A HISTORICAL REVIEW

CABLE ENGINEERING COMMITTEE

1924 - 2008

Prepared by the Cable Engineering Committee – May 1998 (Revised November 2008)

> "In the summer of 1880, Thomas Edison planned the installation of his first incandescent-lighting system in New York. The size of the mains, whose diameter would have to equal the sum of the individual wires leading to the houses, made it impossible to suspend them from poles. They would, therefore, have to be buried like gas pipes.
>
> Edison thought wood was a good insulator and predicted that because of the low voltage of the current, there would be no trouble with leakage. Shallow trenches were dug, wooden moldings laid in them, and the wires placed in grooves. Edison waited for a wet day to conduct a full-scale test. On July 20, the rains came and electricity went in all directions. Even the trees were charged and the lamps appeared like dying fireflies.
>
> An attempt was made to insulate the wires by pouring coal tar into the grooves. It failed, and muslin was wrapped around the wires without improvement. One thing after another was tried, until Edison, finally tiring of random experiments, told Wilson S. Howell to go into the library, read everything on insulation, and report back in two weeks.
>
> Various compounds and combinations were tried. The compound ultimately settled on was Trinidad asphalt mixed with linseed oil and small amounts of paraffin and beeswax. The mixture was cooked up in 250 gallon kettles. Boys dipped two-and-a-half-inch-wide strips of muslin into the hot compound. The wires were lifted from the trenches onto saw horses, and three layers of the saturated muslin were wrapped around them.
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> On November 1, the first part of the reinsulated distribution system passed the test. By the end of the month, 400 lamps, including Edison's house, were connected and operating."

The preceding paragraphs from A Streak of Luck, the Life & Legend of Thomas Alva Edison, by Robert Conot, briefly describe the initial "cable engineering" efforts and results of the most prolific inventor in history and the founder of our industry.

The first insulated cable specification attributed to the Association of Edison Illuminating Companies was dated November 1, 1924, by coincidence or perhaps chance, 44 years after the first circuit was energized. The Specification for Impregnated Paper-Insulated Lead – Covered (PILC) Cable for the Transmission and Distribution of Electrical Energy in Underground Conduit Systems was, "prepared under the auspices of the Lamp

Committee of AEIC in co-operation with the Electrical Testing Laboratories and Representatives of Operating Companies."

Seven operating companies and five manufacturers prepared a comprehensive, thirty-six section specification that established the pattern used through the present edition of AEIC No. 1 for impregnated paper-insulated cables. (The existing designation is CS1.)

The Committee on High Tension Cable was organized in 1926, "to assist in advancing the cable art so that the annual investment and operating costs of the cable systems of our Member Companies will be reduced and the voltages at which cables can be economically employed can be increased."

The National Electric Light Association (predecessor to the Edison Electric Institute) had developed a paper cable specification in 1920 for cables rated up to 15 kV. By the time the Fourth Edition of AEIC No. 1 was issued in 1930, the High Tension Committee reported that the specification was used by many purchasers not affiliated with AEIC and had become the principal specification for impregnated paper insulated cable in this country. Therefore, the Underground Systems Committee of the National Electric Light Association (NELA) recommended withdrawal of the NELA specification.

The High Tension Committee was dissolved in 1937 after it had issued two more revisions to the paper cable specification.

In 1938, the Executive Committee of the Association of Edison Illuminating Companies authorized the president to appoint a new committee to "deal with problems in the transmission and distribution field, charged with evaluating progress and securing action where the work of the existing technical committees in this field may indicate it to be desirable"--"the committee expected generally to confine its attention to the broader aspects of power distribution." This was the beginning of the Power Delivery Committee.

During the first meeting of the new Power Delivery Committee it was recognized that there was a need to carry on the activities of the former Committee on High Tension Cable. This led to the immediate formation of the Cable Engineering Section of the Power Delivery Committee.

The newly formed Cable Engineering Section (CES) was given four assignments:

- The evaluation of cable quality.
- Investigation of physical design and cable construction.
- Determination of permissible cable operating temperatures.
- Review of new developments based upon the results of manufacturers' research on materials, types of construction and factory methods.

The first meeting of the CES was held in Chicago during the month of May, 1938.

The first annual report issued by the CES included a comprehensive record of cable operation and a survey of cable failure causes experienced by the thirteen participating companies.

In 1940 a relationship was formed with the Insulated Power Cable Engineers Association (IPCEA), an engineering forum representing the cable manufacturing industry. Joint meetings held during the CES meetings focused on efforts to simplify and standardize on cable sizes and voltage ratings. Arrangements were also completed with the Edison Electric Institute for combining the previously separate annual cable operating reports into one report prepared by EEI.

The combined efforts of the CES and IPCEA resulted in the issuance of the Simplified Practice Schedule for paper insulated cable. The Power Delivery Committee considered the document an "outstanding contribution" by covering over 75% of the cable used and ordered with 56 standardized sizes.

In January 1943, the CES prepared and issued the first guide to be developed for cable systems entitled, "Guide for Wartime Conductor Temperatures for Power Cables in Service." Four types of power cables used in underground systems were covered: 1) PILC solid type; 2) PILC oil-filled type; 3) varnished-cambric-insulated, lead-covered; and 4) rubber-insulated cable with and without lead sheath. Reduction in cable life due to increased deterioration of insulation, lead sheath movement, increased conduit and earth resistivity and possible problems with joints and potheads were reviewed. A bibliography of 17 technical papers and documents relating to cable loadings was included in the Guide.

The CES continued to meet during World War II, making changes to the specification to recognize the necessity to conserve materials. Reduced insulation thicknesses and increased operating temperature limits were incorporated into the specification for paper insulated cable.

After the war, relations between the CES and the EEI Transmission and Distribution Committee and the new AIEE Insulated Conductor Committee (ICC) became well defined. Technical papers on cable matters originating in all three groups were to be handled through the ICC.

In late 1948, the CES reported having their first discussions of underground distribution systems for new residential developments being created. There was special interest in economical and reliable alternatives for underground distribution.

In September 1951, the initial AEIC specification for high-pressure pipe-type cable from 15 kV to 230 kV was issued. This milestone was the culmination of several years of study and research funded by AEIC, EEI, and the manufacturers. The CES was now responsible for development and maintenance of four cable specifications, all dealing with paper insulated cables: (Paper Insulated Cable - Solid Type, Paper Insulated Cable - Oil Filled, Paper Insulated Cable - Gas Filled, and Pipe Type Cable.)

Even though the IPCEA manufacturers had participated with technical assistance and reviews for the previous editions of the PILC solid type cable specification, some manufacturers took exceptions to the document. The IPCEA even considered issuing its own PILC document. After many meetings, discussions, and correspondence, the ninth edition of "Solid Type Impregnated-Paper-Insulated Lead-Covered Cable Specification" was published in April 1954. In May 1954, this specification was adopted as an IPCEA standard, an unsolicited tribute to the cooperative reconciliation of differences which had prevented similar acceptance of the eight editions. The AEIC office subsequently received many requests for the document from non-members, engineering firms, and others, including many foreign countries.

In November 1955, with a positive recommendation from the CES, the AEIC Executive Committee approved and arranged funding for the Extra High Voltage Cable and Accessory Research Project. A test site was selected and test station designed and constructed. Cable and accessory manufacturers performed special research investigations. They also developed and contributed samples of pipe type and self contained 345 kV cable systems with many innovations for field proof test and evaluation. A three-year test program was scheduled, with the first two years used to evaluate the service aging and the third year to explore probable limits for extrapolation of the application of the cables at higher voltage and conductor temperatures. This program led to the immediate extensive use of 345 kV pipe type cable by one utility, and acceptance by the utility industry resulted in the inclusion of 345 kV in the pipe type cable specification. This program, originally initiated and funded by the AEIC and later co-funded by EEI, resulted in a large scale cooperative research effort by US users and manufacturers of high voltage cable systems. Two special conferences and numerous technical papers were also generated by the effort. The research also led to improvements in lower voltage pipe type cable designs. The development, construction, and operation of this program served as a prototype for later development of the Waltz Mill high voltage test program of the national transmission cable research program. This ultimately led to the establishment of the Electric Power Research Institute (EPRI).

The CES established a task group in the early 1960s to address the increasing interest in synthetic insulation systems. By 1966, the use of polyethylene-based insulations for underground residential distribution (URD) cable systems was widespread. The task group had expressed concern over the variations in quality of these cable systems. The first AEIC specification for synthetic insulated cables was issued in 1969 as an addendum to the IPCEA standard for polyethylene insulated cables. This led to the practice of making the AEIC specification a supplement to the IPCEA documents, hence the exclusion of items such as conductors, etc. This specification covered polyethylene insulated cables rated from 5 to 35 kV.

The participation of the CES in the development of an AEIC specification for synthetic-insulated cables began a long and ongoing project to ensure that the best technology was used in cable manufacture. For instance, in the first generation of the synthetic cable specification, the CES promoted the development and use of much more sensitive partial discharge detection equipment than had been previously considered. The concept of including Qualification Testing was a result of input from Commonwealth Edison. They had such a test program and did not experience some of the problems that other AEIC members had with materials and construction. The inclusion of these tests into the specification was a major step forward in the quest for high quality cable for utility systems.

The AEIC has been responsible for a significant effort that turned polyethylene, crosslinked polyethylene, and ethylene propylene rubber insulated cables into the highly reliable products that they are today. By working with highly dedicated representatives from the cable manufacturers, much better cables were available for the industry.

By 1973, many in the utility industry were asking for a national consensus standard for cables similar to those available for transformers and other equipment. Work was started between the IPCEA and the CES to develop a joint specification after a UL draft specification was presented to ANSI for acceptance as a national specification.

As work progressed on the joint IPCEA-AEIC specification, the CES continued to update and revise the existing AEIC cable specifications to keep them current. This effort was continual, due to the rapid developments in synthetic cable insulations. By 1978, the CES had issued a new specification covering ethylene propylene rubber insulation systems (CS6) and had issued the fifth edition to the specification for polyethylene insulated cables (CS5). In addition, work was ongoing in the development of several new Guides for AEIC members.

The CES membership was active not only in the work of the CES, but also maintained a leadership role in the ICC of the IEEE and in both the transmission and distribution programs sponsored by EPRI.

The effort to complete the national specification dwindled away as it became apparent that the IPCEA goals were different than those of the CES. The manufacturers wanted a standard developed around the capabilities of their industry and were less concerned about some of the utility issues such as cable accessories, guarantees and test requirements. It was concluded that even if a joint standard were to be developed, a supplement would still be necessary to address the needs of the electric utility industry.

New technologies were becoming available that would result in the issuance of new specifications and additional revisions to existing specifications by the early 1980s. The use of high voltage cables was expanding, particularly the use of polyethylene insulated high voltage cables. Laminates of synthetic materials and traditional paper insulation were being developed for pipe type cable systems. Improvements in materials formulations and cable testing regimens were being brought to the marketplace for all varieties of cables. It was a busy time for the CES.

By 1985, the CES and other specification writing organizations were faced with a new problem that had the potential to end their existence. The legal ramifications of participation in specification development became apparent when an organization that had been active in specification writing was found to be at fault in a lawsuit. Significant penalties were imposed. The CES asked the Power Delivery Committee to review the status of the cable related activities that were underway and determine the liability of the CES. After significant review, it was determined that by inclusion of parties outside of the AEIC in the development of the specifications, and maintenance of a proactive approach to suggestions from others, the specification writing activities could continue. A detailed set of guidelines was developed by the CES to ensure that appropriate actions are followed in the development and maintenance of the AEIC specifications. The AEIC reaffirmed the need to continue the activities of the CES based on the recommendations of legal counsel and guidelines established by the CES.

The continued improvement of the cable specifications, particularly the medium voltage specification used to purchase the URD cable that is used so widely throughout the industry, was a high priority with the CES in the late 1980s and early 1990s. Major revisions to CS5 and CS6 were completed in 1994 and 1996 respectively.

In addition, the management of the AEIC companies had asked the CES to look at recommendations for dealing with cable replacements. Millions of feet of extruded dielectric URD cable had been installed over the years. Many utilities had already begun the replacement of cable sections that were not performing well. In response to the request, a new guide was developed by the CES to cover many of the aspects of cable replacement projects. Guides for installation of high voltage cable and also for pulling of extruded dielectric power cables were also issued by the CES as aids to the utility industry. The latest effort is the development of a guide to assist utilities in the establishment of a quality assurance program to ensure that they receive high quality cable from their manufacturers.

In early 1994, the CES was once again confronted with a significant challenge from the manufacturing community. The cable manufacturers expressed a very strong desire to develop a national consensus cable standard. The initial concept for this type of standard was born years before in the IEEE ICC, but progress was very slow. The beneficial relationship that had existed for years between the ICEA (formerly the IPCEA) and the AEIC CES was made more formal with the establishment of a joint working group from both organizations with the express purpose of working to develop a consensus standard. This group, called the Utility Power Cable Standards Technical Advisory Committee (UPCSTAC), was patterned after a similar group formed to deal with communication cable issues earlier. The Power Delivery Committee was asked for approval to participate in this forum and gave its total support to the process.

Progress toward the first national consensus standard was very quick. Within a few months the first draft was under review, and in January 1998 the first standard developed by UPCSTAC covering medium voltage concentric neutral cables was approved by ANSI and issued as a national standard. Additional standards covering other cable designs used by the utility industry continue to be developed through the UPCSTAC process.

In 1998, due to the level of work and the significance that the CES had become, the AEIC decided to elevate the Cable Engineering Section to Committee level naming it the Cable Engineering Committee (CEC).

With the change in thrust of cable specification development, from the traditional utility sponsored specifications to national standards developed in conjunction with the ICEA, the CEC began a review of its activities to ensure that it continued to add value to the utility industry and the utilities within the AEIC organization. A thorough review of its current activities was made. The CEC has set a course that will be more proactive in areas where it can provide significant benefit. The development of guides for cable system operations and system design are high on the list of priorities that was developed by the group.

By continuing to update and modernize the existing guides and specifications, and to develop new ones as the need arises, the CEC expects to continue to be a source of guidance and information for the industry.

Appendix 1

<u>ORGANIZATION OF THE CABLE ENGINEERING COMMITTEE</u>

The Cable Engineering Committee of the AEIC is composed of up to 34 individual representatives from AEIC member companies. Membership is by invitation of the CEC. These members are appointed to serve on the CEC based on their experience, willingness to participate, and approval of their corporate management. They bring to the CEC a wide spectrum of experience with underground systems including design, layout, construction, and testing.

The CEC meets twice each year. The meetings are scheduled to coincide with the semiannual meetings of the Insulated Conductors Committee (ICC) of the IEEE. This allows for economical participation at both meetings since the majority of the CEC members are also active members of the ICC. The meetings are held in the spring and fall of the year in various locations around the country.

The CEC leadership follows through several stages. A member is selected to become the 2nd Vice Chair/Treasurer by the membership task group (comprised of past chairs and current officers). The 2nd Vice Chair/Treasurer serves for two years in this capacity. After two years, if the 2nd Vice Chair/Treasurer is willing to accept the position and has company support, then the 2nd Vice Chair/Treasurer will move into the position of Vice Chair/Secretary for another two years. After serving in the Vice Chair/Secretary position, the member then ascends to CEC chair for a two-year period.

The members volunteer to serve on any of a number of active task groups established by the CEC. These task groups are formed to deal with a particular issue or project. There are task groups for each active specification and guide. The members of a task group undertake the work needed to develop (or revise) a guide or specification. Draft documents are reviewed and ultimately they are submitted to the CEC as a whole for approval. If approved, they are then issued by the AEIC headquarters.

The AEIC specifications are either reaffirmed or revised on a 5-year cycle. Guides follow a 7-year cycle.

Appendix 2

PAST CHAIRS OF THE AEIC CABLE ENGINEERING COMMITTEE

YEAR – CHAIR – COMPANY

1939-1944 – W. F. Davidson – Consolidated Edison

1945-1946 – H. Halperin – Commonwealth Edison

1947-1947 – G. M. Armbrust – Commonwealth Edison

1948-1948 – H. Halperin – Commonwealth Edison

1949-1951 – C. T. Hatcher – Consolidated Edison

1952-1955 – A. H. Kidder – Philadelphia Electric Company

1956-1957 – L. I. Komives – Detroit Edison

1958-1959 – A. S. Brooks – Public Service Electric & Gas Company

1960-1961 – C. S. Schifreen – Philadelphia Electric Company

1962-1963 – A. F. Corey, Jr. – Boston Edison

1964-1965 – R. H. Kolks – Cincinnati Gas & Electric

1966-1967 – J. J. Rueckert – Baltimore Gas & Electric

1968-1970 – J. O. Branch – Potomac Electric Company

1971-1972 – C. N. Peters Wisconsin Electric Power Company

1973-1974 – W. A. Thue – Florida Power & Light Company

1975-1975 – G. P. – Adams – Niagara Mohawk Power Corp.

1976-1977 – R. N. Pallardy – Union Electric Company

1978-1980 – E. T. Schneider – Cleveland Electric Illuminating Company

1981-1982 – J. H. Lawson – Pacific Gas & Electric Company

1983-1984 – E. F. Geary – Boston Edison Company

1985-1986 – J. T. Corbett – Detroit Edison Company

1987-1988 – S. V. Heyer – Philadelphia Electric Company

1989-1990 – C. Walz – Potomac Electric Company

1991-1992 – R. A. Hartlein – Georgia Power Company

1993-1994 – C. Hoogerhyde, Jr. – Public Service Electric & Gas Company

1995-1996 – R. J. Dashner – Boston Edison Company

1996-1998 – W. H. Cochran – Cincinnati Gas & Electric Company

1998-2000 – Dave Bogden – Detroit Edison

2000-2003 – Chris Fletcher – Duke Energy

2003-2005 – Harry Hayes – Ameren

2005-2007 – Dale Metzinger – Oklahoma Gas & Electric

2007- – Richie Harp – Oncor Electric Delivery

Appendix 3

LIST OF SPECIFICATIONS AND GUIDES (with Dates of Issue)

CS1 – Specification for Impregnated Paper-Insulated Metallic-Sheathed Cable – Solid Type

1st Edition 1924

2nd Edition 1926

3rd Edition 1928

4th Edition 1930

5th Edition 1934

6th Edition 1938

7th Edition 1941

8th Edition 1948

9th Edition 1954

10th Edition 1968

11th Edition 1990

CS2 – Specification for Impregnated Paper and Laminated Paper Propylene Insulated Cable – High Pressure Pipe Type

1st Edition 1951

2nd Edition 1967

3rd Edition 1973

4th Edition 1982

5th Edition 1990

6th Edition 1997

CS3 – Specification for Impregnated Paper-Insulated Metallic-Sheathed Cable – Low Pressure Gas Filled Type

1st Edition 1948

2nd Edition 1969

3rd Edition 1990

CS4 – Specification for Impregnated Paper-Insulated Low and Medium Pressure Self Contained Liquid Filled Cable

1^{st} Edition 1934

2^{nd} Edition 1937

3^{rd} Edition 1938

4^{th} Edition 1945

5^{th} Edition 1951

6^{th} Edition 1969

7^{th} Edition 1979

8^{th} Edition 1993

CS8 – Specification for Extruded Dielectric Power Cables Rated 5 through 46 kV

1^{st} Edition 2000

2^{nd} Edition 2006

3^{rd} Edition 2007

CS9 – Specification for Extruded Insulation Power Cables and Their Accessories Rated Above 46 kV

1^{st} Edition 2006

CS31 – Specification for Electrically Insulating Low Viscosity Pipe Filling Liquids for High- Pressure Pipe-Type Cables

1^{st} Edition 1984

2^{nd} Edition 1995

CG1 – Guide for the Application of AEIC Maximum Insulation Temperatures at the Conductor for Impregnated-Paper Insulated Cables

1^{st} Edition 1961

2^{nd} Edition 1968

3^{rd} Edition 1996

4^{th} Edition 2007

CG3 – Guide for the Installation of Pipe Type Cable Systems

1^{st} Edition 1978

2^{nd} Edition 2005

CG4 – Guide for the Installation of Extruded Dielectric Insulated Power Cable Systems Rated 69kV through 138kV

1^{st} Edition 1990

2nd Edition 1997

CG5 – Underground Extruded Power Cable Pulling Guide

1st Edition 1990

2nd Edition 2005

CG6 – Guide for Establishing Maximum Operating Temperatures of Extruded Dielectric Insulated Shielded Power Cables

1st Edition 1995

2nd Edition 2005

CG7 – Guide for the Replacement and Life Extension of Extruded Dielectric 5-35 kV Underground Distribution Cables

1st Edition 1990

2nd Edition 2005

CG8 – Guide for an Electric Utility Quality Assurance Program for Solid Dielectric Power Cables

1st Edition 1995

2nd Edition 2003

CG9 – Guide for Installing, Operating, and Maintaining Lead Covered Cable Systems Rated 5 kV through 46 kV

1st Edition 2000

CG10 – Guide for Developing Specifications for Extruded Power Cables Rated 5 through 46 kV

1st Edition 2002

CG11 – Guide for Reduced Diameter Extruded Dielectric Shielded Power Cables Rated 5 through 46 kV

1st Edition 2002

CG12 – Guide for Minimizing the Cost of Extruded Dielectric Shielded Power Cables Rated 5 through 46 kV

1st Edition 2005

Association of Edison Illuminating Companies

U.S. and International Affiliates

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