

Understanding Crossarm Testing

Joseph Goldenburg, P.E.



About NEETRAC

What:

Research, Testing and Applications Center in the School of Electrical & Computer Engineering at Georgia Tech

Scope:

Electric Energy Delivery (Generator to the Meter)

Approach:

Applied R&D, Membership Based, Consortium Focus, Self-supporting

Membership:

Electric Utility Industry in North America

Size:

39 Members, 30 Staff, \$5,000,000+



Mission:

Advancing the electric grid through collaboration

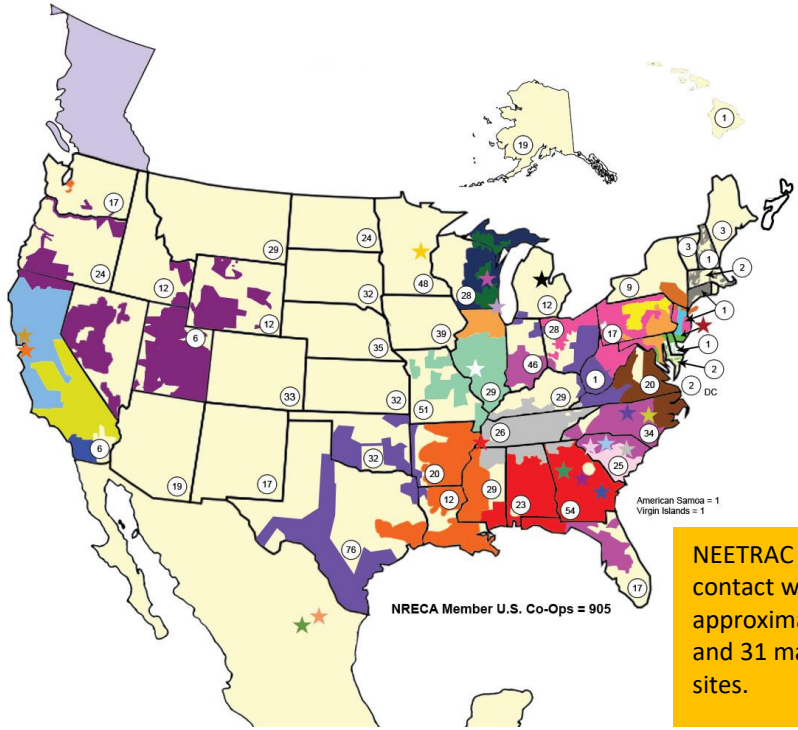
Facilities:

High voltage, medium voltage, mechanical & environmental

Membership

Utility Members	
Ameren	
American Electric Power	
BC Hydro	
Consolidated Edison	
Dominion Energy	
DTE	
Duke Energy	
Exelon	
FirstEnergy	
Nova Scotia Power	
NRECA Member Coops	
Pacific Gas & Electric	
PacifiCorp	
PPL Corporation	
Public Service Electric & Gas	
San Diego Gas & Electric	
Southern California Edison	
Southern Company	
Tacoma Power	
Tennessee Valley Authority	
WEC Energy Group	

Manufacturing Members	
3M	★
Aluma-Form	★
ABB	★
Borealis Compounds	★
Eaton	★
Dow Chemical Company	★
Gresco Utility Supply	★
Hubbell Power Systems	★
LS Cable & System	★
Prolec GE	★
Prysmian Group	★
Raukman	★
S&C Electric	★
Smart Wires	★
Southern States	★
Southwire	★
TE Connectivity	★
Viakable	★



NEETRAC has regular contact with approximately 140 utilities and 31 manufacturing sites.

Georgia Tech | **NEETRAC**
NEETRAC is a 501(c)(3) Non-Profit Organization

2019-2020 NEETRAC Members

School of Electrical and Computer Engineering

The Crossarm White Paper

- Response to numerous questions from several Members regarding testing crossarms and how to interpret the data
- Ten NEETRAC Members funded and participated in the writing and publication of this white paper.
- The white paper covers the following areas of crossarm testing:
 - Mechanical testing
 - Electrical testing
 - Environmental testing
- The white paper discusses test methods that are applicable to a range of crossarm technologies (wood, steel, composite, laminate, etc.).

The Crossarm White Paper

http://neetrac.gatech.edu/publications/18-087-7.11-Crossarm_White-Paper.pdf

2020

TECH ADVANTAGE[®]
EXPERIENCE

 **NRECA**
America's Electric Cooperatives

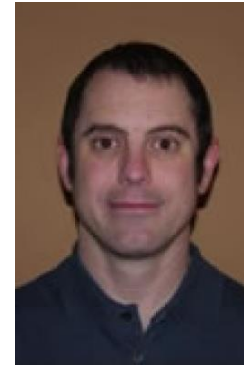
About the Authors

Caryn Riley, Ph.D.



- *Ph.D. in Electrical Engineering*
- *Manages NEETRAC's Electrical Section*
- *22 years experience*

Joe Goldenburg, P.E.



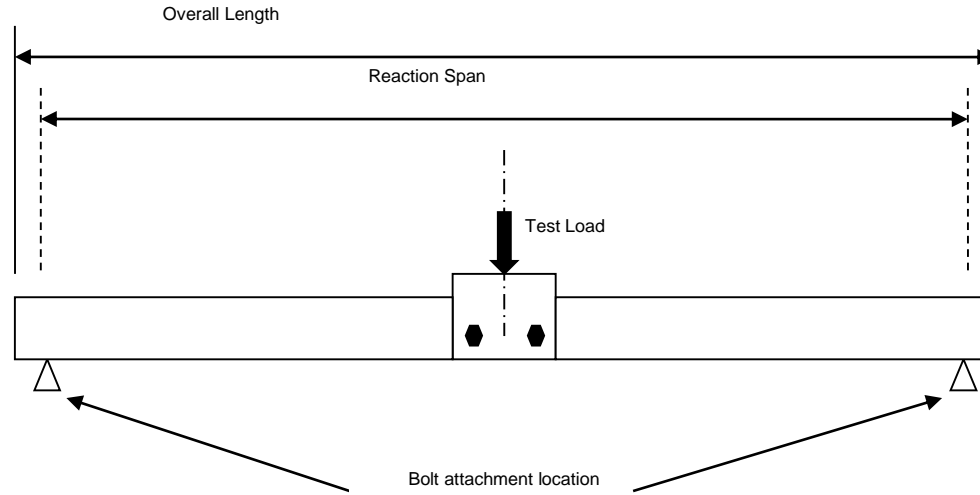
- *Bachelors in Mechanical Engineering*
- *Manages NEETRAC's Mechanical Section*
- *27 years experience*

Mechanical Testing

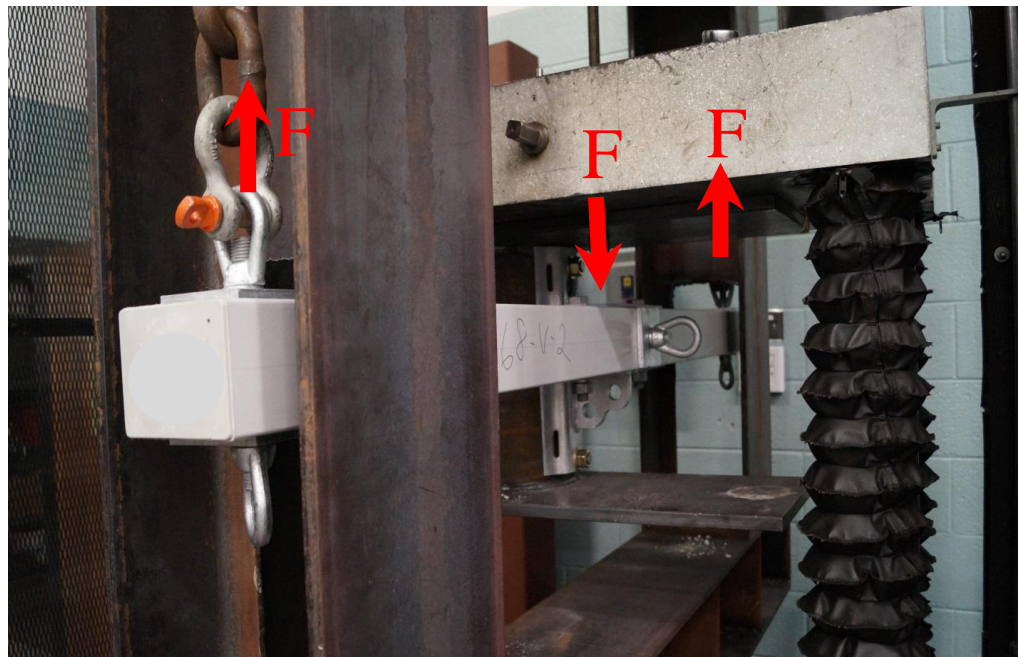
The primary purpose of a crossarm is to support the mechanical load of the conductors, insulators, and related hardware.

- Mechanical loading of crossarms is specified by a variety of documents including:
 - National Electric Safety Code (NESC) requirements
 - Utility internal standards
 - RUS Bulletin 1724E-151, *Mechanical Loading on Wooden Distribution Crossarms*
 - ANSI/IEEE C2 National Electric Safety Code (NESC), 2017.
 - IEEE Std C135.80™-2012, *IEEE Standard for Fasteners for Overhead Line Construction*
 - Manufacturer product specification sheet

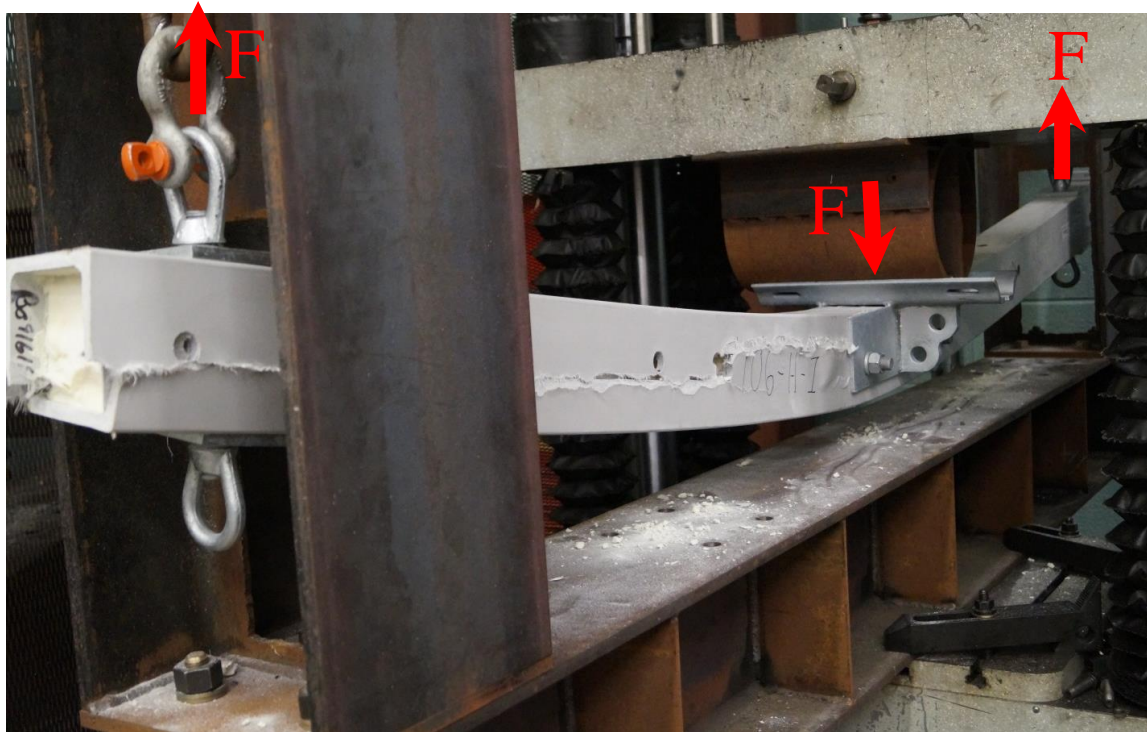
Mechanical Testing



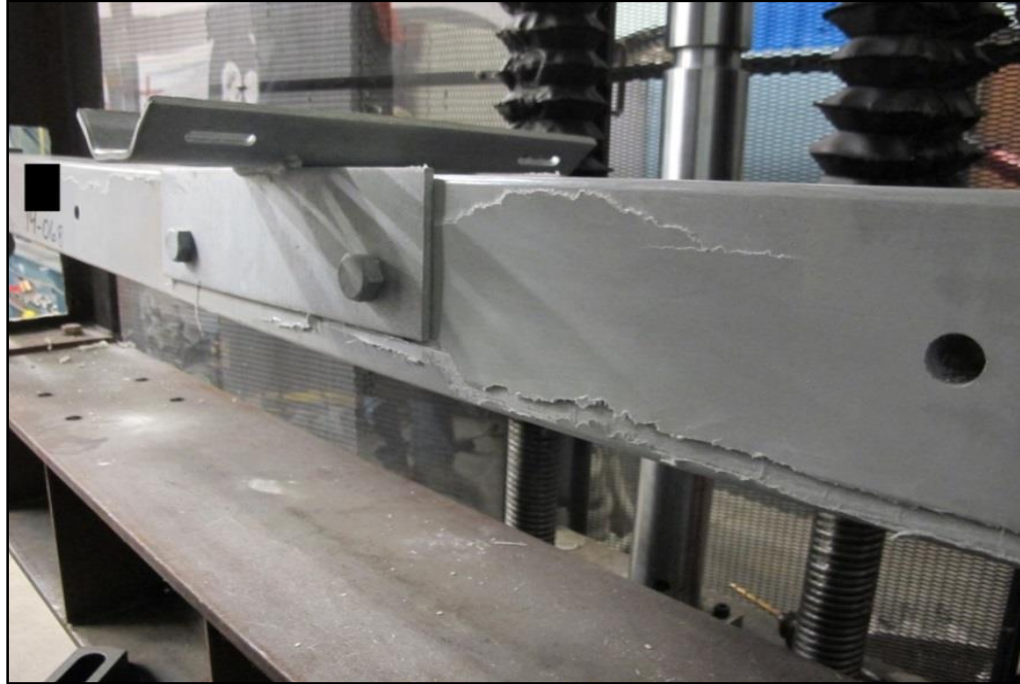
Mechanical Testing



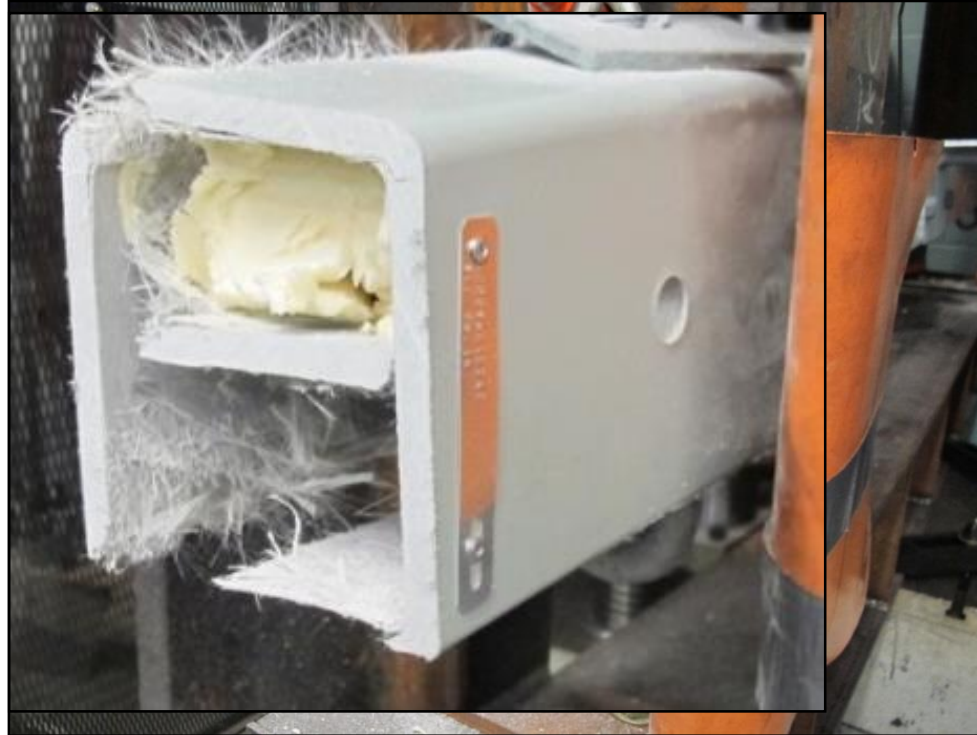
Mechanical Testing



Mechanical Testing



Mechanical Testing

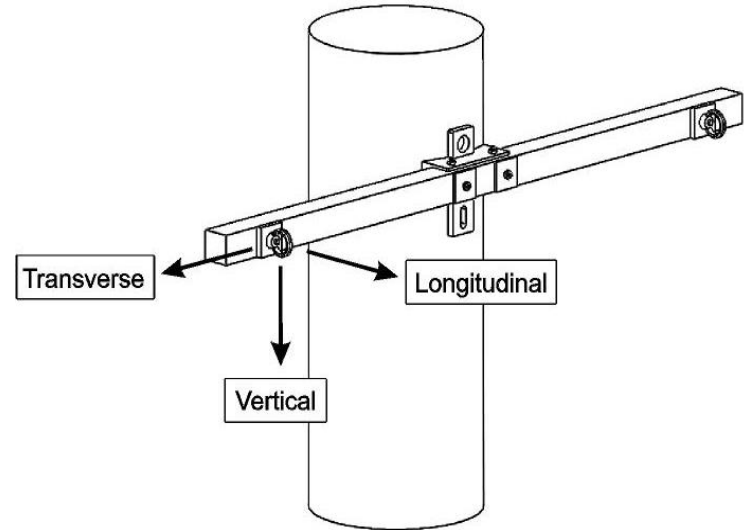


Mechanical Testing



Mechanical Testing

- Test crossarms with the hardware and loading scenarios anticipated in the field.
- There are interactions between various components.
- Any part of the crossarm assembly can fail a test, including the beam, washers, bolts, eyes, and gain.
- When possible, test fully assembled crossarms!



Mechanical Testing



Mechanical Testing



Mechanical Testing



Mechanical Testing



H-6 Trimmed.mp4

Mechanical Testing



Mechanical Testing



Mechanical Testing



Mechanical Testing



Mechanical Testing



Mechanical Testing



Mechanical Testing



H-3 Trimmed.mp4

2020

TECH ADVANTAGE[®]
EXPERIENCE

 **NRECA**
America's Electric Cooperatives

Mechanical Testing



Mechanical Testing

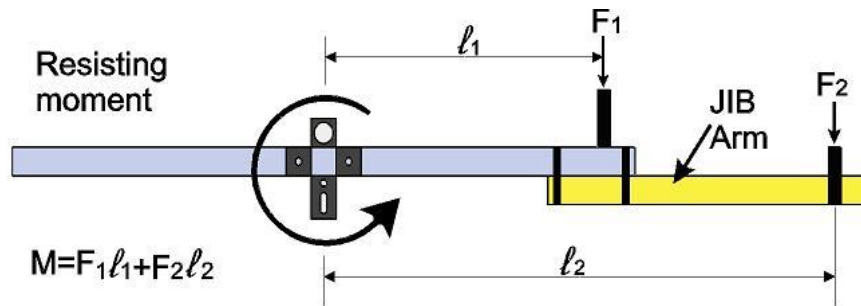
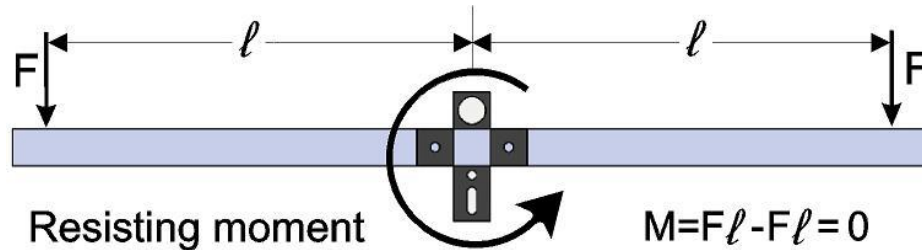


Mechanical Testing

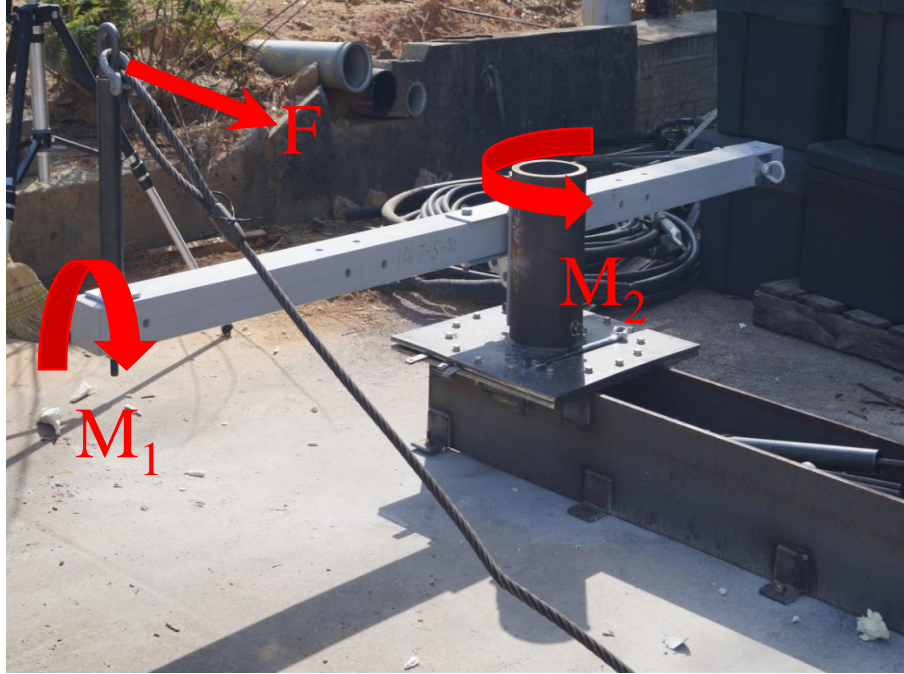


Mechanical Testing

- Imbalanced loading scenarios are common.



Mechanical Testing



Mechanical Testing



68-T-7-22_5 Rendered.mp4

Mechanical Testing



106-T-5-90 C2.MTS

2020

TECH ADVANTAGE[®]
EXPERIENCE

 **NRECA**
America's Electric Cooperatives

Mechanical Testing



Mechanical Testing



Mechanical Testing (Torque)

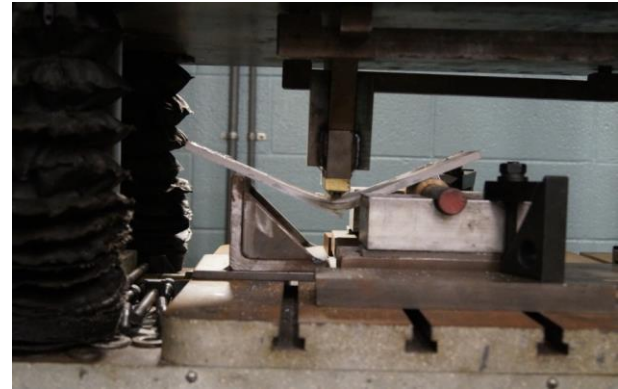


Mechanical Testing



Mechanical Testing

- Some utilities and manufacturers also require tests on individual sections or plaques removed from manufactured crossarms.
- Tests frequently involve pre and post conditioning that could include thermal cycling, UV, or chemical exposure.
- Testing plaques can provide useful information for laboratories conducting research on isolated performance characteristics.
- Utility engineers should be cautious about extrapolating test results to real world performance of a full crossarm.



Electrical Testing

- Traditionally, distribution crossarms **do not** have electrical ratings.
- Non wood alternative crossarm materials such as fiber-reinforced polymer (FRP) crossarms have introduced the concept of testing the electrical properties of the crossarm material itself.
- No North American standards dictate a pass/fail electrical rating for any type of distribution crossarm.
- The physical arrangement of the crossarm components are determined by the voltage rating of the line, the line design, and the required additional equipment such as fused disconnects, surge arresters, transformers, reclosers, etc.

Electrical Testing

- The placement of these components as well as the grounding design dictates the electric field patterns and potential leakage current paths across the crossarm.
- If the dielectric performance of a distribution utility crossarm is to be evaluated, a full-size crossarm setup should be used and the phase-to-phase distances as well as the grounding design must be documented.



Electrical Testing – Power Frequency Testing

- Uses an alternating voltage with a frequency between 45 to 65 Hz. Per IEEE 4-2013, the voltage waveshape should be a sinusoid with a ratio of peak-to-rms values equal to $\sqrt{2}$ within $\pm 5\%$.
- This testing is used to evaluate the apparatus under simulated in-service field conditions.
- Two different types of tests are typically used:
 - Withstand
 - Disruptive discharge (flashover)
- The exact test parameters and pass/fail conditions are left up to the apparatus standard.

Electrical Testing – Power Frequency Testing

- As there are no standards that address the electrical ratings of crossarms, the manufacturer and user need to define their specific requirements.
- Users are cautioned that differences in withstand or disruptive discharge voltages between technologies or within technologies may not be indicative of better or worse performance.
- It may be worthwhile for users to benchmark their existing crossarm technologies and assemblies.

Electrical Testing – Impulse Testing

- Impulse testing uses a voltage with a waveshape characterized by its front time, peak voltage, and time to half-value.
- Two terms are commonly used to discuss impulse ratings of utility components – BIL and CFO.
 - Basic impulse withstand level or basic insulation level (BIL) is accepted by most utilities to be the crest value of a standard lightning impulse for which the insulation exhibits 90% probability of withstand or a 10% probability of failure (where failure is a disruptive discharge).
 - The CFO voltage (critical flashover voltage) has a fixed probability of 50% and is defined as the crest value of a standard lightning impulse for which the insulation exhibits 50% probability of withstand or failure.

Electrical Testing – Impulse Testing

- Research has been conducted on the CFO levels of crossarms of different material types.
- These values are a function of the test setup, sample length, and sample material.
- The majority of the published research was designed to determine a CFO level of the material for comparison.
- Users are encouraged to examine their specific crossarm construction designs as the final CFO level will be affected by:
 - Clearance distances between phases
 - Placement of other apparatus
- This may result in the crossarm material having little to no effect on the electrical rating of the complete system.

Electrical Testing – Materials

- Crossarm materials can be tested to evaluate their relative dielectric strengths.
- Tests are typically performed on small samples and provide an assessment of the material itself, not the full apparatus.
- *ASTM D149-09 Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies*
 - Defines three test procedures to determine the dielectric strength of solid insulation materials at commercial power frequencies.
 - This standard specifically states that “*the results obtained by this test method can seldom be used directly to determine the dielectric behavior of a material in an actual application.*”
- The test results are provided as a dielectric strength typically in V/unit length and are best used for process control, acceptance or research testing.

Environmental Testing – Corrosion

Relevant Standards:

- ASTM A153/A153M-16a, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*
- ASTM B117-16, *Standard Practice for Operating Salt Spray (Fog) Apparatus*
- ASTM G85-11, *Standard Practice for Modified Salt Spray (Fog) Testing*
- ASTM D610-08(2012) *Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces*
- ASTM A1059/A1059M-08(2013), *Standard Specification for Zinc Alloy Thermo-Diffusion Coatings (TDC) on Steel Fasteners, Hardware, and Other Products*

Environmental Testing – Corrosion

- Corrosion is a reduction in a metal component cross-sectional area that occurs when it interacts with oxygen.
- Coatings are typically used to protect metal components by creating a barrier that prevents oxygen from chemically reacting with the metal part.
- ASTM A153 (*Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*) is a manufacturing specification utilities often use to specify the coating on their crossarm hardware.
 - Coating thickness can be measured using a magnetic thickness gauge (non-destructive method) or mass-loss (destructive method).

Environmental Testing – Corrosion

- Salt fog test methods
 - Can only be used to compare the relative performance of various coatings to the selected salt fog test protocol; no life extrapolations to real world exposure.
 - ASTM G85 (Standard Practice for Modified Salt Spray (Fog) Testing) is gaining acceptance.
 - Cycles between spraying salt solution with drying periods
 - Acidic pH of 3
 - Considered more real world as it uses both wet and dry cycles in the test program, especially for acid rain / industrial environments.
 - Annexes allow you to select different environments.
 - ASTM B117 (Standard Practice for Operating Salt Spray (Fog) Apparatus) most frequently used.
 - Provides continuous salt spray
 - Neutral pH of 7

Environmental Testing – Corrosion

- Thermal diffusion galvanizing (TDG) is a relatively new galvanizing technology.
 - ASTM A1059 (*Standard Specification for Zinc Alloy Thermo-Diffusion Coatings (TDC) on Steel Fasteners, Hardware, and Other Products*) provides a loose framework and process controls for thermal diffusion galvanizing.
 - Tests performed at NEETRAC found that there was significant variation in the effectiveness of the thermal diffusion galvanizing processes used by different manufacturers.
- ASTM D610 (*Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces*) provides a useful resource that can be adapted for grading the performance zinc coated parts.

Environmental Testing – Weathering (UV)

- Q-Lab* Technical Bulletins
 - LU-0822: Sunlight, Weathering and Light Stability Testing
 - LU-0833: Correlation Questions and Answers – A discussion of the most frequently asked questions about accelerated weathering
 - LL-9031: QTRAC Natural Sunlight Concentrator Accelerated Natural Outdoor Exposures
 - LU-8030: Errors Caused by Using Joules to Time Laboratory and Outdoor Exposure Tests
 - LU-8009: QUV and Q-Sun A Comparison of Two Effective Approaches to Accelerated Weathering and Light Stability Testing
 - LU-8035: Comparison Between Natural Weathering and Florescent Exposures

*-Global provider of material durability testing products

2020

TECH ADVANTAGE[®]
EXPERIENCE



Environmental Testing – Weathering (UV)

- ASTM International Standards
 - ASTM G154-16 - *Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials*
 - ASTM G151-10 - *Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources*
 - ASTM G155-13 - *Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non- Metallic Materials*
 - ASTM G90-10 – *Standard Practice for Performing Accelerated Outdoor Weathering of Nonmetallic Materials Using Concentrated Natural Sunlight*

Environmental Testing – Weathering (UV)

- Regardless of the accelerated weathering test protocol chosen, the results only allow you to compare the relative performance of samples tested to the spectral light distribution, temperature, and humidity of the test that was performed.
- Caution is required when interpreting UV exposure test results. The amount of radiation incident on the sample is sometimes erroneously considered an accelerating factor to predict the life of a product.
 - For example, if a product receives the equivalent of five years of radiation in six months, this is sometimes wrongly considered to correlate to five years of UV exposure outdoors.
 - Equivalent radiation dosage does not lead to equivalent degradation.

Environmental Testing – Weathering (UV)

- Q-Lab Bulletin LU-8030 explains the reasoning for this warning stating, *“Replicate specimens receiving the same accumulated radiation dosage often show vastly different degradation. This is because timing in Joules does not take into account the substantial variations in weathering stress caused by the following other factors:*
 - *Differences in Spectral Irradiance*
 - *Differences in Exposure Temperature*
 - *Differences in Moisture Exposure”*
- ASTM G151 states that for accelerated testing: *“Even though it is very tempting, calculation of an acceleration factor (ASTM italics) relating x hours of a laboratory accelerated test to y months or years of exterior exposure is not recommended.”*

Environmental Testing – Weathering (UV)

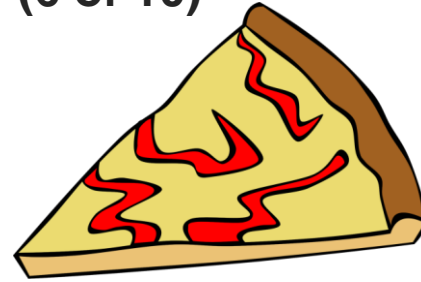
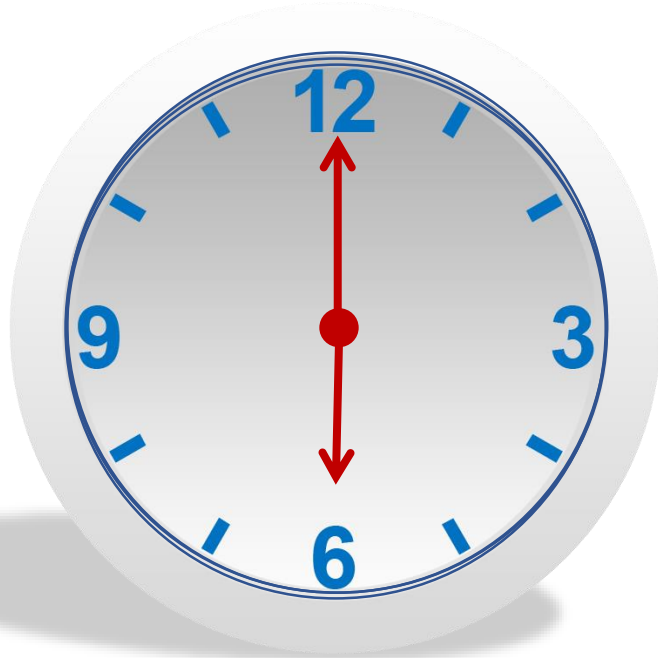


2020

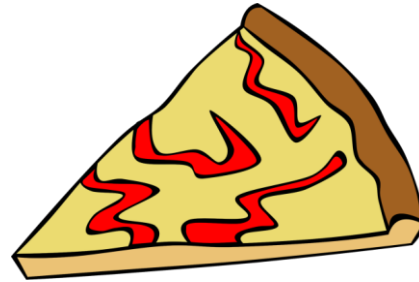
TECH ADVANTAGE[®]
EXPERIENCE

 **NRECA**
America's Electric Cooperatives

Environmental Testing – Weathering UV (6 of 10)



Environmental Testing – Weathering UV (7 of 10)



Environmental Testing – Weathering UV (8 of 10)



Environmental Testing – Weathering (UV)

- Another debate is natural sunlight exposure versus artificial light (fluorescent, xenon arc, etc.).
 - Natural sunlight, especially when concentrated using mirrors, is not as repeatable as an artificial light indoor test where spectral irradiance, temperature, and humidity can be better controlled.
 - ASTM G90 states, “[ASTM G90] should not be used to establish a “pass/fail” approval of materials after a specific period of exposure unless performance comparisons are made relative to a control material exposed simultaneously”.
 - Ideally, accelerated weathering testing should be conducted on full size crossarms. Practically, few laboratories have UV chambers large enough to conduct such testing so plaques are often created from sections of crossarms and placed in test equipment.

Environmental Testing – Weathering (UV)

- Accelerated weathering testing in and of itself may not provide a good indication of crossarm performance.
- Need to ask: “How does UV degradation affect the mechanical and dielectric strength of the crossarm?”
- Physical appearance may not indicate strength reduction.

2020

TECH ADVANTAGE[®]
EXPERIENCE



Summary

- Mechanical testing:
 - Strength is the #1 requirement ALL crossarms must meet.
 - Test full size crossarms in real-world loading scenarios
- Electrical testing:
 - Test full size crossarm setups with the phase spacing and potential additional hardware as installed in the field.
 - Benchmark your current crossarm technology (both new and aged) to compare relative performance with emerging technologies.
- Environmental
 - Corrosion testing on hardware is important.
 - Accelerated UV testing allows you to compare UV performance but...
 - Can't predict life (no accelerating factor)
 - May not correlate to strength loss

Questions