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Technical Note
Why is Ultravex™ Cross Arm Unique?

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Background

The development of the Ultravex™ arm began in early 1993 when Alabama Power began to again look at the new family of fiberglass arms for the replacement of their steel dead end arm. Up until this time, the only viable fiberglass arms were round solid and hollow foam filled fiberglass arms up to 3” in diameter. These fiberglass arms, however, were too weak, very heavy, and very expensive, limiting their use. In addition to the disadvantages noted for the fiberglass arms available at the time, steel was used with some success; however, it too had unacceptable characteristics. These unacceptable disadvantages for both steel and the early fiberglass arms slowed or stopped widespread development. Most of the cross arms in use at that time were wood and although wood had been a very economical material for these applications, strict restrictions on the use of preservatives by the EPA reduced service life and added disposal problems that placed severe limits on the use of wood.

Metallic arms had proven to meet the structural requirements for cross arms; however, metals have problems with conductivity and corrosion which makes them dangerous as a support for conductors. At this time a new family of fiberglass reinforced plastic (composite) arms was in various stages of development and offered both exceptional strength and resistance to environmental attack. Most sizes and shapes paralleled the wood arms and allowed the use of some of the hardware used on wood arms, however, not enough.

The family of composite arms being introduced was either square or rectangular depending on load rating and for extra heavy loads two arms were often specified. For heavy duty (HD) ams the designer used standard beam technology and increased the beam size or element thickness to obtain additional strength. This has always been the protocol for selecting stronger structural sections; steel handbooks list wide flange beams, I–beam, and mechanical structural shapes by size, member thickness and moment of inertia. The engineer selects the most economical (lightest weight) beam that meets his structural need. Since a larger beam is often selected to match heavier loads this method might be called **“designing from the outside-in”**.

Some composite cross arms in use today use I-beam, channel, wide flange or rectangular sections and are usually manufactured using a method known as pultrusion. This method places continuous glass fibers along the length of the arm and the strength is enhanced by maximizing the glass content which can be as high as 70%. As the glass and resin matrix is pulled through dies that determine the shape, heat is applied so that the structure is cured as it passes through the die.

Since the glass is pulled through the die it is under tension and remains under tension until the resin cures. This process enhances strength and stiffness since the reinforcement is pretensioned just as steel rods are pretensioned in concrete beams.

Southern Company (Alabama Power) Cross Arm Objectives for Cross Arm Design

- To provide a cross arm that has walls strong enough so that the bolts with small standard round washers can be used for dead end conductors without pulling thorough the walls of the fiberglass. Thick square washers to be eliminated.

- To provide a structural member, using fiberglass reinforced plastics, capable of meeting the highest load required, and using a standard composite materials to provide an economical structure used as a cross arm for supporting electrical conductors**.**

- To provide a fiberglass cross arm, with a common Gain Plate, that can be used both as a dead end cross arm and a tangent cross arm. This would allow stocking of one arm rather than two.

- To provide a fiberglass cross arm with a small Gain Plate that is light but capable of carrying the required load; but, small enough not to contribute significantly to the overall weight and small enough not to reduce the BIL of the cross arm any more than necessary.

- To provide a fiberglass cross arm that is non-conductive and therefore safe to be used in high voltage applications.

- To provide a fiberglass cross arm that after failure, still has enough residual strength to support the conductor and not fall to the ground.

- To provide a fiberglass cross arm that provides resistance to impact damage which might degrade the structural capability of the arm.

- To provide a = fiberglass cross arm capable of shedding moisture from the upper surfaces where accumulations of moisture could decrease the non-conductive features (BIL) of the arm.

- To provide a fiberglass cross arm that can be drilled, with the appropriate tools of installation, without degrading the structural capability of the cross arm**.**

- To provide a fiberglass cross arm that has a small enough profile allowing the use of all standard hardware.
- To provide a fiberglass cross arm that offers the maximum protection against corrosion and weathering.

- To provide a fiberglass cross arm that can be manufactured in such a way as to insure consistent structural strength.

Early Designs – Omega Arm

A design and manufacturing concept for producing composite beams, referred to as wet pultrusion was successfully used and produced an exceptionally strong beam. Initial beam tests by Alabama Power resulted in strength that was 35% above the desired ratings. This process used a PVC square tube for the outside cover and a round PVC tube that was centered inside the outer tube. Multiple glass rovings were combined and wet with resin before pulling the glass/resin matrix into the interstice between the inner and outer tubes. This was a batch process that produced 20 foot long beams. Each beam as completed was set aside to cure.

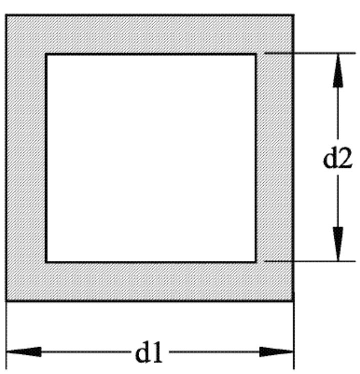
There were a few technical and quality problems that were quickly solved and many samples from the first production run were installed by small utilities in the southeast. The acceptance was very favorable and orders for small quantities were received. The cost of production began to rise as the size of orders increased it became clear that this method fabrication could not be cost competitive. Production and sales were halted and efforts were begun seek other designs and production methods.

Over the next several years more than thirty different shapes and designs were investigated using manufacturing methods including filament winding, contact molding, injection molding and compression molding. However, the designs that met structural goals did not prove to be competitive. The circular shaped core of the Omega arm seemed to offer extraordinary beam strength and was selected as the preferred design for development. The pultrusion was investigated and seemed to offer a competitive solution but when the pultrusion experts reviewed the design it was not projected to be practical because of the shape.

Ultravex™ Cross Arm

In early 2013 the original circular core design was analyzed as a pultruded beam using finite element analysis, FEA, in order to optimize the cross sectional area and reduce weight. The FEA confirmed the core shape of the arm produced exceptional strength and stiffness compared to standard rectangular shapes. Several pultrusion specialists reviewed optimized design and agreed that pultrusion could be possible and economically feasible. A pilot production run was completed and samples of an 8 foot arm were tested with results that were even higher than the FEA calculated rating. This new design was designated as **Ultravex™** and patents were filed that describe the design.

The key feature of the successful **Ultravex™** arm is the unique shape of the internal core. Instead of a rectangular beam that has a rectangular inner core the Ultravex™ arm has a circular or curvilinear core.



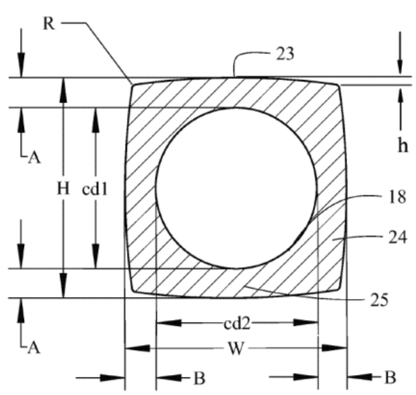
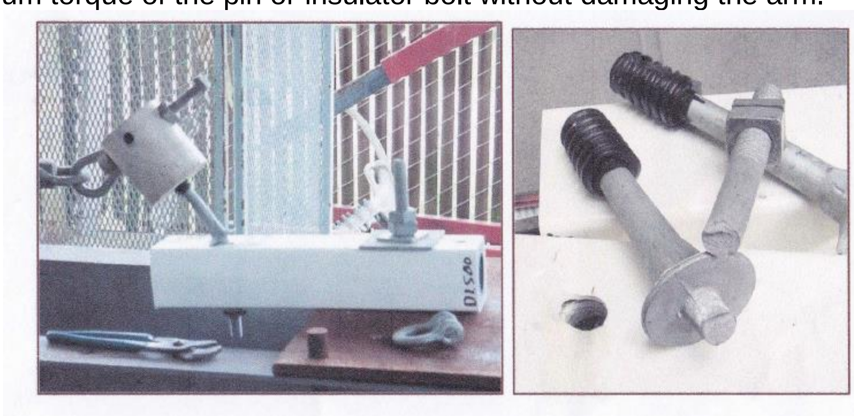


Figure 1
Conventional Arm

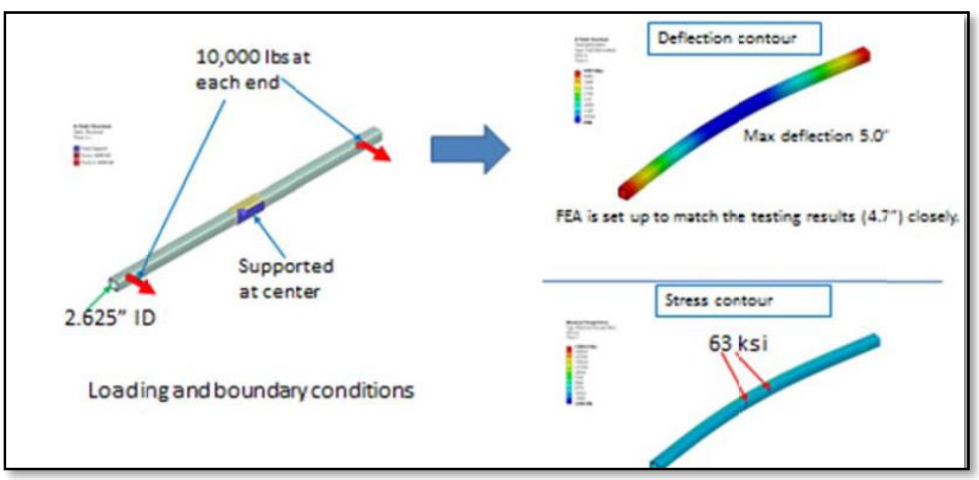
Figure 2
Ultravex™

The circular core offers very distinct and positive advantages over the rectangular shape:

1. There is a smooth transition in thickness. Stress concentrations, resulting from abrupt changes in cross section, that promote premature failures are greatly reduced.
2. The circular core offers a high resistance to torsion. The rectangular shape has poor torsional resistance. Torsional forces, especially cyclic forces, can lead to early failure.
3. The upper cross section of the Ultravex™ arm incorporates the same structural advantages as an arch. The structural efficiency developed in the arch provides the unusual strength of this patent pending design.
4. By making small changes in the core diameter the strength of the arm can be changed to match any load rating without changing external dimensions. This design feature is called **“designing from the inside – out”.**
5. The circular core also provides a much stiffer beam that is as much a 50% more than a rectangular core. This stiffness means less sag when conductor loads are applied and reduces the effect of cyclic or dynamic loads due to wind.
6. This circular core can be completely filled with closed cell foam to block penetrating moisture. A rectangular core is harder to fill and may incorporate voids along the sharp corners where moisture can build.
7. The new shape can be field drilled without the need for inserts and without degrading the structural rating.
8. The arm has exceptional pin strength and testing has shown the arm can withstand maximum torque of the pin or insulator bolt without damaging the arm.



Sample FEA



Only one size, 3-1/2" x 3-1/2" shape has been tested but this size can be manufactured as a standard duty or heavy duty arm with ratings that can be tailored for specific applications and can be used as a dead end or tangent arm. A single metal gain plate can be used for both dead end and tangent service. The gain plate eliminates the need for bracing and the HD arm eliminates the need for a double arm.

Design studies are ongoing to provide an **Ultravex™** composite gain plate that will be available later in 2016. Composite pins, insulators and bolting hardware are also being developed with the goal of an all composite installation. One of the most destructive issues is electrical tracking and flashovers that cause pole top fires. Composite arms and hardware can produce a higher BIL (Basic Impulse Level) and drastically reduce these losses.

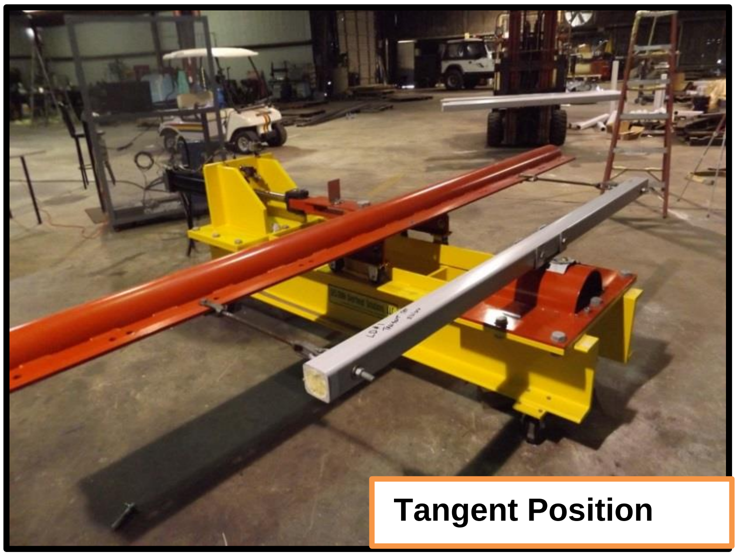
In the design of the **Ultravex™** arm there is a very slight convex surface on all four sides of the arm. The purpose is to shed water and to prevent buildup of contaminates that reduce the BIL of the composite arm. This slight convexity does not affect the fit and function of any attaching hardware.

Construction of the **Ultravex™** arm. A projected 60 year external protection from UV, moisture and contamination is derived from a continuous glass fiber mat that is placed outside of the structural glass rovings. The mat is overlaid with a special polyester veil that protects the arm from UV and offers a resin rich finish that resists environmental contaminates. The surface of the core is protected with the same continuous mat layer to seal the interior. Closed cell solid foam is used to completely fill the core to block out moisture.

Testing

Structural testing of this unique design dates back to 1993; however, structural testing of the pultruded Ultravex™ cross arm began in early 2013 to optimize conservative load ratings and to insure consistent structural quality. A special test stand with a 50K load rating was constructed to test cross arms in the tangent and dead end position in arm lengths up to 12 feet. This test stand is designed to test cross arms exactly as they would be loaded if mounted on a pole.

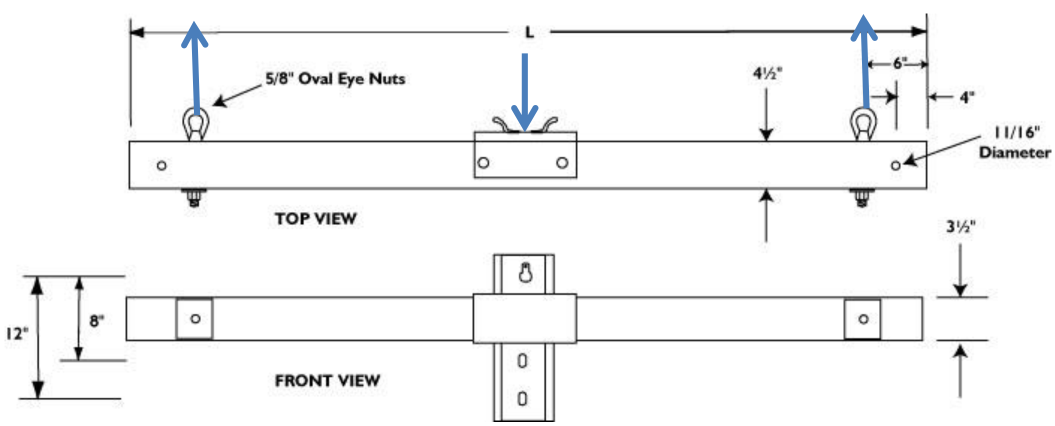
Dead End Position



Tangent Position

Description
The structural test stand is designed to test a composite cross arm in a simulated Dead End Arm or Tangent Arm position and the sample is loaded by applying a variable test load at a ***controlled rate of 500 lbs/ minute*** applied through rods simulating conductor loading. The reaction load is through a standard gain plate mounted to a fixed pole plate. .
Loads are applied in uniform steps and held for 2 minutes after deflection has stopped. Loads are measured and recorded using a calibrated pressure transducer with accuracy +/- .01% range. Displacement is measured using a precision laser distance gauge with accuracy +/- 1/16" over the design deflection range of 20".

Dead End Testing



Conclusion

The Ultravex™ cross arm has a patent pending design and has been subjected to exhaustive testing to develop conservative ratings for two classes; Heavy Duty and Standard Duty in 8 ft., 10 ft. and 12 ft. lengths.

- The Ultravex™ fiberglass cross arm is rated for use as a dead end arm or tangent arm using only one gain plate.
- One profile (3½" x 3½") for dead end and tangent applications. Reduces inventory and allows use of all standard wood arm hardware.

- The Ultravex™ fiberglass cross arms have a 2,500# pin rating (the rating is actually the rating at which the pin fails before the arm is damaged. Pin will always fail before the Ultravex™ fiberglass cross arm. This allows full use of strength of the pin and insulator.
- Heavy washers or inserts are never needed to prevent bolt hardware from pulling through the Ultravex™ arm. Since inserts are unnecessary the arms can be field drilled when required.
- The Ultravex™ fiberglass cross arm provides UV protection for a 60 year life without structural loss. A closed cell foam throughout the core eliminates internal tracking.
- All four sides of the Ultravex™ arm have a slight convex curvature designed to shed water for better BIL (CFO) rating.
- The Ultravex™ design maximizes strength to weight ratio providing the lightest weight and easiest installation.

Biographies
Frank Britt PE
Frank Britt is President and Principal at Britt Engineering, Inc. and has more than 30 years' experience in composite design and testing. Holds a BS in Aeronautical Engineering from the University of Alabama and has specialized structural and stress analysis of fiberglass reinforced plastics.

Ed Mullinax
Principal Engineer Southern Company, Birmingham, Alabama- Retired after 33 years. Responsible for the design of all Overhead Construction Specifications (2.4kV thru 34.5kV), development of Overhead Material Specifications, conducting material testing, evaluation, and approval. responsible for the design, cost estimating and project management of new overhead transmission and distribution lines using wood, concrete, tubular steel, and fiberglass poles and cross arms. BS Electrical Engineering, Auburn University (1968)