbreak Switch Interrupters NEETRAC

Frank C. Lambert
Georgia Tech / NEETRAC

High Voltage Switch Subcommittee
Calgary, Alberta
October 15, 2008

NEETRAC Members 2008 - 2009

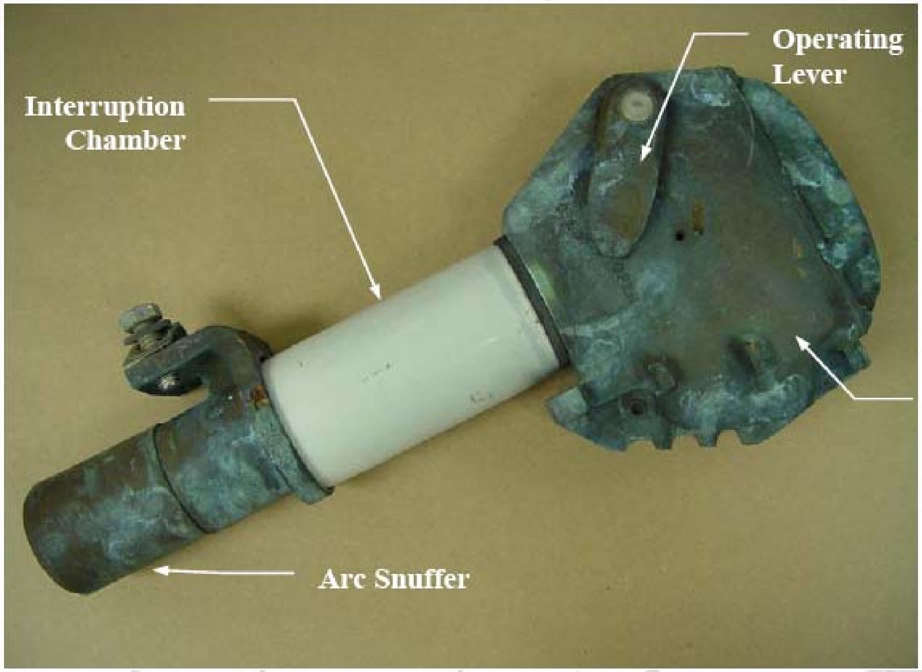
1. 3M
2. ABB
3. ACA Conductor Accessories
4. Ameren Services
5. American Electric Power
6. Baltimore Gas & Electric
7. Borealis Compounds LLC
8. Con Edison
9. Cooper Power Systems
10. Dominion Virginia Power
11. Dow Chemical Company
12. Duke Energy
13. Entergy
14. Exelon
15. Florida Power & Light
16. First Energy
17. GRESCO Utility Supply
18. Hubbell
19. NRECA
20. NSTAR
21. PacifiCorp
22. Prysmian Cables & Systems
23. Public Service Electric & Gas
24. South Carolina Electric & Gas
25. Southern California Edison
26. Southern Company
27. Southern States
28. Southwire
29. Thomas and Betts
30. TVA
31. tyco / Raychem
32. Zenergy Power

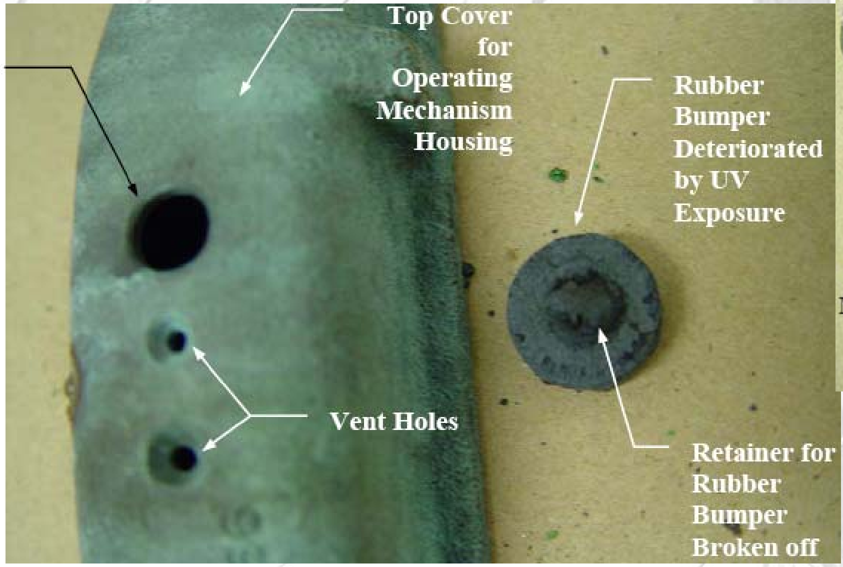
Introduction

- NEETRAC completed a scoping study to identify field problems with distribution loadbreak switch interrupters in 2005.
- Utilities reported problems with “stuck” interrupters or failures when opening.
- 17 loadbreak interrupters were removed from field service and returned to NEETRAC for evaluation.
- Many of the problems with these units appeared to be caused by UV deterioration and corrosion.

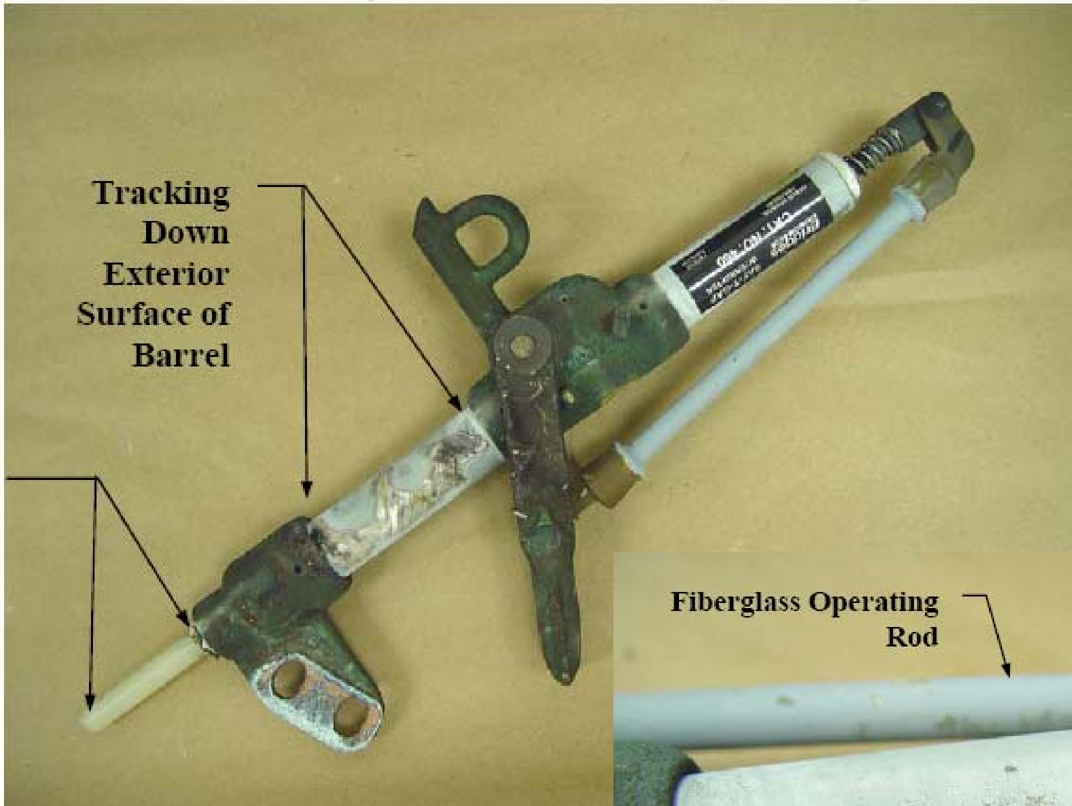
Field Evaluation

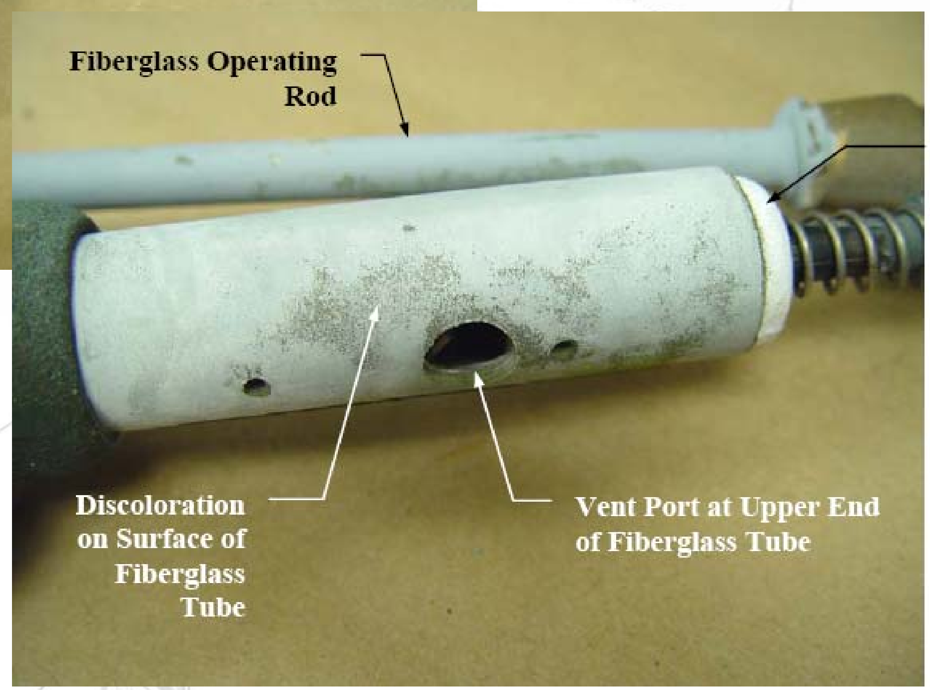
Returned from Field Service:
Alabama Power Company





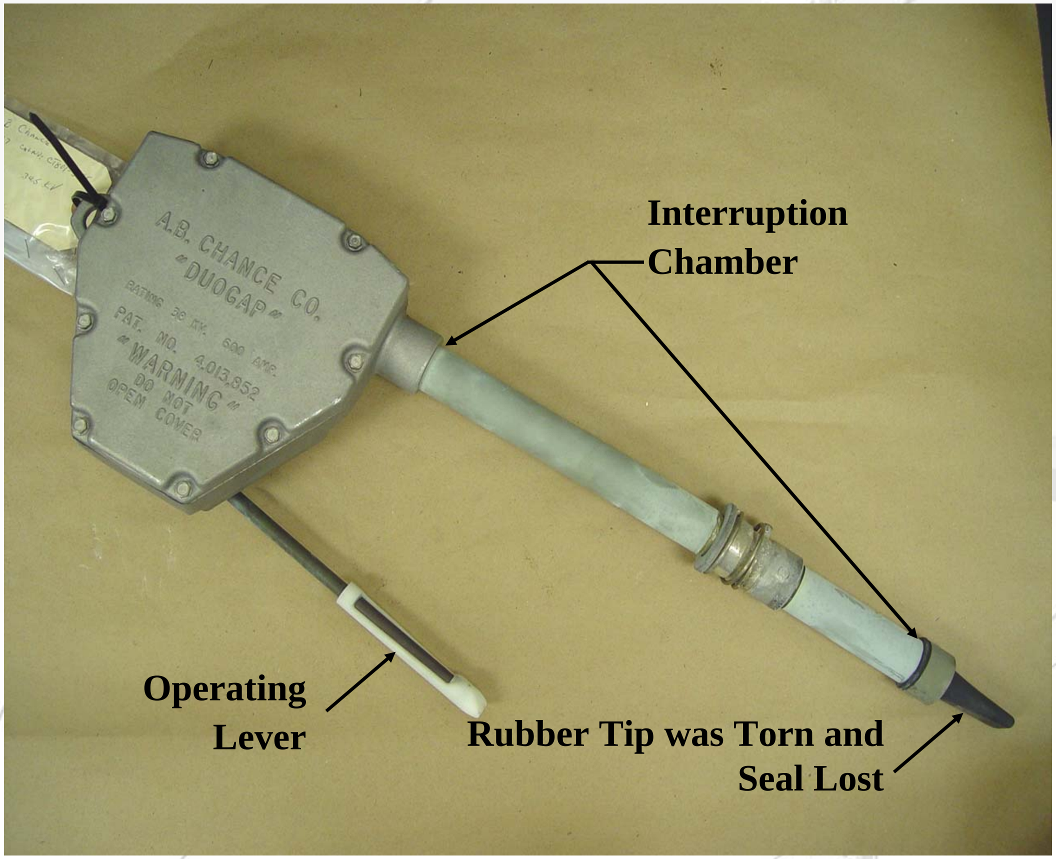
Field Evaluation





Returned from Field Service:
Alabama Power Company

Field Evaluation



Returned from Field Service: Dominion

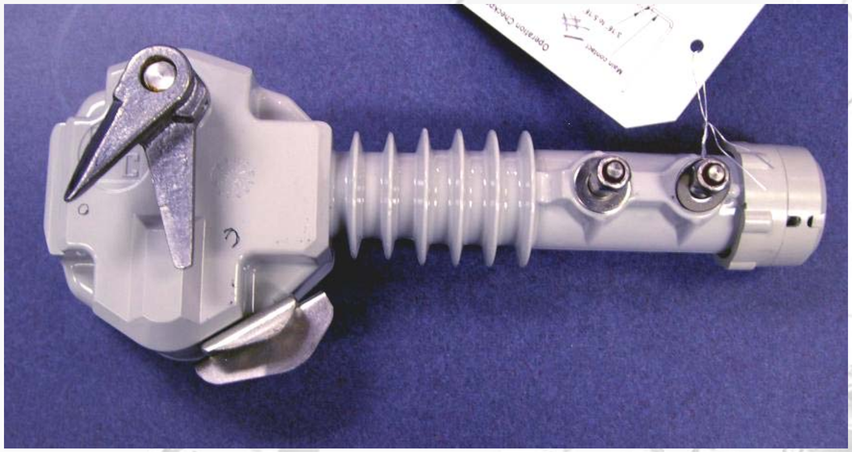
Accelerated Weathering of OH Loadbreak Interrupters

- Based upon a review of the units returned from the field, a project was initiated to investigate the affects of both UV deterioration and corrosion on new interrupters.
- Six different loadbreak interrupters from five manufacturers were exposed to both UV / condensation and salt-fog accelerated weathering at NEETRAC.
- Benchmark tests were performed during the aging process to measure dc contact resistance and mechanical force required for operation.

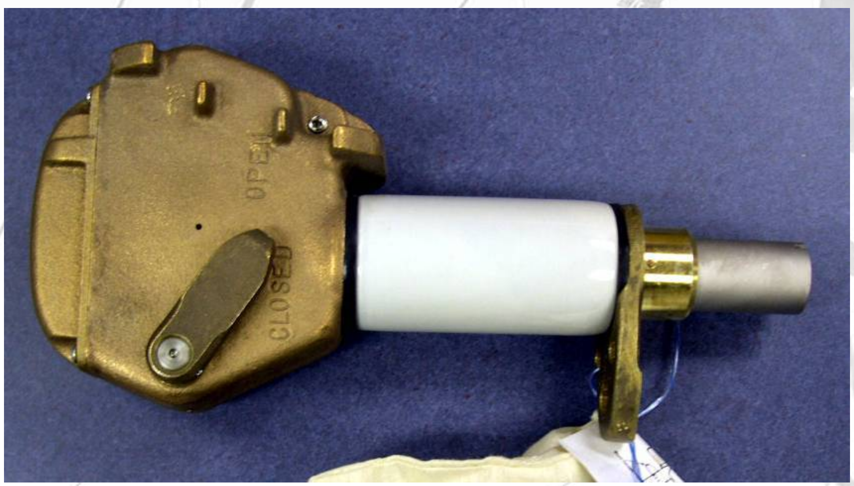
Accelerated Weathering of OH Loadbreak Interrupters

- Both new and aged interrupters were then subjected to the full load current interruption tests according to Section 9.1 of IEEE C37.34 at a high power laboratory.
- Failures from the full load current interruption tests were examined to assess the impact of the weathering on performance.

Samples Tested

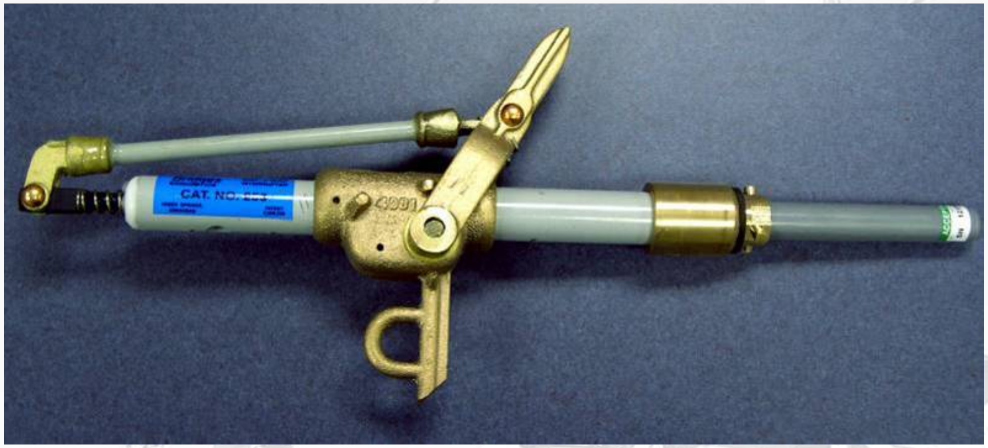


S&C Electric Company
Omni-Rupter
17 kV, 900 A
147442R1-Z3-S115

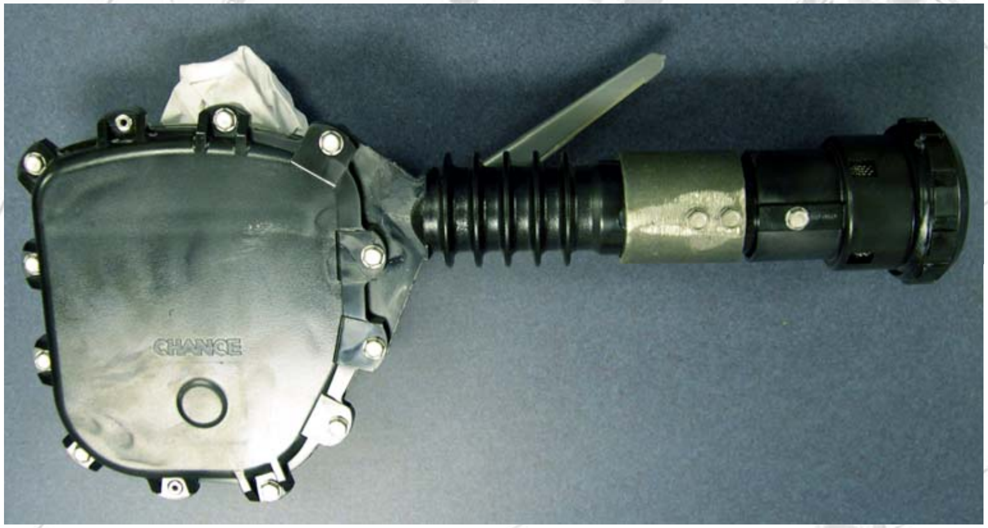


S&C Electric Company
Alduti-Rupter
17 kV, 600 A
137512R7-S102

Samples Tested

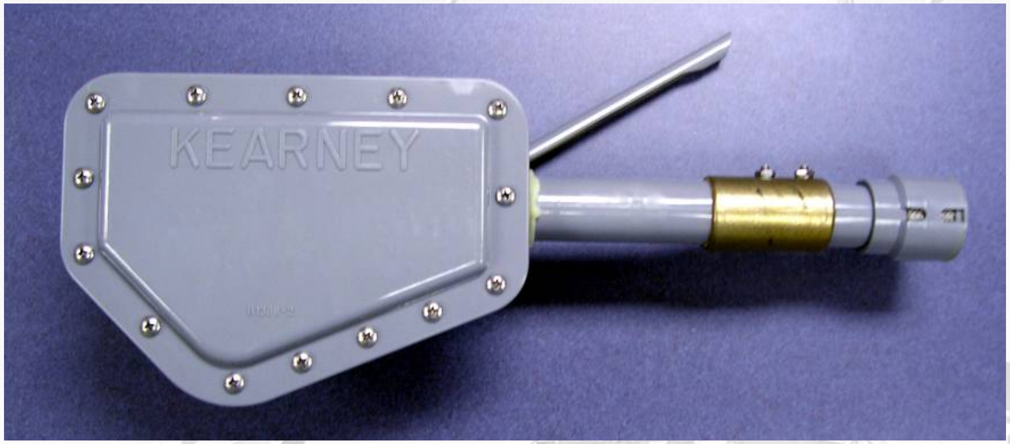


Bridges
Vector
25 kV, 900A
PN963XF-41AS

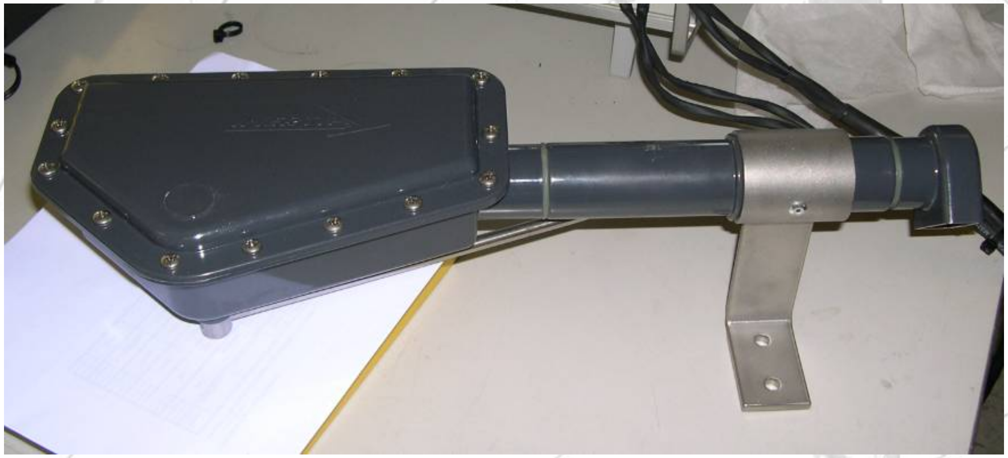


A. B. Chance
Automation Ready
29 kV, 900 A
AR114MSLP

Samples Tested



Cooper Power Systems
M-Force
25.8 kV, 900 A
M2A41SC3AT



Inertia
25 kV, 600 A
TRS26STSHX1125

UV / Condensation Aging

UV / condensation aging according to ASTM D4329-05 and ASTM G154-06 using UVA-340 lamps.

UV / Condensation Aging

- 2,000 hours total aging was required to produce results similar to those observed on field aged units (includes UV & condensation periods).
- The following aging cycle was used:
  - 8 hours of UV at 60 ± 3 °C
  - 0.25 h water spray (no light), temperature not controlled
  - 3.75 h condensation at 50 ± 3 °C
- Rotation of samples approximately every 333 hours, horizontally across the rack.
- Distilled water was used for the chamber.

Salt-fog Aging

- Performed on one sample of each design after 2,000 hours of UV / condensation aging.
- 1,000 hour salt-fog aging test according to ASTM B117-07.
- A continuous fog of 5% salt solution was used.

Benchmark Tests

- dc contact resistance (closed position)
- Mechanical performance – torque, force, etc. (both opening and closing)
- Performed on the samples four times:
  - new
  - after 1,000 hours of UV aging
  - after 2,000 hours of UV aging
  - after 1,000 hours of salt-fog aging
- Sample designations:
  - UV is UV / Condensation aging only
  - UVS is UV / Condensation and Salt-fog aging

Benchmark Test Results

Sample Number	dc Contact Resistance in Ohms					Comments
	Initial	Post 1,000 hr UV Aging	Post 2,000 hr UV Aging	Post Salt-Fog Aging Before Operation	Post Salt-Fog Aging After Operation	
A-UV-4	0.061	0.115	0.830			
A-UV-5	0.085	0.158	0.385			
A-UVS-6	0.067	0.339	0.218	0.068	0.134	
D-UV-4	0.003	0.006	0.005			Interrupter was rusted shut when removed from salt-fog. After interrupter was forced open, internal contacts never opened.
D-UV-5	0.009	0.007	0.032			
D-UVS-6	0.004	0.014	0.003	0.018	12545	
E-UV-4	0.297	0.379	0.182			
E-UVS-5	0.485	0.230	0.235	5.560	1.480	
E-UV-6	0.176	0.286	0.283			
F-UV-4	0.006	0.034	0.014			
F-UVS-5	0.063	0.015	0.078	0.012	0.098	
F-UV-6	0.004	0.028	0.006			
G-UV-4	0.007	0.018	0.010			Could not close interrupter internally after it was operated post salt-fog.
G-UVS-5	0.009	0.020	0.011	0.206	open	
G-UV-6	0.006	0.007	0.008			
H-UV-4	0.054	0.081	0.018			
H-UVS-5	0.068	0.019	0.029	1500	1398	
H-UV-6	0.039	0.031	0.060			

Benchmark Test Results

	Force Measurements in lbs							
	Initial		Post 1,000 hr UV Aging		Post 2,000 hr UV Aging		Post 1,000 hr Salt-Fog Aging	
Sample Number	Open to Closed Contacts	Closed to Open Contacts	Open to Closed Contacts	Closed to Open Contacts	Open to Closed Contacts	Closed to Open Contacts	Open to Closed Contacts	Closed to Open Contacts
A-UV-4	9.8	8.2	10.0	9.8	11.0	10.5		
A-UV-5	11.4	9.9	12.4	10.2	10.5	10.7		
A-UVS-6	9.6	8.8	9.8	10.8	10.0	10.3	13.9	9.9
D-UV-4	25.0	18.0	22.9	21.0	20.7	19.2		
D-UV-5	23.7	20.0	23.0	19.0	21.9	21.8		
D-UVS-6	23.0	21.0	19.9	22.2	20.1	19.4	**24+**	**26+**
E-UV-4	0.6	7.8	0.6	8.1	0.4	7.8		
E-UVS-5	0.9	7.6	0.4	7.5	0.9	7.9	2.0	8.2
E-UV-6	0.9	8.4	0.6	8.2	1.0	7.8		

Sample D-UVS-6 had to be lubricated with rust buster and forced open in order to record the post salt-fog aging measurements.

Benchmark Test Results

	Force Measurements in lbs							
	Initial		Post 1,000 hr UV Aging		Post 2,000 hr UV Aging		Post 1,000 hr Salt-Fog Aging	
Sample Number	Open to Closed Contacts	Closed to Open Contacts	Open to Closed Contacts	Closed to Open Contacts	Open to Closed Contacts	Closed to Open Contacts	Open to Closed Contacts	Closed to Open Contacts
F-UV-4	13.9	9.8	14.5	10.0	15.2	11.0		
F-UVS-5	15.0	9.8	16.0	10.2	14.5	9.3	14.2	16.2
F-UV-6	15.3	9.8	18.7	10.6	15.1	9.8		
G-UV-4	0.3	12.9	0.8	13.1	0.1	11.1		
G-UVS-5	0.4	12.0	0.9	12.6	0.6	12.3	2.0	10.2
G-UV-6	0.4	11.9	0.5	11.4	0.4	12.0		
H-UV-4	3.8	15.0	0.9	15.0	0.4	16.1		
H-UVS-5	5.7	17.0	0.9	15.1	0.5	14.9	4.0	12.6
H-UV-6	2.7	19.0	1.2	16.1	0.2	15.4		

Load Current Interruption Tests

- Performed at Powertech Labs – October 2007
- IEEE Std 1247™ 2005, Clause 8.3.2.1, Load-switching tests

Load Current Interruption Tests

Test plan for each manufacturer’s switch:

1. Perform ***10 load break switching operations*** at 100% load with ***new*** (un-aged) interrupters (as required by IEEE Std 1247™). A five minute “cool down” period was provided between each switching operation.
2. If the unit passed IEEE Std 1247™ requirements, replace interrupters with new (un-aged) interrupters and perform ***three additional load break switching operations*** under ***wet conditions***. Prior to each operation, each interrupter was thoroughly wetted with water using a spray bottle with 100 ± 15 Ω-m water. A five minute “cool down” period was provided between each switching operation.

Load Current Interruption Tests

3. Replace interrupters with the ***aged units*** (two UV aged only and one UV + salt-fog). During setup / calibration, locate the pole that opens first and install the UV + salt-fog interrupter at that location. Perform ***10 load break switching operations*** at 100% load. If an interrupter fails, substitute a new interrupter to try to complete the series to gain as much data as possible from the tests. A five minute "cool down" period was provided between each switching operation.
4. If the unit passed the requirements in (3), perform ***three additional load break switching operations*** under ***wet conditions***. Prior to each operation, each interrupter was thoroughly wetted. A five minute "cool down" period was provided between each switching operation.

Load Current Interruption Test Results

	Number of Successful Interruptions			
Manufacturer	New (10)	New Wet (3)	Aged (10)	Aged Wet (3)
D	7 *1	*2	*2	*2
F	8	3	3	3 *3
E	10	3	2 *4	*4
A	10	3	10	3
H	10	3*5	10	3
G	4	0	0	*6

Notes: *1 – Switch was removed from field service. Interrupters were not new.

*2 – New and aged interrupters' mounting brackets were different. Aged units could not be tested.

*3 – Only the aged F-UV-6 interrupter completed the three wet tests.

*4 – Interrupters pickup hooks were not replaced after the tests on new interrupters. These worn hooks may have contributed to the failure of the aged interrupters.

*5 – Wet tests were performed on the original new interrupters (13 total operations on same units).

*6 – Wet tests were not performed on the aged interrupters due to previous failures.

Benchmark Test Observations

- dc contact resistance measurements did indicate problems with samples D-UVS-6, G-UVS-5, and H-UVS-5 after the salt-fog aging.
- Force measurements also indicated problems with D-UVS-6 after the salt-fog aging.

Interruption Test Observations

- Wet tests did not affect results of the load current interruption tests.
- Three of the interrupters were ***definitely affected*** by the accelerated weathering tests.
  - D-UVS-6 seized up due to corrosion.
  - F-UV-4 and F-UVS-5 failed after only three successful interruptions.
  - H-UVS-5 experienced corrosion of a riveted connection that vaporized during testing, but none-the-less passed as the connection arced over.

Interruption Test Observations

- Two of the interrupters ***may have been affected*** by the accelerated weathering tests.
  - Manufacturer E interrupter tests terminated early due to pickup clip failure.
  - Manufacturer G failed interruption tests (new units also failed).
- One interrupter was ***definitely not affected*** by the accelerated weathering tests.
  - Manufacturer A interrupter passed all of the tests.

Recommendations for IEEE C37.34

- Add requirements for accelerated UV / Condensation aging prior to interrupting tests in Section 9 for usual service conditions.
- Add requirements for accelerated UV / Condensation aging and salt-fog aging prior to interrupting tests in Section 9 for unusual service conditions involving contaminated environments.

Contact Info

Frank C. Lambert
Georgia Tech / NEETRAC
404-675-1855
frank.lambert@neetrac.gatech.edu