United States Department of Agriculture
Rural Development
Rural Utilities Service

RUS Bulletin 1724E-220

SUBJECT: **Procurement and Application Guide for Non-Ceramic Composite Insulators, Voltage Class 34.5 kV and Above**

TO: All Electric Borrowers

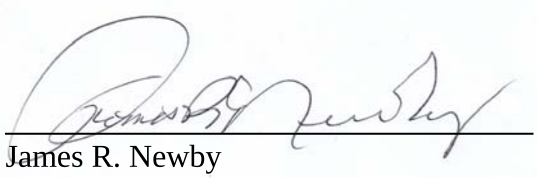
EFFECTIVE DATE: Date of Approval.

OFFICE OF PRIMARY INTEREST: Transmission Branch, Electric Staff Division, Electric Program

FILLING INSTRUCTIONS: This is a new bulletin. File with 1724.

AVAILABILITY: This bulletin can be accessed via the internet at http://www.usda.gov/rus/electric/bulletins.htm.

PURPOSE: This bulletin provides a basis for procuring non-ceramic composite insulators for voltage class 34.5 kV and above.



March 17, 2005

Date

James R. Newby
Assistant Administrator
Electric Program

BLANK PAGE

ACKNOWLEDGMENTS

The following current and former members of the Transmission Line Subcommittee of the National Rural Electric Cooperative Association, Transmission and Distribution Engineering Committee provided invaluable assistance in preparing this document:

1. Dominic Ballard, **East Kentucky Power Co-op.**, Winchester, KY
2. John Burch, **Florida Keys Electric Coop.**, Tavernier, FL
3. Donald Heald, USDA, **Rural Utilities Service**, Washington, DC
4. Bill Hetherington, **Lee County Electric Coop.**, North Fort Myers, FL
5. Robert Johnson, **Arkansas Electric Coop.**, Little Rock, AR
6. Charles Lukkarila, **Great River Energy**, Elk River, MN
7. Charles McCall, **Georgia Transmission Company**, Tucker, GA
8. Steve Mundorff, **Tri-State G & T Association, Inc.**, Denver, CO
9. Norris Nicholson, USDA, **Rural Utilities Service**, Washington, DC
10. Robert Oldham, **Southern Maryland Electric Coop. (Retired)**, Hughesville, MD
11. Robert Saint, **National Rural Electric Cooperative Association**, Arlington, VA
12. Art Smith, **Burns & McDonnell**, Atlanta, GA
13. David Turner, **Lower Colorado River Authority**, Austin, TX
14. John Twitty, **Alabama Electric Co-op.**, Andalusia, AL

Also contributing:

15. Paul Dolloff, **East Kentucky Power Co-op.**, Winchester, KY

Table of Contents

INDEX:

ABBREVIATIONS

ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
ASQ	American Society for Quality
BIL	Basic Insulation Level
CBL	Cantilever Breaking Load
E	Electrical
ECR	Electrical Chemical Resistant
EPDM	Ethylene Propylene Diene Monomer
EPM	Ethylene Propylene Monomer
EPR	Ethylene Propylene Rubber
FRP	Fiberglass-Reinforced Plastic
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
M&E	Mechanical and Electrical
MDCL	Maximum Design Cantilever Load
NESC	National Electrical Safety Code
psi	pounds per square inch
RCL	Reference Cantilever Load
RIV	Radio-Influence Voltage
RTL	Routine Test Load
RUS	Rural Utilities Service
SCL	Specified Cantilever Load
SML	Specified Mechanical Load
SR	Silicone Rubber
STL	Specified Tensile Load

BLANK PAGE

1. PURPOSE

The objective of this guide is to assist users in developing specifications for procurement of non-ceramic composite insulators. Information in this bulletin will assist users not familiar with non-ceramic composite insulators and current standards in developing purchase specifications.

This bulletin provides recommended design and manufacturing criteria to ensure acceptable of non-ceramic composite insulators performance on electrical facilities operating at voltages 34.5 kV and above. This guide is consistent with present day criteria already developed for non-ceramic composite insulator standards.

Since this guide is general in nature, it may not address specific utility applications. Therefore, users should consider their own particular needs and select those criteria that are appropriate for a specific installation of a non-ceramic composite insulator.

2. STANDARDS

The latest editions of the following standards are relevant to non-ceramic composite insulators:

2.1 AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C29.1 - 1988	"Test Methods for Electrical Power Insulators"
ANSI C29.2 - 1992	"For Insulators, Wet-Process Porcelain and Toughened Glass – Suspension Type"
ANSI C29.11 - 1989	"Composite Suspension Insulators for Overhead Transmission Lines - Tests"
ANSI C29.12 - 1997	"Insulators - Composites - Suspension Type"
ANSI C29.13 - 2000	"Insulators - Composite Distribution Deadend Type"
ANSI C29.17 - 2002	"For Insulators - Composite - Line Post Type"
ANSI C29.19*	"Solid Rod Fiberglass Insulators (Apparatus Post Type)"

2.2 AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM A153 - 2004	"Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware"
ASTM D412 - 1998A	"Standard Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension"

* This standard is currently only available in draft form.

ASTM D495 - 1999	"Standard Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation"
ASTM D518 - 1999	"Standard Test Method for Rubber Deterioration-Surface Cracking"
ASTM D570 - 1998	"Standard Test Method for Water Absorption of Plastics"
ASTM D573 - 2004	"Standard Test Method for Rubber-Deterioration in an Air Oven"
ASTM D575 - 1991	"Standard Test Methods for Rubber Properties in Compression"
ASTM D623 - 1999	"Standard Test Methods for Rubber Property-Heat Generation and Flexing Fatigue in Compression"
ASTM D624 - 2000	"Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers"
ASTM D750 - 2000	"Standard Practice for Rubber Deterioration Using Artificial Weathering Apparatus"
ASTM D790 - 2003	"Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials"
ASTM D1149 - 1999	"Standard Test Method for Rubber Deterioration-Surface Ozone Cracking in a Chamber"
ASTM D1499 - 1999	"Standard Practice for Filtered Open-Flame Carbon-Arc Type Exposures of Plastics"
ASTM D2240 - 2004	"Standard Test Method for Rubber Property—Durometer Hardness"
ASTM D2275 - 2001	"Standard Test Method for Voltage Endurance of Solid Electrical Insulating Materials Subjected to Partial Discharges (Corona) on the Surface"
ASTM D2565 - 1999	"Standard Practice for Xenon Arc Exposure of Plastics Intended for Outdoor Applications"
ASTM G21 - 1996	"Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi"
ASTM G154 - 2000A	"Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials"

ASTM G155 - 2004 "Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials"

2.3 AMERICAN SOCIETY FOR QUALITY (ASQ)

ASQ Z1.4 - 2003 "Sampling Procedures and Tables for Inspection by Attributes"

ASQ Z1.9 - 2003 "Sampling Procedures and Tables for Inspection by Variables for Percent Nonconforming"

2.4 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 4 - 1995 "Standard Techniques for High-Voltage Testing"

IEEE 539 - 1990 "Standard Definitions of Terms Relating to Corona and Field Effects of Overhead Power Lines"

IEEE 957 - 1995 "Guide for Cleaning Insulators"

IEEE 987 - 2001 "Guide for Application of Composite Insulators"

IEEE C2 - 2002 National Electrical Safety Code

2.5 INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 60507 - 1991 "Artificial Pollution Tests on High-Voltage Insulators to Be Used on A.C. Systems"

IEC 60815 - 1986 "Guide for the Selection of Insulators in Respect of Polluted Conditions"

IEC 61109 - 1992 "Composite Insulators for A.C. Overhead Lines with a Nominal Voltage Greater than 1,000 V - Definitions, Test Methods and Acceptance Criteria"

IEC 61466-1 - 1997 "Composite String Insulator Units for Overhead Lines with a Nominal Voltage Greater than 1,000 V - Part 1: Standard Strength Classes and End Fittings"

2.6 INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 9001:2000 "Quality Management Systems- Requirements"

2.6 PURCHASE OF RELATED SPECIFICATIONS AND STANDARDS

All ANSI and IEC standards may be purchased from:

American National Standards Institute, Inc.

> 25 West 43rd Street, 4th Fl.
> New York, NY 10036
> Telephone: 1-212-642-4900
> Website: www.ansi.org

All ASTM standards may be purchased from:

American Society for Testing Materials

> 100 Barr Harbor Drive
> West Conshohocken, PA 19428
> Telephone: 1-610-832-9585
> Website: www.astm.org

All ASQ standards may be purchased from:

American Society for Quality

> 600 North Plankinton Avenue
> Milwaukee, WI 53203
> Telephone: 1-800-248-1946
> 1-414-272-8575 (outside the U.S. and Canada)
> Website: www.asq.org

All IEEE standards may be purchased from:

Institute of Electrical and Electronics Engineers

> 445 Hoes Lane
> PO box 1331
> Piscataway, NJ 08855-1331
> Telephone: 1-800-678-4333
> 1-732-981-0060
> Website: www.ieee.org

All ISO Standards may be purchased from:

International Organization for Standardization

1 rue de Varembé
CH-1211 Geneva 20
Switzerland
Telephone: 4-122-749-0111
Website: www.iso.org

3. DEFINITIONS

Cantilever Breaking Load (CBL) - A load specified by the manufacturer that represents the failing load of a non-ceramic composite post insulator. The failing load is the maximum load attainable under Cantilever Load testing and is greater than or equal to the Specified Cantilever Load (SCL).

Chalking - A condition wherein filler material becomes exposed on the surface of rubber as a result of weathering (ultraviolet exposure).

Core - The internal part of a composite insulator. The core is the mechanical load-bearing component of the insulator. The core consists mainly of glass fibers impregnated with a resin-based matrix so as to achieve maximum strength. It is also called a fiberglass-reinforced plastic (FRP) rod.

Coupling Zone - The part of the metal end fittings of the insulator that transmits applied mechanical load to the line hardware, to the structure, or to accessories that are external to the insulator. The coupling zone does not include the interface between the core and the end fittings.

Cracking - Any surface fracture of a depth greater than 0.1 mm.

Crazing - The formation of surface microfractures of depths up to 0.1 mm resulting from ultraviolet exposure.

Damage Limit - The long-term mechanical bending tests performed on line post insulators by the manufacturer to determine a damage limit for the fiberglass–resin core. Below the damage limit, the core exhibits elastic behavior where, with the test load removed, the core returns to its original position (possibly after several days) with no degradation. Above the damage limit some fibers begin to break and, when the test load is removed, the core does not return to its original position. If the test load is maintained, rod deflection begins to increase with time and more fibers break until eventually the insulator fails.

Design Tests - Tests to evaluate the electrical design of the non-ceramic composite insulator that are required only on insulators of new design. Design tests may also be used to evaluate various mechanical characteristics.

End Fittings, Metal - The metal attachment hardware that is connected to the insulator core that transmits the mechanical loads to the core at the ends of the insulator.

EPM (Ethylene Propylene Monomer) - Sometimes used as a base polymer in non-ceramic composite insulator rubber formulations.

EPDM (Ethylene Propylene Diene Monomer) - Commonly used as a base polymer in non-ceramic composite insulator rubber formulations.

EPR (Ethylene Propylene Rubber) - The generic term that includes both EPDM and EPM.
Erosion - Nonconductive loss of material from the insulating surface caused by leakage current, corona discharge, or dry band arcing. Erosion can be uniform, localized, or tree-shaped. Shallow surface traces, commonly tree-shaped, can occur on composite insulators, as on ceramic insulators, after arcing (flashover). Erosion is unobjectionable as long as it is non-conductive. When it becomes electrically conductive, it is known as tracking.

Filler - A material that is used to improve the performance of the housing material.

Grading Device - A device for controlling the potential gradient at the end fittings.

Housing - The insulator component which is external to the core and contains both a sheath and weathersheds. The sheath–weathershed system protects the core and provides the required leakage distance. The weathersheds also provide wet electrical strength.

Hydrolysis - A chemical process involving the reaction of a material with water in liquid or vapor form. It can lead to electrical and mechanical degradation (depolymerization).

Hydrophobicity - The ability of a material to repel water.

Interfaces - The surface between different materials. Examples of interfaces in composite insulators are as follows:

- Glass fiber/impregnating resin
- Filler/polymer
- Core/housing
- Weathershed/sheath
- Housing/metal end fittings
- Core/metal end fittings

Lot - A number of insulator units in which each constituent component of the units (core, housing, metal end fittings, etc.,) comes from the same production run and the units are assembled in the same manner and process. Each lot should, as far as is practicable, consist of units of product of a single type, grade, class, size, or composition manufactured under essentially the same conditions and in contiguous time periods. The units will have the same Specified Mechanical Load (SML) or Specified Cantilever Load (SCL) rating. The number of units in a lot should normally be set at some number not to exceed 500 units.

Maximum Design Cantilever Load (MDCL) - The non-ceramic composite line post insulator cantilever load rating assigned by the manufacturer. The maximum load that can be applied to the post insulator every day with no deleterious effect on the service life of the insulator. Some manufacturers list this rating as the Reference Cantilever Load (RCL).

Mechanical Load Test - A mechanical test for non-ceramic composite suspension insulators as specified in ANSI C29.11 and used to determine if a lot of insulators meet the Specified Mechanical Load (SML) requirements. The historical failure loads from this test justify the manufacturer's choice of SML. Mechanical testing is also performed on every insulator to check its Routine Test Load (RTL) rating.

Non-Ceramic Composite Insulator - An insulator unit that is made from material other than porcelain, glass, or other ceramic material. It consists of a load-bearing resin-impregnated fiberglass core, metal end fittings, and external elastomeric housing.

Post Insulator - Primarily intended to be loaded in a cantilever mode, although specific applications may require loading in tension or compression. The most common types are: (1) horizontal line post where the insulator projects nearly horizontally from a structure and is loaded in bending by the conductor, (2) braced line post or horizontal Vee application, and (3) a station post insulator used as a bus support in an outdoor substation. Post insulators used in disconnect switch applications may also be loaded in torsion.

Prototype Tests - Tests to evaluate and verify the suitability of materials, interfaces, prototype design, and method of manufacture. Prototype tests are performed only once and are considered valid for the whole class of insulators represented.

Quality Assurance Program - A program that includes quality conformance testing and statistical control of the manufacturing process to ensure quality of the product.

Quality Conformance Tests - Destructive or nondestructive tests that are used to verify insulator conformance to specific characteristics and determine acceptability of an insulator lot.

Reference Cantilever Load (RCL) - A rating assigned by the manufacturer which indicates the maximum load that can be applied to the post insulator every day with no deleterious effect on the service life of the insulator. Some manufacturers list this rating as the Maximum Design Cantilever Load (MDCL).

Routine Test - A test performed on every insulator from each lot to identify insulators with manufacturing defects.

Routine Test Load (RTL) - The load applied to non-ceramic composite suspension insulators that is equal to or greater than 50 percent of the insulator Specified Mechanical Load (SML) rating. Also, considered to be the maximum continuous working load of the insulator.

Silicone Rubber (SR) - Usually in the form of polydimethylsiloxane, it is used as a base polymer in non-ceramic composite insulator rubber formulations. It is known for its hydrophobic (water-repellent) properties.

Specified Cantilever Load (SCL) - A load specified by the manufacturer that represents the ultimate strength of a non-ceramic composite line post insulator under cantilever loading. The strength should be verified during cantilever load tests, and the historical failure loads (CBL) should justify the manufacturer's choice of SCL. The SCL forms the reference point for selection of a composite line post insulator. It is not the maximum working load of the insulator. See MDCL.

Specified Mechanical Load (SML) - A load specified by the manufacturer that represents the ultimate strength of a non-ceramic composite suspension insulator under tension. The strength should be verified during Mechanical Load Tests, and the historical failure loads should justify the manufacturer's choice of SML. It forms the reference point for selection of a non-ceramic composite suspension insulator. It is not the maximum working load of the insulator. See RTL. The SML of an insulator may be reduced by the class of hardware used for the end fittings.

Specified Tensile Load (STL) - The load specified by the manufacturer that represents the ultimate strength of a non-ceramic composite line post insulator under tension. The strength is verified by the same testing procedures used to determine the Specified Mechanical Load (SML) for composite suspension insulators.

Suspension Insulator - Any insulator intended primarily to carry tension loads. It includes tangent, dead-end, and vee-string installations.

Tracking - The formation of electrically conductive carbonized paths starting and developing on the surface of the insulating material and causing irreversible deterioration of surface material. These paths are conductive even under dry conditions. Tracking can occur on surfaces in contact with air and also on the interfaces between insulating materials.

Treeing - The formation of micro-channels within the housing material causing irreversible internal deterioration. The micro-channels can be either conducting or non-conducting and can progress through the bulk of the material until electrical failure occurs.

Ultimate Strength - An insulator's tensile, compressive, or cantilever loading at which any part of the insulator fails to perform its function of providing mechanical support. Damage to the insulator core is likely to occur at loads lower than the insulator failing load.

Weathershed - The part of the insulator's housing which protrudes from the sheath and used to provide added leakage distance.

4. GENERAL

Actual line loads on an insulator consist of a combination of loads. The loads involved are quite different for a suspension insulator (tensile) as compared to a line post insulator (compressive, bending, and tensile). The non-ceramic composite insulator's mechanical strength is determined by the fiberglass-reinforced resin core. The core strength depends on the type and ratio of glass fibers and resin, the polymerization process, and the core diameter. Insulator strength is directly related to core diameter and attachment strength of the metal end fittings.

Because of the difficulty in acquiring new transmission line rights-of-way, and the need for efficient use of existing transmission line rights-of-way with minimal environmental impacts, utilities have focused on compact line designs utilizing line post insulators. Non-ceramic composite insulators are flexible and respond well to line post configuration stresses that cause unbalanced longitudinal, vertical, and transverse loads such as unbalanced ice loads, unbalanced extreme wind loads, a combination of unbalanced wind and ice loads, sudden impacts (vehicular), line drops, and seismic activity.

Insulator loading requirements are described in IEEE C2, "National Electrical Safety Code". The NESC considers two weather loadings: (1) combined ice and wind loading and (2) extreme wind loading. Where both rules apply, the required loading should be the one that has the greater effect. The code requires that calculations be performed to determine the vertical, transverse, and longitudinal loading on line supports. The engineer should consider and accommodate these loads when choosing the insulator's mechanical strength.

Vertical loads on an insulator should consist of the insulator's own weight, associated hardware, plus the conductor, including radial ice loads. The effect of any difference in elevation of the supports should also be considered in the vertical load.

Transverse loads are horizontal loads on conductors created by wind pressure applied at right angles to the direction of the line against the projected area of the conductors and associated materials including the radial thickness of ice. At angles, the transverse load should be the vector sum of the transverse wind load and wire tension load.

Longitudinal loads occur at (1) changes in grades of construction, (2) deadends, and (3) unbalanced line tensions in adjacent spans created by asymmetric ice loading or sag loading of unequal spans.

The NESC specifies the insulator's strength requirements. Insulators should withstand all applicable loadings as specified in the code except those of extreme wind loading without exceeding the following percentages of their rated ultimate strength: Cantilever (40 percent), Compression (50 percent), and Tension (50 percent). Proper allowance should be made for extreme wind loading.

4.1 Advantages and Disadvantages of Non-Ceramic Insulators

Non-ceramic composite insulators are designed to withstand long-term mechanical and electrical stresses for the lifetime of the unit. They provide excellent performance when used on overhead transmission line designs utilizing suspension insulators and line post insulators. Suspension insulators generally carry tension loads and can be applied in I-string, vee-string, and dead-end-type applications. Line post insulators are generally loaded in bending or compression and can be applied in horizontal post, vertical post, or braced post configurations. Occasionally, they are used for substation bus supports and disconnect switch applications.

Non-ceramic composite insulators have improved flashover performance characteristics as compared to ceramic insulators with equivalent leakage distances, particularly in areas of heavy airborne contamination. Ceramic suspension insulators generally have a convoluted profile that allows the contaminant to more easily attach to the insulator surface. Non-ceramic composite insulators have simple, smooth shed profiles that enhance the performance of an insulator, especially in contaminated environments.

Environmental contaminant magnitude, insulator leakage distance, and composition of weathershed material determine the flashover performance of the insulator. In general, utilities take a conservative approach and purchase non-ceramic composite insulators with leakage distances greater than or equal to ceramic insulators for the same application, thus allowing for additional protection from leakage current and flashovers.

The type and composition of weathershed material affect the long-term contamination performance of an insulator. Silicone Rubber (SR) is hydrophobic and tends to resist wetting and causes beads of water to form from the moisture that comes into contact with the silicone material. If any environmental contamination adheres to the surface of silicone, the lightweight silicone chains in the SR material saturate the pollution layer and, upon wetting, form beads of water, and the contaminants roll off the weathersheds and clean the insulator. Therefore, it is recommended that SR insulators be utilized in contaminated environments. SR material greatly reduces the likelihood of pollution flashover. It should be noted that if continuous electrical discharge activity occurs, degradation in SR material may occur at a more rapid rate than with other insulating materials. This degradation will cause SR material to lose its hydrophobicity thus greatly reducing the insulator's performance in contaminated environments.

Other types of insulator surface materials are categorized as hydrophilic and tend to wet easily, forming a thin water film over the surface of the insulator material. Ceramic and ethylene propylene rubber {EPR includes both ethylene propylene monomer (EPM) and ethylene propylene diene monomer (EPDM) materials} are hydrophilic. In contaminated environments, EPR may generally allow higher magnitudes of leakage current activity without significant degradation in the material. During foggy and light rain conditions, the insulators with hydrophilic materials in a contaminated environment may allow leakage currents to flow along the surface of the insulator, which can substantially increase the risk of flashover. Although EPR materials have exhibited better short-term flashover performance than ceramic insulators in contaminated environments, the risk of flashover may be reduced by increasing the basic insulation level (BIL) of the insulator or by utilizing insulators made of SR. Silicone additives have been combined with ethylene propylene rubber to create a material claiming better performance in contaminated environments than standard EPR materials. Hydrophilic insulator materials may be mechanically stronger than hydrophobic materials and may better resist leakage current activity.

Non-ceramic composite insulators may be more desirable than ceramic insulators in areas of high vandalism because of gunshot damage. In-service non-ceramic composite insulators with a gunshot hole in the weathershed material will generally not pose a serious problem. However, bullets lodged in the fiberglass rod could create a serious problem, and these insulators usually are quickly removed from service.

Additional benefits of non-ceramic composite insulators include the following:

1. High strength-to-weight ratio creates ease of transportation and handling, thus reducing construction and maintenance costs.

2. The lighter weight allows less loading on structures.

3. Radio noise is reduced due to elimination of ball and socket joints.

4. Maintenance is reduced with hydrophobic materials, which generally require no cleaning of the insulator.

5. Ceramic line post insulators are brittle and do not deflect. This lack of resiliency may cause a cascading failure due to longitudinal loading (shearing). Non-ceramic composite insulators are flexible and better protect the line from sudden impacts, line drops, wind gusts, asymmetric ice loading, and other longitudinal loads.

4.2 Composite Insulator Materials

4.2.1 Core: The internal core of a non-ceramic composite insulator consists of a fiberglass-reinforced plastic (FRP) rod. It is the primary mechanical load-bearing component of the insulator. The strength of the rod depends on the types of materials used, the diameter, and the percentage composition of glass fiber and impregnating resin. Generally, almost all manufacturers use E-glass (electrical) fibers and epoxy resin. ECR-glass (electrical chemical resistant) fiber is generally no longer used in the manufacturing process, but acid-resistant fiber is becoming available upon request. Acid resistant fiber may protect against brittle fracture caused by stress corrosion of the rod when the rod is exposed to moisture and corona discharge. Polyester and vinylester resins have been used but are uncommon.

During fabrication, the individual glass fibers are equally tensioned to axially align each fiber parallel to the rod axis. The fibers are placed in a resin matrix such that each glass fiber is impregnated with the resin. The combination is then cured at a high temperature, allowing the individual fibers to bond to the resin matrix. This manufacturing technology is known as pultrusion. Generally, 60 to 70 percent of the FRP rod volume contains glass fibers.

4.2.2 Metal End Fittings: The strength of a composite insulator not only depends on rod materials and rod diameter, but also on the metal end fittings material type and the bonding procedures used to attach the metal end fittings to the FRP rod. Metal end fittings should be made from a good commercial grade of iron or steel and should be galvanized in accordance with ASTM A153, “Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware”. Metal end fittings may also be manufactured from a good grade of stainless steel. Aluminum is not recommended.

Metal end fittings should be designed to effectively transmit the mechanical loads to the insulator core (FRP rod). The attachment of the metal end fittings to the FRP rod is important and should be performed with a symmetrically controlled crimping method that compresses the metal radially onto the rod without damage to the rod fibers or resin matrix. Excessive compression may crush the rod and cause de-bonding between the rod and the end fittings, which may reduce the mechanical strength of the insulator. Insufficient compression may cause slippage between the rod and the end fittings. It is critical that the manufacturer provide the utility with documentation that details quality control procedures and crimping machine control mechanisms that prevent FRP rod damage and metal end fittings slippage.

Metal end fittings should be properly sealed to prevent moisture contact with the FRP rod. This seal should never be broken during testing or otherwise.

ANSI C29.11, "Composite Suspension Insulators for Overhead Transmission Lines - Tests" defines the following testing procedures for composite suspension insulators to confirm the integrity of the metal end fittings interface:

Prototype Tests:	Power Frequency Voltage Test
	Sudden Load Release Test
	Thermal Mechanical Test
	Water Penetration Test
	Steep Front Impulse Test
Sample Test:	Mechanical Load Test
	Galvanizing Test
Routine Tests:	Tension – Proof Test

The tensile strength of metal end fittings attached to the FRP rod should equal or exceed the specified mechanical load (SML) rating defined for the composite suspension insulator. Similar testing procedures to confirm the integrity of the metal end fittings interface for composite line post insulators are specified in ANSI C29.17, "Insulators - Composite - Line Post Type".

4.2.3 Housing: The housing is composed of a sheath and weathersheds, both are made of a polymeric compound. The sheath covers the fiberglass core to protect it from the external environment while the weathersheds provide the required leakage distance and electrical insulation strength.

It is important when considering housing materials to determine which type of material is best suited for the insulator application. Housing materials are generally made from EPR or SR. An alloy material of EPDM and silicone additive is also available. The weathersheds and sheath may be bonded together during the vulcanization process or molded into one piece by injection molding. The sheath is generally bonded to the rod, but a void-free silicone grease interface is also available. The housing may be either bonded to the metal end fittings or sealed to prevent moisture ingress to the FRP rod.

Experience has shown that the performance of different formulations varies for a given environment. Therefore, the utility should obtain written verification from the manufacturer that the insulator housing material considered will provide satisfactory performance in the particular environment to which the insulator is to be subjected by the purchaser. SR housing materials have exhibited the best short-term flashover performance and are generally recommended in areas with heavy contamination.

4.2.4 Grading Devices: When the electrical field created by a high voltage ionizes the air and discharges, it creates corona. Corona activity can degrade the composite insulator housing and core. Generally, corona activity occurs at the surface of line conductors and insulators, and at the energized hardware. Corona activity creates energy loss, radio influence voltage (RIV) audible noise.

The electrical field distributed along a ceramic suspension insulator string is capacitively graded by the individual insulators' metal caps and pins. Composite insulators have no metal components along their length, resulting in high electrical field magnitudes concentrated around the energized metal end fittings. In addition, corona activity generally increases at energized locations when environmental contaminants are present. Experience has shown that composite insulators subjected to continuous contamination may be damaged from corona activity concentrated along the molding seam of the insulator and occurring at the energized end of the housing of the insulator. Therefore, it is important to consider the addition of grading devices at the end fittings when using composite insulators to evenly dissipate electrical stress. Grading devices are generally shaped like large metal rings and are designed to alter the distribution of electric fields at the ends of the insulator. These metal rings, called corona rings, are designed to either reduce or eliminate corona discharge activity under wet and dry conditions.

The IEEE 987, "Guide for Application of Composite Insulators", specifies when grading devices are required for composite insulators. In general, suspension and dead-end insulators operating at voltages above 345 kV require grading devices at both ends. Voltages of 345 kV to 230 kV (inclusive) require grading devices at the energized end. Phase-to-phase insulators require grading devices at or above 161 kV, and line post insulators require grading devices above 230kV. These recommendations may not prevent serious dry or wet corona activity, and although manufacturers generally specify when grading rings are required, the decision should be made by the utility.

Electrical field magnitudes will vary depending on the geometrical configuration of the insulator pole-top unit. Reduced phase spacing due to compaction of lines, voltage uprating of existing lines, contaminated environments, weather, and high altitudes may increase corona activity and possibly degrade the insulator materials. Therefore, it is recommended that grading devices be used on the energized end of all suspension insulators and dead-end insulators operating at a voltage of 138 kV and above, and on both ends of suspension insulators operating at 345 kV and above (including horizontal vee and braced post configurations), and at the energized end of all line post insulators operating at 230 kV and above. In environments subjected to long periods of contamination or salt air, or where the geometry of the structure hardware arrangement enhances the probability of corona activity, the utility should consider using corona rings on the energized end of all suspension insulators operating at 69 kV and line post insulators operating at 138 kV. In some expected severe cases the electrical field stresses may need to be calculated by a field plot and appropriate remedial measures should be added to the design.

Corona rings may reduce the strike distance of the insulator. Care should be taken when replacing ceramic insulators with non-ceramic composite insulators to ensure that the addition of corona rings does not reduce the leakage distance of the insulator to undesirable levels, possibly increasing the probability of flashover. If the utility considers there is a possibility of flashover or corona damage then it is prudent to require the manufacturer to verify acceptable performance of the grading devices by conducting radio influence voltage and visual corona tests with the insulator, hardware, and conductor assembly that will be used. A visual corona test method using a light amplifier is provided in Section 10.3 of this bulletin. If the utility or manufacturer does not have the test capabilities, there are several independent laboratories available that can perform these tests.

5. DESIGN CONSIDERATIONS FOR SUSPENSION INSULATORS

5.1 <u>Mechanical Considerations</u>: Mechanical ratings for non-ceramic composite suspension insulators are similar to those for ceramic suspension insulators. The difference is non-ceramic suspension insulators are given a SML rating and ceramic suspension insulators are given a combined Mechanical and Electrical (M&E) rating. These two ratings are directly interchangeable for comparing their mechanical strengths. The maximum continuous working load applied to a non-ceramic suspension insulator should not exceed 50 percent of the SML rating.

Suspension insulators are usually subjected to tension loads. Normally suspension insulators do not have compression, bending, or combined load ratings. For applications such as vee-string or horizontal vee installations where combined loading may occur, the manufacturer should be consulted to provide combined load ratings.

When non-ceramic composite suspension insulators are installed horizontally, they may be subjected to twisting. The torsional loading capacity of a non-ceramic suspension insulator depends on the combined torsional strength of the rod and the method of attaching the end fittings to the rod. The manufacturer should be consulted regarding torsional loading, since long conductor dead-end spans may twist the insulator, exceeding its torsional strength. In the case where a single insulator is used to deadend a single conductor, a twist may inadvertently be placed on the insulator during tensioning. Composite insulators have various torsional capabilities based on their fiberglass rod characteristics. However, this torsional capability is small. It becomes necessary to watch the insulator during line stringing because long insulators can twist 360 degrees. When some degree of twisting is unavoidable, be certain it is within the manufacturer’s limits. Otherwise, the use of parallel units or stress-relief hardware may be required.

5.2 <u>Electrical Considerations</u>: Ceramic and non-ceramic suspension insulators having the same section length may not have the same dry arc distance. The ability of an insulator to protect against flashovers could be affected by a reduction in dry arc distance. A reduction in the dry arc distance can be attributed to the length of the end fittings and placement of grading rings. Generally, the dry arc distance is the linear length of the polymeric material between the metal end fittings or the linear length between the grading rings. To maintain similar lightning performance and critical impulse flashover protection of ceramic insulators, the replacement non-ceramic composite insulator should have the same dry arc distance. Care should be taken to ensure proper clearances are maintained between phases and adjacent structures. Swing angle should also be considered.

The short-term flashover performance of non-ceramic composite insulators is better than that of ceramic insulators. Where wet switching surge or contamination is a primary concern, non-ceramic composite insulators generally provide improved performance over ceramic insulators.

5.3 <u>Insulator Interchangeability and Replacement</u>: The mechanical working loads suspension insulators are required to withstand are specified in NESC Rule 277. Suspension insulators should not be loaded in tension beyond 50 percent of their rated ultimate strength except under extreme wind loading.

The ultimate mechanical strength of a ceramic (porcelain or glass) suspension insulator is the "Combined Mechanical and Electrical Strength" as defined in ANSI C29.1, "Test Methods for Electrical Power Insulators". ANSI C29.2, "For Insulators, Wet-Process Porcelain and Toughened Glass – Suspension Type", requires the manufacturer to subject each assembled ceramic suspension insulator to a "Tension-Proof Test" load of 50 percent of its ultimate mechanical strength. This value is the maximum working load of the insulator. All insulators that fail the test do not meet the requirements of ANSI C29.2.

The ultimate mechanical strength of a non-ceramic composite suspension insulator under tension is the SML rating as defined in ANSI C29.11. The manufacturer's selection for the value of the SML of an insulator is based on its historical failure load record. ANSI C29.11 requires the manufacturer to subject each assembled suspension insulator to a "Tension-Proof Test" load equal to or greater than the routine test load (RTL) rating. The RTL is a rating equal to 50 percent of the SML. This is the maximum working load of the insulator.

When insulators are expected to be subjected to tension and compression loading it is important to check that the insulators selected are intended for such use. If insulators are expected to be subjected mainly to tension loading applications but may occasionally be subjected to compression loads, it is important to check to be certain the insulators have compression load carrying ability satisfactory for the expected load. On some types of tension insulators, the grip of the metal end fittings to the fiberglass rod have a low compression load carrying ability and may not be suitable for installation where compression loading will be expected. It is especially important to check to be certain acceptable compression loading ability exists on insulators designed for tension used as phase-to-phase spacers.

Non-ceramic composite suspension insulators come in a wide variety of metal end fittings including oval eye, Y-clevis, socket, ball, clevis, and tongue. Oval eye and Y-clevis end fittings are generally not available with ceramic insulators. When replacing ceramic suspension insulators with composite suspension insulators, careful consideration should be given to the required insulator length to maintain proper sag/tension requirements.

6. DESIGN CONSIDERATIONS FOR POST INSULATORS

6.1 <u>Mechanical Considerations</u>: The mechanical characteristic by which non-ceramic composite line post insulators are rated is the specified cantilever load (SCL). The SCL represents the ultimate strength of a composite post insulator under cantilever loading.

The maximum working load allowed for line post insulators is specified in NESC Rule 277. Except under extreme wind loading, loading of line post insulators should not be allowed to exceed 40 percent of the manufacturer specified cantilever load.

The maximum design cantilever load (MDCL) or reference cantilever load (RCL) rating of a non-ceramic composite post insulator is defined as the maximum cantilever load that can be applied to a post insulator every day with no deleterious effects on the service life of the insulator. The MDCL or RCL load rating generally represents 40 percent, but may be as much as 50 percent (per ANSI C29.17), of the insulator's ultimate cantilever strength and is determined by the manufacturer's specified failing loads, which are based on cantilever load testing.

Post insulator deflection table values are based on the insulator loaded at its MDCL rating. An insulator's specific deflection values should be included when determining clearances to ground. Generally, deflections are linear in this range, and a linear relationship can be assumed when evaluating deflections at lower loading values.

It should be noted that the MDCL or RCL rating is for a single cantilever load applied to the insulator and should not be used solely to determine line post insulator loading limits. Line post insulators placed in service on overhead line applications are actually subjected to more than just a cantilever load along one axis. Horizontal line posts in actual use are subjected to vertical, transverse, and longitudinal loads simultaneously. Vertical, transverse, and longitudinal loads each contribute to the total bending moment, or total applied stress on the insulator's core. Manufacturers provide combined loading application curves, which represent the mechanical strength limits of a non-ceramic line post insulator is when subjected to simultaneous loading. The loading curves are used to determine how a specific insulator's combined loading requirements compare with its cantilever (bending) strength. The combined loading application curves are used during the engineering stage to evaluate whether the mechanical strength of a specific insulator is suitable for the specific line loading criteria.

The actual expected loading of an insulator should be calculated first and the results compared with the application curves. Insulator loading calculations are based on conductor type, weight and diameter. Conductor loading calculations are generally performed for three types of conditions: (1) everyday loading, (2) maximum wind or extreme wind loading, and (3) combined ice and wind loading. The loading requirements are specified in the NESC.

Everyday loading is generally a vertical load determined by conductor weight. Transverse loading is created by horizontal wind pressure against the projected surface area of the conductor. Extreme wind loading creates a large transverse load on the insulator rod either in compression or tension. It should be noted that a composite post insulator's strength is most limiting in compression. Combined ice and wind loading generally causes a larger vertical load than with everyday loading due to the weight of ice on the conductor.

Combined loading application curves based on the MDCL of a non-ceramic composite post insulator is used in determining the suitability of a specific insulator for a particular installation. Using the manufacturer's application curves that are based on the insulator's MDCL rating, first plot the everyday insulator loading that was calculated using the specific line design criteria and location where the insulator will be installed. Next, plot the maximum wind loading for the same installation site. Similarly plot the insulator's combined ice and wind loading on the application curve. It is now possible to determine whether the manufacturer's mechanical values of the insulator will be able to sustain the expected simultaneous loading without exceeding 40 percent of the insulator's ultimate cantilever strength rating.

It should be noted that the insulator's allowable vertical and compressive load limits are dependent on the insulator's longitudinal loading. Longitudinal loading on line post insulators is generally caused by unbalanced line tension created from asymmetric ice or sag loading. As the longitudinal load requirement decreases, the allowable vertical and compressive load limits increase.

Actual conductor loading may exceed values given in the NESC as a result of local weather conditions or exceptional loading conditions. Care should be taken to evaluate the insulator strength based on realistic expected conductor loading conditions for the intended installation.

To ensure long-term performance of composite line post insulators under extreme ice or extreme wind loading conditions, it is recommended that the manufacturer's specified "damage limit" rating of the insulator used be greater than the expected cantilever (bending) load for realistic worst-case conditions in the particular line under construction. If the "damage limit" of the insulator is exceeded, the core could be irreversibly damaged. If cantilever loads remain below the "damage limit" during extraordinary conditions. The composite line post insulator should provide satisfactory performance without any decrease of strength over time.

To establish the "damage limit," the manufacturer determines the insulator's maximum allowable cantilever or bending moment (stress). The manufacturer does this by testing specific rod sizes and rod lengths under various bending loads and time durations. The insulator is subjected to various magnitudes of bending loads for specific time periods and the resulting deflection values are recorded. Low stress bending loads are those loads to which a specific insulator design can be subjected to, incur deflection, and return to the original unloaded position after the bending load is removed. High stress bending loads are those loads on a specific insulator that cause the rod to deflect in such a way that the rod fibers become damaged (permanent deformation) and upon removal of the load the insulator does not return to the original unloaded position. Deflection variations with time are plotted for increasing applied bending stresses in the embedded cross-section of the rod and the "damage limit" or high stress load that causes permanent undesirable deflection of the rod is established. The "damage limit" is a zone between the elastic-type behavior and plastic-type behavior of the rod.

According to manufacturers, the damage limit for a fiberglass–resin core can occur at approximately 50 percent of the core's ultimate cantilever strength. The engineer should be aware that different manufacturer's damage limit ratings vary, and the specific manufacturer should be consulted regarding how values are determined for the intended insulator. A combined loading application curve based on the insulator's strength below its damage limit should be evaluated for line post insulator loading applications under extreme wind, extreme ice, or exceptional loading conditions. For specific extreme loading design applications, some manufacturers may formulate a special or non-standard fiberglass–resin core with a higher damage limit rating. The manufacturer should be contacted for the availability of this design option.

Care should be taken when using the manufacturer's combined loading application curves. While some manufacturers supply separate application curves based on the MDCL and damage limit ratings mentioned above, others may supply only one combined loading application curve. It is important to know which rating the application curve is based.

6.2 <u>Electrical Considerations</u>: Non-ceramic composite line post insulators can be obtained with the same or better electrical characteristics as the porcelain line posts they are intended to replace, and no electrical interchangeability problems are known. The engineer should, however, be certain that added accessories (corona rings, etc.,) do not adversely affect the electrical characteristics of the base insulator design.

6.3 <u>Insulator Interchangeability and Replacement</u>: The maximum working load for line post insulators, except under extreme wind loading, is specified in the NESC. Line post insulators should not be subjected to loads that exceed the following percentages of their rated ultimate strength: 40 percent cantilever, 50 percent compression, and 50 percent tension.

The rated ultimate strength of ceramic line post insulators should be determined as specified in ANSI C29.17. The ratings are determined from the recorded values obtained during ultimate cantilever strength and tensile load testing. The manufacturer is required to subject each assembled insulator to a routine tensile load test using a load of not less than 50 percent of the rated specified tensile load (STL). This ANSI test load is the recommended working load for a ceramic line post insulator subject to loads in tension and it doubles as a metal end fittings crimping verification test which checks the integrity of the core and end fittings connection.

Presently, no routine cantilever test is required by the standard for a ceramic insulator, but the customer may require that the manufacturer perform a cantilever breaking load (CBL) sample test to confirm the manufacturer's choice of the SCL rating.

Non-ceramic composite line post insulators are rated by their ultimate strength and generally either by their MDCL or RCL. The ultimate cantilever strength is defined as the SCL, and this rating is based on the statistical results of historical cantilever load testing of composite line post insulators. The SCL is not the maximum working load of the insulator. The maximum working load of the insulator is defined as the MDCL or RCL, and this load may be applied in cantilever to the line post insulator every day with no harmful effect on its service life. The MDCL or RCL rating generally represents 40 percent of the insulator's SCL rating specified by the manufacturer. It is recommended that the line post insulator's working load, except under extreme ice or wind loading conditions, not be greater than 40 percent of the insulator's SCL rating.

When applying line post insulators in compression, it is important to check that they are suitable for such use. It is especially important to check the suitability of line post insulators used on inside angle structures, or as struts on braced post applications.

Care should be given to select a non-ceramic composite line post insulator strength based on the simultaneous combined loading as seen by the insulator during its service life. Manufacturers generally provide application curves for line post insulators that detail the simultaneously combined compressive, vertical, and longitudinal load capability of the insulator. Subjecting non-ceramic composite insulators to a simultaneous combination of loads may reduce the vertical load carrying capability of the insulator.

Non-ceramic composite line post insulators can be obtained with the same or better electrical characteristics as the porcelain posts they are intended to replace, and no electrical interchangeability problems are known. The engineer should, however, be certain that added accessories (corona rings, etc.) do not adversely affect the electrical characteristics of the base insulator design.

Direct interchangeability of line post insulators based on electrical characteristics is a common practice since small changes in length generally are not a problem. For the pole or structure end, there are more choices for mounting dimensions and bolt sizes than are usually available for porcelain posts.

7. STATION POST INSULATORS

Ceramic station post insulator ratings are specified in draft standard ANSI C29.19, "Solid Rod Fiberglass Insulators (Apparatus Post Type)". Non-ceramic station post insulators may not have the same electrical characteristics as ceramic insulators of the same length. Compression ratings should be dependent on the compressive forces expected for the installation and an insulator rated to be able to withstand these forces should be selected. Compression ratings are generally determined by the ceramic insulator that is to be replaced. Torsion ratings are a concern with switching applications. Combined load ratings should be considered and mounting dimensions should be thoroughly reviewed. The manufacturer should be contacted for information on interchangeability.

8. ENVIRONMENTAL CONSIDERATIONS

The engineer should give careful consideration to the environment in which the insulator will be placed. Environments of particular concern include those prone to fog, salt spray, high humidity, airborne industrial contaminants, and aerially applied agricultural fertilizers and sprays.

The engineer should be confident that the insulator leakage distance is adequate for the specific application environment. The leakage distance is the shortest path along the surface of the insulator between the metal end fittings. The required leakage distance will vary with the type and amount of contamination present. In many cases, the utility's experience will determine the leakage distance requirements for non-ceramic composite insulators. A guide that is generally used by utility companies for the selection of insulators in polluted environments is IEC 60815, "Guide for the Selection of Insulators in Respect of Polluted Conditions". This guide defines pollution level categories for ceramic insulators. It is recommended that this guide also be used when selecting non-ceramic insulators in polluted environments. The following tables from IEC 60815 may be used to determine the required leakage distance for insulators in polluted environments.

Table 1

Pollution Level	Examples of Typical Environments
I – Light	• Areas without industries and with low density of houses equipped with heating plants • Areas with low density of industries or houses but subjected to frequent winds and/or rainfall • Agricultural areas • Mountainous areas All these areas shall be situated at least 10 km to 20 km from the sea and shall not be exposed to winds directly from the sea.
II – Medium	• Areas with industries not producing particularly polluting smoke and/or with average density of houses equipped with heating plants • Areas with high density of houses and/or industries but subjected to frequent winds and/or rainfall • Areas exposed to wind from the sea but not too close to the coast (at least several kilometers' distance)
III – Heavy	• Areas with high density of industries and suburbs of large cities with high density of heating plant producing pollution • Areas close to the sea or in any case exposed to relatively strong winds from the sea
IV – Very Heavy	• Areas generally of moderate extent, subjected to conductive dusts and to industrial smoke producing particularly thick conductive deposits • Areas generally of moderate extent, very close to the coast and exposed to sea spray or to very strong and polluting winds from the sea • Desert areas, characterized by no rain for long periods, exposed to strong winds carrying sand and salt, and subjected to regular condensation

[1] Use of fertilizers by spraying, or the burning or crop residues, can lead to a higher pollution level due to dispersal by wind.
[2] Distances from the sea coast depend on the topography of the coastal area and on the extreme wind conditions.

The minimum "Specific Leakage Distance" of ceramic insulators in regard to pollution level is provided in IEC 60815.

Table 2

Pollution Level	Minimum Nominal "Specific Leakage Distance" Inches/kV (mm/kV)
I - Light	0.63 (16)
II – Medium	0.79 (20)
III – Heavy	0.98 (25)
IV – Very Heavy	1.22 (31)

The "Specific Leakage Distance" is defined as the ratio of the leakage distance of the insulator divided by the rms phase-to-phase maximum voltage for the equipment expected on the electrical system to which the insulator will be installed. It is recommended that non-ceramic composite insulator leakage distance be equal to or greater than that recommended for ceramic insulators. The "Specific Leakage Distance" values recommended are provided as a guideline, and environments of severe pollution may require "Specific Leakage Distance" values greater than 1.22 inches/kV. If a ceramic insulator installed in the field has performed satisfactorily, then a non-ceramic composite insulator with similar leakage distance may be used as a replacement. If ceramic insulator performance has proven to be problematic, then the leakage distance requirement for a non-ceramic replacement insulator should be increased.

The composition of non-ceramic insulator weathershed materials is based on ethylene EPR or SR. A combination of EPDM and silicon additives is available. Laboratory testing and field installations have shown that these non-ceramic insulating materials exhibit improved short-term flashover performance over ceramic insulators in contaminated environments.

Generally, EPR insulators are hydrophilic and allow a thin film of water to form on the surface. EPR materials may exhibit hydrophobic properties initially due to residues left on their surface from the manufacturing process. Once the insulator is exposed to the environment, these residues wear off, allowing the surface material to wet out. This may lead to greater leakage current activity under contaminated environments and reduce the flashover performance of the insulator.

SR insulators provide a hydrophobic weathershed surface by resisting surface wetting and forming water beads from moisture contact. A continuous water layer cannot form, thereby reducing the probability of leakage currents and associated discharge activity. When environmental contamination adheres to the surface of silicone, the lightweight silicone chains in the SR material saturate the pollution layer. Upon wetting, this saturated pollution layer mixes with the beads of water that form. This mixture eventually becomes heavy enough so that the water along with the contaminant rolls off the weathersheds thus cleaning the insulator. SR materials have exhibited superior flashover performance and aging characteristics compared to those of EPR and are recommended for areas of heavy contamination. It should be noted that excessive electrical discharge activity may cause degradation in the SR material to occur at a more rapid rate than with other insulator materials. This degradation will cause the SR material to lose its hydrophobicity thus greatly reducing the insulator's performance in contaminated environments.

Non-ceramic composite insulators have performed well in contaminated environments and have been used to correct numerous flashover problems. In severely contaminated environments where heavy airborne pollution is present, a periodic inspection program should be performed to detect actual damage to the insulator. If non-ceramic composite insulators will be located in a contaminated environment, then it is recommended that test results be obtained from the manufacturer documenting the performance of the specific insulator elastomeric formulation in contaminated areas similar to the proposed installation environment.

9. QUALITY ASSURANCE PROGRAM

The utility should ask the manufacturer to furnish a description of its Quality Assurance Program including fabrication, testing, and inspection. Any material (i.e., rubber), components (i.e., rod) or hardware (i.e., end fittings) the manufacturer has had fabricated by others should also be included. Manufacturing methods and material composition documentation should be acquired and kept for future reference. It is recommended that the manufacturer have a Quality Assurance Program conforming to ISO 9001:2000, “Quality Management Systems - Requirements”, or the latest equivalent.

10. TESTING

When procuring non-ceramic composite insulators, the engineer should specify the electrical and mechanical parameter values and the testing the utility requires the manufacturer to conduct in order to demonstrate product conformance to the utility’s specifications. Although testing is specified in the ANSI standards, use of the standards by manufacturers is completely voluntary. Therefore, in procuring non-ceramic composite insulators it is recommended utilities require manufacturers specify and specifically cite the ANSI standards along with the minimum test parameter values the utility will accept for demonstrating compliance.

10.1 Composite Suspension Insulator Testing: ANSI standards C29.11 and C29.12, “Insulators - Composites - Suspension Type”, describe important characteristics and testing evaluations for non-ceramic composite suspension insulators intended for use on overhead transmission lines 70 kV and above. ANSI C29.12, “Insulators – Composite – Suspension Type”, specifies materials and testing applicable to non-ceramic composite suspension insulators, and ANSI C29.11 specifies the specific testing methods and procedures.

A discussion of the ANSI tests that should be specified when procuring non-ceramic composite suspension insulators is provided in Sections 10.1.1 through 10.1.5 of this bulletin.

10.1.1 Prototype Tests: Prototype tests verify the suitability of design, materials, and manufacturing methods. They are described in ANSI C29.11, Sections 4.1 and 7. Prototype testing should be considered valid for the whole class of insulators represented by the specific prototype design. Prototype tests are performed only once for each particular type of insulator design and the results are documented in a test report. It is recommended that the test reports be obtained from the manufacturer prior to procurement of a class of insulators to verify successful completion of the prototype testing. The testing is done in four parts and is described in Sections 7.1, 7.2, 7.3, and 7.4 of ANSI Standard C29.11. The testing should include the following:

- Tests on Interfaces and Connection of End Fittings
  - Test Specimen – Three insulators should be tested
  - Power Frequency Voltage Test
  - Sudden Load Release Test
  - Thermal Mechanical Test
  - Water Penetration Test
  - Verification Tests
    - Visual
    - Steep Front Impulse Voltage Test
    - Power Frequency Voltage Test
    - Dye Penetration Test

- Core Time – Load Test
  - Test Specimen – Six insulators should be tested
  - Determination of Average Failing Load of the Core
  - Core Time Load Test

- Housing Tracking and Erosion Test
  - Test Specimen – Two insulators should be tested
  - The Test Chamber, Conditions, and Evaluation shall be performed as specified in ANSI C29.11

- Core Materials Test
  - Dye Penetration Test
  - Water Diffusion Test

See ANSI C29.11 for a complete description of the testing and acceptance criteria.

10.1.2 Electrical Design Tests: Electrical design tests verify the insulator's performance characteristics based on its size and shape. The tests are performed only once on complete, full-scale insulators of a specific electrical design. The design testing that should be performed is defined in ANSI C29.12. The procedures describing how the testing will be performed are documented in ANSI C29.11 and C29.1.

It is recommended that the test reports be obtained from the manufacturer prior to procurement of a specific voltage class of insulators so the utility can verify completion of design testing as required by ANSI C29.12. This testing should include the following:

- Low-Frequency Dry Flashover Test
- Low-Frequency Wet Flashover Test
- Critical Impulse Flashover Tests – Positive and Negative
- Radio-Influence Voltage (RIV)

If grading rings are to be purchased, then the utility should request that the manufacturer provide reports of successful electric field modeling or testing for the specific insulator design to be purchased.

10.1.3 Quality Conformance Tests: ANSI C29.12 specifies the quality conformance testing that should be performed on non-ceramic composite insulators. The specific testing procedures are defined in ANSI C29.11 and C29.1. The test procedures are identified as sample tests in C29.11. The insulators are selected from the production lot at random with the purchaser having the right to make the selection. Testing is required on each lot. The tests verify that the insulators conform to the requirements of the ANSI standards. ANSI C29.12 requires the following tests be performed on at least three insulators from each lot:

- Dimensional Tests
- Galvanizing Test
- Specified Mechanical Load Test

Some ambiguity exists between ANSI C29.12 and C29.11 regarding sample selection quantity. ANSI C29.11 was completed in the 1980s in an attempt to get a usable standard out to the public. ANSI C29.12 was published in 1997 and is a more recent standard. Because of the ambiguities, it is recommended that the utility include in its specific requirements the test quantity of insulators to be subject to Quality Conformance Testing (sample tests). It is recommended that for lots of more than 200 insulators, the utility specify at least three samples be tested for both the dimensional tests and galvanizing test. At least one sample should be mechanical load tested. For lots of 200 insulators or less, the number of samples tested should be determined by agreement between the utility and manufacturer. The utility should feel comfortable that the sample quantity tested is sufficient to represent quality conformance for all insulators procured. The utility should also determine an acceptance criteria based on the number of tested samples. In the event one insulator or metal part fails to comply with the requirements of a sample test, a re-test procedure is described in ANSI C29.11, paragraph 9.6.

10.1.4 Routine Testing: Routine testing should be performed on every insulator produced to help eliminate procurement of insulators with manufacturing defects. ANSI C29.12 specifies two routine tests:

- Tension – Proof Test
- Visual Examination

The test procedures are defined in ANSI C29.11.

10.1.5 Development of ANSI Standards: The development of ANSI standards regarding non-ceramic composite insulators is an ongoing process. Testing methods for electrical power insulators are defined in ANSI C29.1. Testing methods included in ANSI C29.1 have been generally utilized for ceramic insulators. In an attempt to define testing methods and procedures for composite suspension insulators, ANSI C29.11 was developed. ANSI C29.11 is considered the test standard. ANSI C29.12 was developed to define the tests that are required to be performed to meet minimum requirements for the manufacturing and procurement of composite suspension insulators. ANSI C29.12 is considered a product standard, similar to ANSI C29.2 for ceramic insulators. ANSI is presently developing standards for composite station post insulators (ANSI C29.19).

10.2 Composite Line Post Insulator Testing: ANSI C29.17 describes the test procedures applicable to non-ceramic elastomeric composite line post insulators intended for use on overhead lines in electric power systems energized at 70 kV and above.

A discussion of the ANSI tests that should be specified when procuring non-ceramic composite line post insulators is provided in Sections 10.2.1 through 10.2.4 of this bulletin.

10.2.1 Prototype Tests: The purpose of prototype testing is to verify the suitability of product design, materials, and method of manufacture. ANSI C29.17 specifies the design characteristics for the various classes of non-ceramic composite line-post insulators. The prototype test is performed only once for a class of insulators. When changes in a design occur that exceed the classification limits, prototype testing should be repeated in accordance with the standard. Prototype testing is performed in five parts. The test specimen should pass each part of the tests in sequence. It is recommended that the utility obtain a copy of the prototype test report from the manufacturer prior to insulator procurement to verify successful completion of prototype testing as specified in the ANSI standard. Prototype testing should include the following tests:

1. Tests on Interfaces and Connection of End Fittings
    - Test specimens – three insulators should be tested
    - Pre-stressing
        - Thermal – mechanical test (Cantilever Load Test at 50% of SCL)
        - Water Immersion Test
    - Verification Tests (should be completed within 48 hours following removal from water immersion test)
        - Visual Examination
        - Steep-Front Impulse Test
        - Power Frequency Voltage Test (a fourth reference insulator should also be tested)

2. Assembled Core Load Tests
    - Core Time – Load Test
        - Test Specimens – three insulators should be tested.
        - Core Time–Load Test
        - Evaluation
            - Visual Examination
            - Dissection and Dye Penetration
    - Tensile Load Test
        - Test Specimens – three insulators should be tested
        - Tensile Test
        - Evaluation

3. Housing Tracking and Erosion Tests
   - Aging or Weathering Test –two insulators should be tested
4. Core Material Tests
   - Dye Penetration Test (ten samples)
   - Water Diffusion Test (six samples)
5. Flammability Test

10.2.2 Electrical Design Tests: Design tests are performed on full-scale insulators to establish the electrical capabilities of an insulator class. Design tests are performed only once for a class of insulators. It is recommended that the utility obtain a copy of the test report be obtained prior to insulator procurement to verify successful completion of testing as required by ANSI C29.17. The following design tests are required:

- Low Frequency Wet Flashover Test on one insulator
- Low Frequency Dry Flashover Test on one insulator
- Lightning Critical-Impulse Tests: positive and negative on one insulator
- Radio-Influence Voltage and Visible Corona Test on one insulator

10.2.3 Sample Tests: These tests verify conformance of the insulators purchased to the manufacturing requirements. The insulators are selected from the production lot at random with the purchaser having the right to make the selection. It is recommended that for lots of more than 200 insulators, the utility specify that at least three samples from each lot be tested for both Dimensional Tests and Galvanizing Tests. At least one sample from each lot should be tested to verify the Cantilever Strength, and one sample from each lot should be tested to verify the Tensile Strength. For lots of 200 insulators or less, the number of samples tested should be determined by agreement between the utility and manufacturer. Testing is required on each lot. The utility should feel secure that the sample quantity tested is sufficient to represent quality conformance for all insulators procured. The utility should also determine an acceptance criteria based on the number of tested samples.

ANSI C29.17 requires the following sample tests be performed:

- Verification of Dimensions
- Galvanizing Test
- Verification of Cantilever Strength Test
  - Cantilever Strength Verification
  - Cantilever Breaking Load (CBL) Test
- Specified Tensile Load Test
- Retest Procedure of Sample Tests (if required)

10.2.4 Routine Tests: Routine testing should be performed on every insulator produced to verify the final quality acceptance of the manufactured insulators. These routing tests will help to eliminate the procurement of insulators with manufacturing defects. The following tests should be performed:

- Tensile Load Test
- Visual Examination

10.3 Insulator Assembly Visual Corona Testing (Suspension or Post Insulators): It is recommended that a sample of each type of insulator with appropriate hardware and corona grading devices attached be tested. The test unit should duplicate the field application unit including the conductor arrangement and insulator assembly dimensions and hardware material. Each conductor may be simulated by using either the actual conductor type or a conductive buss bar no larger than the conductor plus 0.10 inches.

The insulator assemblies and grading rings, if any, should be subjected to a 60 Hz voltage to determine that the corona extinction voltage level is not less than 1.15 times the maximum line-to-ground voltage rating of the insulator under clean, dry conditions, with ground plane (12 feet x 20 feet +) at a maximum of 15 feet from the assemblies. The 15 percent voltage factor accounts for variation in design and application, but not moisture. The corona detection device should be a light amplifier with a gain of 30,000 or more with F/2.8 or faster lens. The test specimen image when viewed should be no smaller than 20 percent of the light amplifier screen (described in "IEEE Transactions on Power Apparatus and Systems", PAS Vol. 100, No. 2, February 1981, page 885). The device should be able to detect light generated by corona in the visual spectrum.

Proper operation of the light amplifier should be demonstrated in a dark laboratory prior to testing. The test insulator should be energized just above the corona threshold and the detection of glow corona verified.

Continue testing in a dark laboratory with a source voltage higher than 1.15 times the insulator's maximum line-to-ground voltage (high enough to create corona), voltage should be lowered to 1.15 times L-G voltage. The test specimen should be viewed from at least two directions approximately 180° apart on the plane of the building floor that has the best view of the flat plane or planes of the test specimen. There should be no visible corona (through the night viewing device) on the test specimen and grading rings. The effects of continuous corona on the housing surface may cause insulator housing damage.

An insulator with the weathershed material partially encapsulating the metal end fittings should have the encapsulating material removed for the corona test.

10.4 Insulator Assembly Modeling Test (Suspension or Post Insulator): When grading rings are required it is recommended that the utility request a digital finite analysis electric field modeling test of the exact configuration to which the non-ceramic insulator will be applied. This is to verify the effectiveness of grading rings. The model should be three dimensional with results containing drawings depicting the electric field in various colors, each of a different voltage level. The result of this study should show that the voltage field surrounding the non-ceramic insulator is not greater than 0.45 kV/mm along the entire length of the insulator, with the effected hot end of the insulator being a critical location. The threshold at which corona may or may not be present is defined as 0.45 kV/mm.

11. INSULATOR HANDLING

Handling practices for non-ceramic composite insulators should be different from those used for ceramic insulators. A single cut, puncture, or tear in the polymeric housing material covering the FRP rod may expose the rod to moisture and eventually cause mechanical failure of the insulator. A single cut or tear in the weathershed material, particularly near the hot end fittings, may cause excessive corona activity, resulting in eventual degradation of the housing material and possible exposure of the rod to moisture.

Insulators should be properly stored and transported to the job site in their original shipping containers. If the insulators are stored outside of their shipping containers (which may result because of prolonged exposure of the shipping container to weather and eventual deterioration of the container), they should never be lying down against the ground, walked on, stacked on top of each other, or transported hanging over the tailgate of a pickup truck. Composite insulators may also be damaged by rodents during storage, and proper safeguards should be taken.

Care should be taken when unpacking insulators to ensure that the polymeric housing is not cut or punctured. Insulators should be inspected for damage after removal from shipping containers.

Composite insulators should never be lifted by their weathersheds. Long suspension insulators should be carried by two workers and, if lifting with a rope or strap, attach it only to the insulator end fittings. Long suspension insulators should also be supported in the middle by workers to avoid bending since suspension insulators are generally not designed for bending or compressive loads.

If composite insulators are removed from their original shipping containers and then transported to the job site, extreme care should be taken at all times to avoid damaging the polymeric housing material. No sharp objects, materials, tools, or corona rings should be placed either on top, or situated below the insulators. Composite insulators should not be tied down with rope over the housing material during transport or transported on overhead racks of line crew trucks where bending of the insulator occurs.

During installation, the composite insulator should not be subjected to any loads that it would not normally see in service. The insulator should be thoroughly inspected before and after installation. Damaged insulators should not be used and should be marked for inspection by qualified utility personnel.

EXHIBIT A

TECHNICAL PROCUREMENT SPECIFICATIONS FOR NON-CERAMIC COMPOSITE INSULATORS (SAMPLE SPECIFICATION)

Instructions for the use of Exhibit A

Exhibit A is a sample purchase specification for non-ceramic composite insulators. It does not include front-end documents or specifications for construction. The user of this specification must add front-end documents including general conditions and any supplemental instructions to the bidders. This specification was written for the procurement of non-ceramic composite suspension and line post insulators. Although it may be used to procure station post insulators, it is intended to be used to procure line post insulators. If the utility wishes to use this document for the procurement of station post insulators, additional information may be required regarding insulators compression and torsion ratings, depending on the application.

If non-ceramic composite insulators are competitively bid, use of this Procurement Guide should eliminate ambiguities that might cause confusion between the owner and manufacturer. The owner is responsible for completing this specification by adding additional information, drawings, and supplemental requirements as appropriate. It may be necessary to modify this specification in order to consider special applications or preferences of the owner.

When replacing existing ceramic insulators, Attachment A can be used with the Specification to provide the manufacturer with information on the existing insulators. The manufacturer should supply all information requested on this form regarding the proposed replacement insulators and return the form with the manufacturer's proposal. The owner may use this form to compare the existing insulator details with the manufacturer's proposed insulator details. The owner may also use this form to specify minimum requirements for the proposed insulators. Attachment A, Insulator Replacement Information Form, is provided at the end of this specification.

TABLE OF CONTENTS

BLANK PAGE

TECHNICAL PROCUREMENT SPECIFICATIONS FOR NON-CERAMIC COMPOSITE INSULATORS

1. SCOPE

This purchase specification covers the technical aspects of manufacture, testing and preparation for delivery of non-ceramic composite insulators. It does not include front-end documents or specifications for construction. The user of this specification must add front-end documents including general conditions and any supplemental instructions to the bidders. This specification was written for the procurement of non-ceramic composite suspension and line post insulators. Although it may be used to procure station post insulators, it is intended to be used to procure line post insulators. If the utility wishes to use this document for the procurement of station post insulators, additional information may be required regarding insulators compression and torsion ratings, depending on the application.

If non-ceramic composite insulators are competitively bid, use of this Procurement Guide should eliminate ambiguities that might cause confusion between the owner and manufacturer. The owner is responsible for completing this specification by adding additional information, drawings, and supplemental requirements as appropriate. It may be necessary to modify this specification in order to consider special applications or preferences of the owner.

When replacing existing ceramic insulators, Attachment A, Insulator Replacement Information Form, can be used with the Specification to provide the manufacturer with information on the existing insulators. The manufacturer should supply all information requested on this form regarding the proposed replacement insulators and return the form with the manufacturer's proposal. The owner may use this form to compare the existing insulator details with the manufacturer's proposed insulator details. The owner may also use this form to specify minimum requirements for the proposed insulators. Attachment A is provided at the end of this specification.

2. DEFINITIONS

Cantilever Breaking Load (CBL) - A load specified by the manufacturer that represents the failing load of a non-ceramic composite post insulator. The failing load is the maximum load attainable under Cantilever Load testing and is greater than or equal to the Specified Cantilever Load (SCL).

Core - The internal part of a composite insulator. The core is the mechanical load-bearing component of the insulator. The core consists mainly of glass fibers impregnated with a resin-based matrix so as to achieve maximum strength. Also called a fiberglass-reinforced plastic (FRP) rod.

Design Tests - Tests to evaluate the electrical design of the non-ceramic composite insulator that are required only on insulators of new design. May also be used to evaluate various mechanical characteristics.

End Fittings, Metal - The metal attachment hardware that is connected to the insulator core that transmits the mechanical loads to the core at the ends of the insulator.

EPDM (Ethylene Propylene Diene Monomer) - Commonly used as a base polymer in non-ceramic composite insulator rubber formulations.

EPR (Ethylene Propylene Rubber) - The generic term that includes both EPDM and EPM.

Grading Device - A device for controlling the potential gradient at the end fittings.

Housing - The insulator component which is external to the core and contains both a sheath and weathersheds. The sheath–weathershed system protects the core and provides the required leakage distance. The weathersheds also provide wet electrical strength.

Lot - A number of insulator units in which each constituent component of the units (core, housing, metal end fittings, etc.,) comes from the same production run and the units are assembled in the same manner and process. Each lot should, as far as is practicable, consist of units of product of a single type, grade, class, size, or composition manufactured under essentially the same conditions and in contiguous time periods. The units will have the same Specified Mechanical Load (SML) or Specified Cantilever Load (SCL) rating. The number of units in a lot should normally be set at some number not to exceed 500 units.

Maximum Design Cantilever Load (MDCL) - The non-ceramic composite line post insulator cantilever load rating assigned by the manufacturer. The maximum load that can be applied to the post insulator every day with no deleterious effect on the service life of the insulator. Some manufacturers list this rating as the Reference Cantilever Load (RCL).

Mechanical Load Test - A mechanical test for non-ceramic composite suspension insulators as specified in ANSI C29.11 and used to determine if a lot of insulators meet the Specified Mechanical Load (SML) requirements. The historical failure loads from this test justify the manufacturer's choice of SML. Mechanical testing is also performed on every insulator to check its Routine Test Load (RTL) rating.

Non-Ceramic Composite Insulator - An insulator unit that is made from material other than porcelain, glass, or other ceramic material. It consists of a load-bearing resin-impregnated fiberglass core, metal end fittings, and external elastomeric housing.

Post Insulator - Primarily intended to be loaded in a cantilever mode, although specific applications may require loading in tension or compression. The most common types are: (1) horizontal line post where the insulator projects nearly horizontally from a structure and is loaded in bending by the conductor, (2) braced line post or horizontal Vee application, and (3) a station post insulator used as a bus support in an outdoor substation. Post insulators used in disconnect switch applications may also be loaded in torsion.

Prototype Tests - Tests to evaluate and verify the suitability of materials, interfaces, prototype design, and method of manufacture. Prototype tests are performed only once and are considered valid for the whole class of insulators represented.

Quality Conformance Tests - Destructive or nondestructive tests that are used to verify insulator conformance to specific characteristics and determine acceptability of an insulator lot.

Reference Cantilever Load (RCL) - A rating assigned by the manufacturer which indicates the maximum load that can be applied to the post insulator every day with no deleterious effect on the service life of the insulator. Some manufacturers list this rating as the Maximum Design Cantilever Load (MDCL).

Routine Test - A test performed on every insulator from each lot to identify insulators with manufacturing defects.

Routine Test Load (RTL) - The load applied to non-ceramic composite suspension insulators that is equal to or greater than 50 percent of the insulator Specified Mechanical Load (SML) rating. Also, considered to be the maximum continuous working load of the insulator.

Silicone Rubber (SR) - Usually in the form of polydimethylsiloxane, it is used as a base polymer in non-ceramic composite insulator rubber formulations. It is known for its hydrophobic (water-repellent) properties.

Specified Cantilever Load (SCL) - A load specified by the manufacturer that represents the ultimate strength of a non-ceramic composite line post insulator under cantilever loading. The strength should be verified during cantilever load tests, and the historical failure loads (CBL) should justify the manufacturer's choice of SCL. The SCL forms the reference point for selection of a composite line post insulator. It is not the maximum working load of the insulator. See MDCL.

Specified Mechanical Load (SML) - A load specified by the manufacturer that represents the ultimate strength of a non-ceramic composite suspension insulator under tension. The strength should be verified during Mechanical Load Tests, and the historical failure loads should justify the manufacturer's choice of SML. It forms the reference point for selection of a non-ceramic composite suspension insulator. It is not the maximum working load of the insulator. See RTL. The SML of an insulator may be reduced by the class of hardware used for the end fittings.

Specified Tensile Load (STL) - The load specified by the manufacturer that represents the ultimate strength of a non-ceramic composite line post insulator under tension. The strength is verified by the same testing procedures used to determine the Specified Mechanical Load (SML) for composite suspension insulators.

Suspension Insulator - Any insulator intended primarily to carry tension loads. It includes tangent, dead-end, and vee-string installations.

Ultimate Strength - An insulator's tensile, compressive, or cantilever loading at which any part of the insulator fails to perform its function of providing mechanical support. Damage to the insulator core is likely to occur at loads lower than the insulator failing load.

Weathershed - The part of the insulator's housing which protrudes from the sheath and used to provide added leakage distance.

3. CODES AND STANDARDS

The manufacturer shall conduct all testing in accordance with the most recent codes and standards as indicated in this section:

3.1 American National Standards Institute (ANSI)

ANSI C29.1 - 1988	"Test Methods for Electrical Power Insulators"
ANSI C29.11 - 1989	"Composite Suspension Insulators for Overhead Transmission Lines - Tests"
ANSI C29.12 - 1997	"Insulators – Composites - Suspension Type"
ANSI C29.17 - 2002	"For Insulators – Composite - Line Post Type"
ANSI Y14.5.1M - 1994	"Mathematical Definition of Dimensioning and Tolerancing Principals"

3.2 American Society for Testing and Materials (ASTM)

ASTM A153	"Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware"

4. GENERAL REQUIREMENTS

The design, fabrication, processes, tolerances, and inspection of non-ceramic composite insulators shall conform to the following:

4.1 Language and Units

4.1.1 All correspondence, literature, drawings, and markings shall be in the English language.

4.1.2 Dimensioning and tolerancing shall conform to ANSI Y14.5.1M, “Mathematical Definition of Dimensioning and Tolerancing Principals”. Dimensions shall be in the U.S. customary units, unless SI (metric system) units are requested. If fabricating in SI units, both U.S. and SI units shall be shown on the drawings. Conversion dimensions shall be 1 inch = 25.4 mm. Conversion dimensions may be rounded off to the nearest 1/32 of an inch (0.794 mm) provided the rounded dimension falls within the design limits.

4.2 Design and Material Requirements

4.2.1 Core: The internal core shall consist of a FRP rod consisting of E-glass fibers and epoxy-based resin. If required, an acid-resistant fiber may be used. All fibers of the insulator core shall be fully and completely coated with the epoxy resin matrix. During fabrication of the insulator core, the glass strands in the insulator core shall not be allowed to touch one another without resin matrix surrounding each individual fiber. Fibers shall be continuous between rod ends and oriented parallel to the rod axis. Glass content shall equal or exceed 60 percent by volume of the fiberglass-epoxy mixture. All areas in the rod not occupied by fiberglass strands shall be filled with epoxy. All fiberglass strands and epoxy shall be fully bonded together. The insulator core shall be mechanically and electrically sound, free from voids, foreign substances, and manufacturing flaws. The core shall have the same diameter throughout the entire length of the rod.

4.2.2 Housing: The core of the non-ceramic composite insulator shall be completely covered by a continuous housing consisting of a sheath-weathershed system. The weathersheds and sheath shall be bonded together during the vulcanization process or molded into one piece by injection molding. The sheath shall be bonded to the rod or have a void-free silicone interface. The housing shall be bonded to the metal end fittings or be properly sealed to prevent moisture or contaminant ingress to the FRP rod. The housing shall fully protect the fiberglass rod for the service life of the insulator. The housing shall be smooth and free from imperfections.

The housing shall be made of a polymer compound consisting of either ethylene-propylene-diene monomer (EPDM), silicone rubber (SR), or a combination of EPDM and silicone oil compounds formed during vulcanization. The material shall be strong both electrically and mechanically. The housing shall have a thickness of not less than 3.0 mm along the entire length of the housing. The core/housing interface shall be manufactured so as to prevent leakage current flow over the surface of the core. The color and consistency of the material shall be uniform.

The manufacturer shall determine if additional leakage distance is required based on the long-term performance of the housing material and the proposed insulator environmental conditions. The manufacturer shall provide the owner documentation which demonstrates satisfactory test results of specific formulations subjected to applicable environmental contamination together with satisfactory performance data of insulators (manufactured of the specified formulation) which have been installed on existing utility lines energized at the same voltage and in the same type of proposed environment. The manufacturer will define if or when insulators may require washing and the specific washing procedures required to protect insulators from mechanical damage.

4.2.3 Metal Parts: The metal end fittings shall be designed to transmit the mechanical load to the core and the end fittings shall maintain uniform and consistent mechanical strength.

Materials and methods used in the fabrication of metal parts shall be selected to provide good toughness and ductility. Metal end fittings and bases shall be made from a quality commercial grade of iron or forged steel and shall be hot-dipped galvanized in accordance with ASTM A153, “Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware”.
Metal end fittings and bases shall be uniform and without sharp edges or corners and shall be free of cracks, flakes, slivers, slag, blow-holes, shrinkage defects, and localized porosity. The attachment to the FRP rod shall be performed with a symmetrically controlled crimping method that compresses the metal radially onto the rod without damage to the rod fibers or resin matrix while providing a strength equal to or greater than the defined and specified ultimate strength of the insulator.

Each insulator shall be permanently sealed at the interface between the metal end fittings and the housing to ensure that no moisture or foreign materials shall enter. The metal end fittings and the housing of non-ceramic composite insulators after complete assembly shall be coaxial with one another and with the core, resulting in no eccentric loading.

Cotter keys shall be grade 304L stainless steel (minimum grade).

Bolts, nuts, and spring lockwashers shall be made of steel and hot-dipped galvanized in accordance with ASTM A153, unless otherwise specified. Bolts may have either rolled or cut threads and shall have thread engagements capable of developing the specified strength of the unit. Nuts may be re-threaded after galvanizing to ensure clean threads, but bolts shall not be threaded or re-threaded after galvanizing. Threaded holes and nut threads shall be tapped oversize to closely fit those of the galvanized bolt with no unnecessary looseness, but free enough to permit the nut to be turned on freely with the fingers over the entire thread length.

4.2.4 Grading Devices: Non-ceramic suspension insulators operated at 138 kV and above, and line post insulators operated at 230 kV and above, shall require a grading device attached to the end fittings of the energized end of the insulator. The size and placement of the metallic grading device shall be designed to prevent corona along the entire length of the insulator. At voltages of 345 kV and above, grading rings should be provided at both ends of a suspension insulator. All grading rings and brackets shall be designed as an integral part of the insulator assembly with a positive mounting system that allows mounting in only one position. The design of the grading ring shall be such that the ring can only be mounted with its orientation towards the weathersheds for maximum RIV and corona control. Grading rings shall be designed in such a manner that the rings can be readily installed and removed with hot line tools without disassembling any other part of the insulator assembly.

4.3 Materials and Workmanship

4.3.1 Materials specified in the design and fabrication requirements of this specification shall be unused, recently manufactured, and free of defects or irregularities.

4.3.2 All components of the same design and designation shall be identical, and like components shall be interchangeable.

4.3.3 Owner will accept offers only from manufacturers who intend to isolate insulators for lot control (if the order is large enough to contain lots) during manufacturing, quality control, and shipping.

4.4 Markings

4.4.1 All suspension insulators shall be clearly and permanently marked in accordance with ANSI C29.11, "Composite Suspension Insulators for Overhead Transmission Lines - Tests", with the following information:

- Manufacturer's Name or Trademark
- Year Manufactured
- Specified Mechanical Load (SML) in pounds
- Routine Test Load (RTL) in pounds and identified by the word "TEST" or "RTL"

4.4.2 All line post insulators shall be clearly and permanently marked with the following information:

- Manufacturer's Name or Trademark
- Year Manufactured
- Specified Cantilever Load (SCL) in pounds
- The marking should also include the Maximum Design Cantilever Load (MDCL) or Reference Cantilever Load (RCL) in pounds

4.4.3 A serial number and lot number (if the order is large enough to contain lots) shall be required on each insulator. The manufacturer shall keep documented records describing the insulator information, serial numbers, and lot numbers for each insulator throughout its useful life for future reference.

5. INSPECTION AND TESTING

5.1 General

5.1.1 Non-ceramic composite insulator testing shall be performed in accordance with procedures as specified in ANSI C29.11 and C29.12, "Insulators - Composites - Suspension Type", for suspension insulators and ANSI C29.17, "For Insulators - Composite - Line Post Type", for line post insulators. The testing standards and procedures as defined in ANSI C29.11, C29.12, and ANSI C29.17 shall be strictly adhered to. Although these standards are for composite insulators intended for use on overhead transmission lines 70 kV and above, the owner requires the same characteristic testing as defined in ANSI C29.11, C29.12, and C29.17 for all non-ceramic composite insulators the owner will procure.

5.1.2 The manufacturer should provide the owner with certified ultimate cantilever strength documentation (Specified Cantilever Load) based on historical Cantilever Load Tests for each classification of line post insulator procured under this request.

5.1.3 A code shall be selected by the manufacturer for the purpose of identifying the "lot" or the insulator production run. The units shall use the same type of polymeric and rod materials. The insulator units shall have the same ultimate strength rating. The end fittings shall be attached in the same manner.

5.1.4 The number of insulator units in a lot should normally be set at some number not exceeding 500 units. Sample sizes for quality conformance testing shall conform to the requirements of ANSI C29.12 for suspension insulators and ANSI 29.17 for line post insulators. The test insulators shall be marked with their corresponding lot number.

5.2 Prototype Testing

5.2.1 Prototype testing is generally performed only once for each particular type of insulator design and is considered valid for the whole class of insulators represented.

5.2.2 The manufacturer shall provide the owner with copies of certified testing, evaluation and acceptance reports detailing conformance to the specific tests noted below which were conducted in accordance with procedures specified in ANSI C29.11 for suspension insulators and ANSI C29.17 for line post insulators:

- Tests on Interfaces and Connection of End Fittings
- Assembled Core Load Tests
- Housing Tracking and Erosion Tests
- Aging or Weathering Test
- Core Material Tests
- Flammability Test

5.2.3 In addition to the testing reports conforming to ANSI C29.11 and ANSI C29.17 for prototype testing, the manufacturer shall provide the owner with reports documenting the testing procedures and results of an accelerated aging test similar to the CIGRÉ 5000 hour test performed on insulators of the particular type of design as represented by the prototype.

5.2.4 For non-ceramic suspension insulators, the manufacturer shall provide the owner with reports documenting the torsion strength testing as specified by ANSI C29.1, "Test Methods for Electrical Power Insulators".

5.3 Design Testing

5.3.1 Design testing is generally performed only once on complete, full-scale insulators of a specific electrical design. The manufacturer shall provide the owner with copies of certified testing, evaluation, and acceptance reports detailing conformance of all insulators procured under this request to the provisions of ANSI C29.11 and C29.12 design tests of suspension insulators and ANSI C29.17 design tests for line post type insulators. The reports shall include the results from the following tests:

- Low-Frequency Dry Flashover Test
- Low-Frequency Wet Flashover Test
- Critical Impulse Flashover Test, Both Positive and Negative
- Radio-Influence Voltage (RIV) Test and Visible Corona Test

5.3.2 In addition to the above electrical design tests, if a particular insulator design requires a grading device, the manufacturer will provide the owner with certified testing reports that the insulator design with applicable grading device has successfully passed a grading device test. The grading device test performed should be similar to the following described test:

> Grading devices shall be tested using a mechanical shaker with at least a one-inch stroke at the grading device and a frequency of no less than three cycles per second for a duration of 2,000,000 cycles. Movement shall be along the long axis of the insulator. The test shall reflect the manufacturer's recommended method for attaching the grading device to the insulator. The grading device shall be attached to the insulator and the insulator attached to the shaker in a vertical position. The test shall be considered successful if no movement is detected in the ring with respect to the insulator and there is no physical damage to the grading device and the attachment assembly.

5.3.3 The manufacturer shall provide the owner with documentation that the insulator design with applicable grading devices will minimize or eliminate corona discharge activity under wet and dry conditions for the type of pole-top configuration proposed. The effects of corona discharge activity on insulator life shall be negligible.

5.3.4 Under normal use and all but the worst environments, the insulator should not require washing. However, if the environment specified by the owner at the beginning of this request is, in the opinion of the manufacturer, such that cleaning is required, the manufacturer should provide the owner with certified documentation that the insulator has passed a high-pressure wash test. The test performed should be similar to the following described test:

> A pressure sprayer with a minimum nozzle pressure of 600 psi and a minimum flow rate of 7 liters per minute shall be applied on the underside of each weathershed at a distance that is similar to but less than the actual field application for 15 seconds minimum. Ordinary tap water must be used. After spraying, a low-frequency wet flashover test shall be conducted in accordance with ANSI C29.1, Section 4.3. A visual inspection test shall then be performed with careful attention given to any dislodgement between the weathersheds and sheath and the end fittings seals. A dye penetration test conforming to ANSI C29.11 shall be performed after spraying on the section of insulator containing the end fittings and filler material. Dislodgment of weathersheds or failure to pass visual inspection, dye penetration test, or low-frequency wet flashover test shall constitute failure.

5.4 Quality Conformance Testing (Sample Tests)

5.4.1 ANSI C29.12 specifies the quality conformance tests that shall be performed on non-ceramic composite suspension insulators. ANSI C29.17 specifies the quality conformance tests (sample tests) that shall be performed on non-ceramic composite line post insulators. For each lot, the quantity of units to be tested shall be as defined in the respective ANSI standards. The number of insulator units in each lot shall not exceed 500 units. Insulators shall be selected from each lot at random with the owner having the right to make the selection. The manufacturer shall provide the owner with certified documentation that details the results of the following test for all samples tested:

- Dimensional Tests
- Galvanizing Test
- Specified Mechanical Load Test (suspension insulators)
- Cantilever Load Test (line post insulators)
- Specified Tensile Load Test (line post insulators)

5.4.2 The owner must be assured that the sample quantity tested is sufficient to represent quality conformance for all insulators procured. If one insulator or metal part fails to comply with the requirements of a sample test as defined by ANSI standards, the retest procedure as described in the standards shall be performed. If one insulator or metal part fails a sample test, a new sample equal to twice the original quantity submitted to that test shall be re-tested. If two or more insulators or metal parts fail to comply with any of the sample tests, or if any failure occurs during the re-testing, the complete lot shall be withdrawn for offer to this owner by the manufacturer at not cost to the owner.

5.5 Routine Testing

5.5.1 Routine testing shall be performed on every insulator unit produced for procurement under this request and shall be performed in accordance with the requirements of ANSI C29.12 for suspension insulators and ANSI C29.17 for line post insulators. The manufacturer shall provide the owner with certified documentation that details the results of the following tests:

- Tension – Proof Test
- Visual Examination

5.6 <u>Certified Test Reports</u>

5.6.1 Certified test reports shall include information that allows the owner to clearly identify the units tested. The following information shall be included on the test reports:

- Purchase Order Number
- Shipment Date
- Destination
- Catalog Numbers
- Utility's Code Number
- Specified Mechanical Load of the Insulator's Core
- ANSI Class End Fittings
- Number of Lots in the Shipment
- Number of Insulators in Each Lot
- Lot Code Numbers
- Date of Testing
- Name of Individual(s) Documenting the Tests

5.6.2 The owner's inspector shall be allowed to witness all special design testing, quality conformance testing, and routine testing performed for each lot of insulators ordered and shall have the right to make an inspection before authorizing shipment of the insulators.

6. DOCUMENTATION

The manufacturer shall submit a complete bid proposal to the owner including the following documentation:

- Insulator Unit Cost Information
- Applicable Drawings with Associated Information as Specified in the RFP
- Ultimate Strength of Insulator (Suspension SML Rating, Line Post SCL Rating)
- Maximum Continuous Working Load Ratings of Insulators (Suspension RTL Rating, Line Post MDCL Rating)
- Warranty Information
- Certified Prototype and Design Testing Reports
- Applicable Deflection and Combined Loading Application Curves
- Documentation of Insulator Performance in Proposed Installation Environment
- Insulator Washing Requirements and Procedures, If any
- Grading Device Information
- Testing Reports as Specified in the RFP
- Delivery Date and Location
- Packaging and Shipping Details
- Special Application and/or Design Details
- Handling and Installation Details

7. PACKAGING AND SHIPPING

7.1 Insulator Packaging

7.1.1 The packaging of insulators and any grading devices shall provide proper protection for both products from damage during handling, shipping, and storage. If the insulators are to be stored outdoors, they shall be packaged in wooden containers completely enclosed on all sides with plywood and internal wooden supports constructed so each layer of insulators is self-supported by their own end fittings and not supported by a lower layer of insulators.

7.1.2 Wooden containers shall be treated to resist degradation using treating materials that have been determined not to harm the environment or the enclosed insulator in any manner. Weathersheds shall not rest against adjacent insulator weathersheds such that bending of the weathershed occurs. The number of insulator units per container shall be reasonable and the containers shall be designed for forklift handling. The containers shall be strong enough to support stacking of the containers to a maximum level of three containers high. The insulator containers shall never be stacked during transport since insulators and containers may become damaged due to sudden impacts. If insulators will be stored indoors, particleboard containers are acceptable.

7.1.3 The containers shall be marked, in English, with the number of insulators contained, manufacturer's name, insulator catalog number, insulator description, owner's purchase order number, and production lot number.

7.2 Grading Device Packaging

7.2.1 The appropriate number of grading devices shall be packaged in a separate enclosed container and shipped in the same wooden container as the insulators they attach to. If the grading devices are large, or the grading device container may damage the insulators during shipment, the grading devices may be shipped separately. If shipped separately, the grading device container and its associated insulator container must be clearly marked with easy to read matching identification.

7.2.2 Prior to the insulator delivery, the manufacturer shall supply the owner with documentation explaining the use of matching identification number grading ring installation, insulator lot numbers and insulator identification numbers.

8. DRAWINGS

Drawings for each type of proposed insulator shall be submitted with the proposal. Each drawing shall clearly show the following dimensions (including manufacturing tolerances) and ratings:

- Connection Length
- Number of Sheds
- Dry Arc Distance
- Leakage Distance
- Approximate Weight
- Low-Frequency Dry Flashover
- Low-Frequency Wet Flashover
- Critical Impulse Flashover Positive
- Critical Impulse Flashover Negative
- For Suspension Insulators:
  1. Specified Mechanical Load
  2. Routine Test Load
- For Line Post Insulators:
  1. Specified Cantilever Load
  2. Maximum Design Cantilever Load or RCL
- Rod Material
- Housing Material
- End Fitting Material
- Cross-Sectional View of Insulator Unit with Dimensions
- Size and Dimension Details for Both End Fittings
- Insulator Description
- Manufacturer's Catalog Number
- Manufacturer's Drawing Number
- Grading Ring Dimensions and Orientation
- Insulator Color

All drawings shall be approved by the owner before fabrication begins.

ATTACHMENT A

INSULATOR REPLACEMENT INFORMATION FORM
MINIMUM REQUIREMENTS

REQUIREMENTS	Post		Suspension	
	Existing	Proposed	Existing	Proposed
Manufacturer				
Catalog Number *				
Structure/Pole Type				
System Voltage				
END FITTINGS				
Structure End				
Energized End				
DIMENSIONS				
Length, in.				
Leakage Distance, in.				
Dry Arc Distance, in.				
Number of Bells/Sheds				
Diameter of Bells/Sheds, in.				
Core Diameter, in.				
CORONA RING				
Structure End Ring, diameter				
Energized End Ring, diameter				
MECHANICAL VALUES				
Combined M & E Strength, lbs				
SML Rating, lbs				
RTL Rating, lbs				
SCL Rating, lbs				
STL Rating, lbs				
MDCL Rating, lbs				
ELECTRICAL VALUES				
Low-Frequency Dry Flashover, kV				
Low-Frequency Wet Flashover, kV				
Critical Impulse Flashover				
Positive, kV				
Negative, kV				
Basic Impulse Level (BIL), kV				

NOTE to Owner:
* If possible, supply existing insulator drawings with mounting details in bid proposal.

BLANK PAGE

EXHIBIT B

METRIC CONVERSION FACTORS

TO CONVERT FROM	TO	MULTIPLY BY
Foot (ft)	meter (m)	0.3048
Inch (in)	centimeter	2.5400
Pound per cubic foot (pcf) (lb/ft^3)	kilogram per cubic meter (kg/m^3)	16.0185
Pound per square inch (psi) (lb/in^2)	kilogram per square meter (kg/m^2)	703.0696
Degrees Fahrenheit (°F)	degrees Celsius (°C)	5/9(X°-32)