Electrical Insulating Materials

International Issues

Marcelo M. Hirschler, editor

STP 1376

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Foreword

This publication, *Electrical Insulating Materials: International Issues,* contains papers presented at the symposium of the same name held in Seattle, Washington, on 15, March, 1999. The symposium was sponsored by ASTM committee D27 on Electrical Insulating Liquids and Gases and D09 on Electrical and Electronic Insulating Materials. The symposium Chairman was Marcelo M. Hirschler.

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Overview

The *ASTM Symposium on Electrical Insulating Materials: International Issues* (*1999*) took place in Seattle, WA, on March 15, 1999, and led to this STP. It was sponsored by Committee D09, on Electrical and Electronic Insulating Materials, in cooperation with Committee D27 on Electrical Insulating Liquids and Gases, to commemorate the 90th anniversary of the creation of Committee D09 (in 1909), which in turn was the source of Committee D27 fifty years later.

Electrotechnical products rely on electrical or electronic insulating materials to provide the protection required for the safety of people and the insulation of conductors from one another. Solid electrical insulations are often based on plastic materials, either thermoplastic, thermoset, or crosslinked, and they represent a major use of such materials. Electrical insulating liquids and gases are, however, also essential when used singularly or as combinations as electrical insulation or as an environment for electrical insulation. Standards have been issued, both in the United States and internationally, dealing with specifications for such materials, and with test methods for assessing a variety of properties for those materials. In particular, such standards may address a variety of safety issues which help to ensure the proper protection of the public. Moreover, international harmonization of electrical standards has profound effects on international trade and may present opportunities for export as well as removing barriers to trade. The sympsoium was intended to address all of these issues. In effect, it addressed five major types of issues: standards, properties of electrical insulating fluids, fire properties, and electrical issues.

Standards: The first section of this STP addresses writing standards and contains five papers. The first paper, by Kenneth Mathes, a winner of the prestigious Arnold Scott award and one of the most senior members of the committee, addresses the history of committee D09, and mentions the creation of committees D20, on plastics (in 1937), and of committee D27, on Electrical Insulating Liquids and Gases (in 1959). The history of ASTM D09 is associated with the rapid and increasing development, evolution, and complexity of the overall electrical industry, which depends on ASTM D09 for standard tests and specifications. This paper includes a list of those having received honors and awards from ASTM and from D09. David Baker discusses the present-day structure of committee D09, which now administers almost 150 standards, within 17 subcommittees. Interestingly, the 1999 membership of the committee barely exceeds the number of its standards. Joseph Kelly describes the activities of committee D27, which promotes knowledge pertaining to insulating liquids and gases, whether of synthetic or natural origin, and develops standards and specifications pertinent to these materials. The fluid materials covered include oils of petroleum origin, synthetic liquids, and halogenated and other gases used as electrical insulation in transformers and other electrical equipment. The paper gives examples of the work undertaken by the committee. Standards for electrical insulating materials are written by organizations outside of ASTM, both internationally and in the USA. International organizations include the International Electrotechnical Commission (IEC), while the National Electrical Manufacturers Association (NEMA) is a US trade association producing standards. Nicholas Maennling and Daniel Strachan, respectively, explain the process by which IEC TC89 (Technical Committee on Fire Hazard Testing) and NEMA develop standards and give an overview of the standards available (and under development) in 1999. IEC TC89 is a technical committee addressing the reduction of the risk of fire in electrotechnical products. It is a "horizontal" committee within the IEC, with a safety pilot function which helps other committees in search of fire safety answers through its nine working groups. IEC TC89 standards are of particular interest nowadays with the globalization of trade and the consequent need for harmonization of requirements outside of the North American borders. The importance of IEC standards is heightened by the fact that ASTM D09 bylaws now specify that every new standard should carry a statement addressing whether it is, or is not identical or even technically similar to some IEC standards. The paper explains that NEMA has a history of issues that are of particular interest to ASTM D09, including military specification conversions for electrical materials and the New York State smoke toxicity data base for electrical materials and products.

The remaining sections of this STP deal with specific individual issues, ranging from electrical insulating fluids, to fire issues and electrical issues. The papers cover a broad range of investigations, giving a thorough overview of active research on electrical materials. The issues include testing (for moisture content, fire properties, discharge properties, thermal endurance, physical stability), biodegradability, transformer maintenance, and new materials and products for the associated industries (including new electrical cables and new additives for cable materials).

Electrical Insulating Fluids: The second section of this STP addresses electrical insulating fluids and contains five papers addressing a variety of subjects. Clair Claiborne, T. V. Oommen, and E.J. Walsh explain the development of a fully biodegradable dielectric fluid based on a vegetable oil (with high oleic acid content) for use in electrical equipment, and its implications. A consequence of developing a novel material with different advantages is that specifications for the existing materials are often unsuitable for the new material which can hinder its commercialization until new standards are created. In this case, the existence of biodegradable insulating fluids is leading ASTM to work on new standards specific to such liquids to permit their field application to electrical transformers. Marius Grisaru gives six case histories in which transformers were withdrawn from service in Israel, by a power utility. The decisions were analyzed afterwards by the Central Chemical Laboratory who looked at the transformer's operational conditions based mainly on the concentration of gases and on the operation of Bucholtz relays. Based on this consideration it was found that four transformers had been properly removed from service and showed real faults while the other two had been removed prematurely. The two other transformers were then opened, tested, and returned to service. Samuel Margolis discusses an analytical technique to test for moisture using the Karl Fischer method in petroleum products. The paper explains that the results are affected by the method (volumetric or coulometric) used to make the measurement, the composition of the solution in the titration vessel, the degree of solubilization of the oil in the solvent, and the presence of trace amounts of materials in the solvent. The results are, however, independent of the ability of the instrument to titrate the water in a water standard. The investigation also suggests that the measurement of a falsely reduced moisture content is likely to be related to the ability of the undissolved oil in a heterogeneous system to sequester the water in a form that is not accessible to the Karl Fischer reagent. John Sabau and Rolf Stokhuyzen propose a new test to diagnose faults in high-voltage transformers. The test determines the physical stability of insulating oils by measuring changes in the absorption spectra and free radical concentration of transformer oils after they have been subjected to ionization in a discharge cell. Existing tests tend to be based on the analysis of gaseous degradation products which are thought to result from incipient electrical failures inside the windings. Paul Griffin, Joseph Kelly, and Thomas Rouse review the specifications for electrical insulating mineral oils, as well as the more common such products available. Emphasis is placed on comparisons between the ASTM and IEC standards (ASTM D 3487 and IEC 60296, which address physical, electrical, and chemical properties of the fluids.

Electrical Tests: The third section of this STP contains three papers dealing with test methods for properties of electrical interest. Hans-Jörg Mathis, Martin Baur, Rudolf Blank, Rudolf Woschitz, and Thomas Überfall introduce a test method for assessing disruptive discharge in lquid and gaseous insulation. The dielectric breakdown voltage is a variable with a statistical distribution of results so that any test procedure must be based on a set of single test sequences with minimal effect of one sequence on others to get reliable results. The article describes new ways to recognize dielectric breakdown voltages as well as new switching-off techniques. The article also discusses the advantages and disadvantages of various test methods. Ray Bartnikas addresses standardized testing procedures in partial discharge measurement. This comprehensive review has about 60 references and presents a comparison of the different standardized methods of discharge detection and measurement on electrical components, apparatus and cables. In particular, the standard methods from ASTM, IEC and IEEE (Institute of Electrical and Electronic Engineers) are compared. The ASTM approach is shown to constitute the basis for most standards, with the exception of those on rotating machines and compressed gas cables where very high frequency test methods are employed. Stephen Giannoni and Gian-Carlo Montanari present a study on accelerated aging of organic electrical insulating materials, particularly those used at elevated service temperatures. They determined long-term thermal endurance using traditional accelerated aging techniques alone and in combination with isothermal differential scanning calorimetry measurements of oxidation induction times. As there are practical limits on the maximum test temperatures for traditional aging, and as there is always an interest in decreasing test times while ensuring an accurate representation of the service degradation of the material, the combined DSC-aging technique results in a reduction in test times without compromising the accuracy of the determined service limit.

Fire issues: The final section of this STP has three papers addressing the response of electrical materials and products to fire. Ronald Markezich discusses the flame retardancy of various nylon (Nylon 6 and Nylon 66) and poly(butylene terephthalate) (PBT) insulation materials (with and without glass reinforcement), using mixtures of flame retardants which contain a chlorinated material. He addresses the various options available with special emphasis on the use of synergists. The paper also discusses effects of the additives on the electrical properties, especially the comparative tracking index which is improved by some of the systems used. Richard Whiteley and David Gardner present a study on ways of decreasing the mass and volume of electrical cabling systems, which is particularly important for transportation environments. The size and weight of wire and cable installations can be decreased by moving from thick and medium wall insulations to thin wall insulations. The paper compares the various fire properties of a number of wires based on ignition resistance, reaction to fire, and the production of smoke, acid/corrosive gases, and toxic fire products, together with the functional properties of the wires. Marcelo Hirschler presents a review of fire tests for electrical materials and products, both in the USA (ASTM, National Fire Protection Association, NFPA, and Underwriters Laboratories, UL) and internationally (International Organization for Standardization, ISO, and IEC). The properties discussed in this review (with almost 70 references and a large bibliography of fire standards) include ignitability, flame spread, heat release, (now considered to be the most critical fire property) and smoke release (smoke obscuration). Smoke toxicity and smoke corrosivity are also addressed to some extent, as is the need to conduct overall fire hazard assessments to get the best understanding of the potential problems associated with any electrical system.

Much goes into organizing a symposium and its documentation into an STP. The editor acknowledges and extends his thanks to Monica Siperko and Kathy Dernoga (of ASTM's publications group), Pat Picariello (staff manager to both committees ASTM D09 and ASTM D27), Dorothy Fitzpatrick (of the ASTM Symposia group), Joseph Kelly (chairman of committee ASTM D27), Loren Caudill (chairman of subcommittee ASTM D09.97, on planning), Thomas Robertson and David Baker (past and present chairman of committee ASTM D09, respectively) and Mark Marcus (from the Committee on Publications), as well as all of the authors.

Marcelo M. Hirschler
GBH International
Symposium Chairman and Editor

Standards

K. N. Mathes[1]

ASTM Committee D09—A History of Success

Reference: Mathes, K. N., "**ASTM Committee D09 - A History of Success,**" *Electrical Insulating Materials: International Issues, ASTM STP 1376,* M. M. Hirschler, Ed., American Society for Testing and Materials, West Conshohocken, PA, 2000.

Abstract: *Historical Aspects:* A long history of continued, active use is in itself a measure of success. Methods D 149 (1922), D 150 (1922), D 257 (1925) on electrical tests have been used extensively and even today are being periodically revised and updated. Much the same is true for D 115 (1941) varnish, D 202 (1924) paper and D 229 (1925) rigid sheet and plate plastics. D 495 (1938) dry tracking is generally now recognized as a technical failure, but a commercial success. This standard is still widely used and referenced! Standards D 69 (1920) friction tape, D 295 (1928) varnished cotton fabric and D 748 (1961) shellac, were once very important, are still needed, but today are seldom used.

Technical Concepts and Materials: In 1948 two technical papers, one by Ken Mathes on functional tests and another by Tom Dakin on thermal aging provided a basis for the adequate acceptance and use of the many new insulating materials that were becoming available. First, the Electrical Institute of Electrical Engineers, AIEE (now the Institute of Electrical and Electronic Engineers, IEEE), and then ASTM committee D09 followed with the much needed new approaches and standards—then and still outstanding successes. Tremendous growth in the use of plastics led to the formation of Technical Committee ASTM D20 from subcommittee status in D09. Committee D27 on Insulating Liquids and Gases also split away from D09. New elastomeric materials for cable led to their incorporation as Subcommittee 18 of D09 from their origins in ASTM D11 on rubber.

The subjects of treeing and surface failure (tracking) are extremely important, but today are still, to some extent, goals rather than completed accomplishments. *Instrumentation:* The Electronic revolution has been successfully incorporated by D09 in many electrical, mechanical, and physical tests for insulating materials. Methods for very high resistance are an example. *Organizational and Government Support:* Public Utilities, the Electrical Industry, NIST (originally NBS), the US Navy, NEMA, NASA, and UL have periodically been responsible for outstanding accomplishments in D09. UL continues in the forefront especially in thermal aging. D09 participation in the International Electrotechnical Commission (IEC) is of particular importance. *Publications:* Symposia, Publications like STPs and Research Reports have often highlighted D09 activity and success.

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Individuals: Success is possible only with the technical and organizational skills of dedicated individuals. Many ASTM awards have recognized such accomplishment. *Summary*: This abstract can only touch on the foregoing aspects, which are described with more detail in the following paper.

Keywords: ASTM D09, ASTM D20, ASTM D27, ASTM D11, NIST, NBS, NASA, NEMA, US Navy, IEC, industry, public utilities, ASTM publications, STP, ASTM Report, ASTM symposia, ASTM award, insulating material, dielectric, electronics, plastic, history

Introduction

The author has been an active member of ASTM Committee D09 (the American Society for Testing and Materials on Electrical and Electronic Insulation) since 1942 (57 years!). The word "Electronic" was added to the title of D09 only in recent years. The wonderful personal association with many members of the committee over so many years and my involvement in many ways has provided the background and much of the information for this paper. Ed McGowan has been of special help.

Electrical insulation is vital to the operation of many types of electrical equipment from fingernail-size electronic components to huge turbine generators. A large variety of insulating materials with very different characteristics and often properties specific to the application is needed. The growth and increasing complexity of the electrical industry and the associated materials have led to a huge number of materials which need to be evaluated. In 1937 General Electric tried to standardize and limit its use to 8 kinds of insulating varnishes _ now there are thousands, for example, polyurethanes, polyesters, epoxies, silicone and so on! The development and required consensus for needed standards in such a complex arena is an ever-ongoing, technically challenging and time-consuming process _ not the "mature technology" often mistakenly envisioned by much industrial top management following the example of General Electric.

The two aspects of this paper _ "history" and "success" _ need definition. Here history is defined for methods by the date of "original issue," the dates on other documents and sometimes approximately by personal memories. Success is defined as technical excellence, especially when accompanied by commercial acceptance. (Occasionally, commercial interests may be involved without meritorious technical accomplishment.) Contributing factors to success include economic, scientific and engineering evolution and development.

Early Standards

Standards under the jurisdiction of ASTM D09 are found in the Annual Book of ASTM Standards Volumes 10.01 and 10.02. Volume 10.01 includes 79 standards issued from 1920 to 1965. All of these standards are reviewed, but in the absence of active technical interest some just may be edited and not revised. For example, friction tapes still have limited use without much technical interest. So D09-96 (1920)[2] on Test Methods for Friction Tapes is included in 10.01 with only editorial editing in 1996. Much the same is true for D295 (1928) for Varnished Cotton Fabrics Used for Electrical Insulation and D411-94 (1935) on Shellac Used for Electrical Insulation. A specification D784 (1961) for Orange Shellac and Other Indian Lacs for Electrical Insulation is also maintained. Just recognizing these seldom used methods and keeping them in the book for so many years, is in itself a measure of their *success.*

In marked contrast, D149-95a (1922), on AC Loss Characteristics and Permittivity, and D257-93 (1925) on DC Resistance or Conductance have been constantly technically revised and updated over many years of very active use. D150 and D257 have lists of references to technical papers written over many years by the most technically competent experts in prestigious organizations: among them H. L. Curtis (National Bureau of Standards, NBS now NIST in 1915 and 1939); R. F. Field (General Radio in 1944, 1945, 1946 and 1954); A. H. Scott (NBS in 1939. 1962 and 1965). Unreferenced work by world famous engineers, including Steinmetz of GE on voltage breakdown between 1910 and 1925, is reflected in D149. Each of these methods have important detailed appendices, which also have been continuously updated technically, as new concepts and measurement techniques developed. These three methods on electrical properties are referenced in many other standards in more than ten categories under the jurisdiction of D09 and separately by several other ASTM Technical Committees, as well. D149, D150 and D257 illustrate not only historical, but, also ongoing, outstanding *success.*

Other standards for which great *success is* measured by continuing technical update and very active use over many years include as examples: D115-96 (1941) for Solvent Containing Varnishes for Electrical Insulation; D202-98 (1924) for Untreated Paper Used for Electrical Insulation; D229-96 (1925) for Rigid Sheet and Plate Materials for Electrical Insulation; D348-95 (1932) for Rigid Tubes Used for Electrical Insulation; D374-94 (1933) for Thickness of Solid Insulation; D47093 (1937) for Crosslinked Insulations and Jackets for Wire and Cable; D876-95 (1946) for Non-Rigid Vinyl Chloride Polymer Tubing Used for Electrical Insulation and D902-95 (1946) for Flexible Resin Coated Glass Fabric and Tapes Used for Electrical Insulation.

Technical content of D495-94 (1938) for High-Voltage, Low Current, Dry-arc Resistance is now very questionable, but this method is often referenced. Thus D495 is a commercial success, that can not be removed from print.

New Materials and Technical Concepts

Originally, many insulating materials were based on natural products such as wax, mica, glass, ceramics, cements, cotton, silk, rubber, asphalt, shellac and oils like linseed. Early in the 1920's and 30's synthetic materials including first urea and then rayon, acetates, phenolics (Bakelite), saturated polyesters and poly(vinyl chlorides) began to appear Needed methods for these materials, as electrical insulation, were

2 The date in parenthesis indicates the year of original issue

developed in ASTM D09 on insulating materials and to some extent in D11 on rubber and D13 on textiles.

Starting with silicones in the late 1940's and continuing today new chemistry has led to an accelerated, tremendous, rapid growth in new materials. Many of these were developed first for application as electrical insulation. Examples include silicones, polyesters for wire enamel and films (polyethylene terephthlate and polycarbonates). As use of these materials expanded into broader applications, their costs fortunately decreased. Other materials initially were developed for other applications like polytetrafluoroethylene for gaskets and epoxies for adhesives. These materials were subsequently used for electrical insulation. Many methods were developed to meet new requirements for these materials _ a *success* in D09.

The use of polymeric materials has always extended beyond electrical applications. For example, urea based resins were first used for billiard balls. Phenolic resins were used for many molded products in the early 1920's. ASTM standardization of these products, however, was largely carried out in D09 emphasizing the electrical applications. With the very rapid growth of plastics in the 1940's, it became apparent that a new committee devoted to the non-electrical applications of plastics was needed. The formation of D20 on plastics from its roots in a subcommittee of D09 was overall a very great *success*. Somewhat later D27 on insulating fluids was another outgrowth from D09, organized primarily by Frank Clark of General Electric. Clark felt that the area of fluids, including dielectric gases, was not being adequately developed by D09.
An opposite trend occurred, when individuals in D11 on rubber felt, that their needs for electrical applications (especially in electric cables) were not being met adequately. In consequence, these aspects of D11 were moved to form D09 Subcommittee 18. This logical addition to D09 brought with it important new technology and technical expertise _another *success* for D09.

At the same time electrical technology was expanding rapidly in new areas like electronics and aircraft. New conditions such as high humidity in the tropics had to be met. Many examples can be listed. D1000-93 (1948) for Pressure Sensitive Adhesive coated Tapes for Electrical Applications is illustrative. B. H. Thompson at General Electric recognized the importance of electrolytic corrosion especially for adhesive tapes. He developed needed tests including improved means for controlling very high humidity with glycerine solutions. Many other tests to meet specific needs, like adhesion and blocking, were included in D1000 _ again illustrative of *success*.

Technical concepts had to change to meet the needs of new materials and their application. The concept of functional tests to meet application needs was introduced in a paper by Ken Mathes of General Electric in 1948. In the same year, Tom Dakin of Westinghouse introduced concepts of thermal aging based on reaction rate theory (the Arrhenious equation). A tremendous amount of activity followed in AIEE (now IEEE) and ASTM D09. It became apparent that temperature limits based on the broad description of insulating materials (first defined by Steinmetz of GE and Lamme of Westinghouse in 1913) were no longer technically adequate or appropriate.

First in IEEE generally and then in ASTM D09, heat aging tests based on reaction rate theory were developed. These tests provided thermal *indices* based on change of electrical properties, mechanical properties or weight loss for many insulating materials including magnet wire, varnishes, tubing and sheet. Higher thermal limits for electrical insulation based on these tests permitted the design of smaller and otherwise improved electrical equipment. The *success* achieved in this case is, perhaps, the most important of all achievements in D09 over the years.

The problem of surface failure on electrical insulation in electrical apparatus had been recognized. Surface resistivity (described in D257) and voltage breakdown over an insulation surface (flashover) in some test for solids evolved in D09 over the years. Detroit Edison developed a wet tracking (a kind of surface failure) test in about 1925. This test was difficult to control and failed to gain the acceptance of D09. However, a variation of the Detroit Edison wet tracking test was considered by the British Admiralty and then adopted by the British Standards Institute (BSI). Further variations of the test were developed in Germany and Switzerland. A much improved version was developed in Norway and finally adopted by the International Electrotechnical Commission (IEC) Committee TC15 as IEC 112. Underwriters Laboratory (UL) adopted IEC 112 and sponsored it's acceptance in D09 as D5288-97 (1992). Unlike D495, D5228 is both a technical and commercial *success.* However, it should be recognized that no test can meet all of the requirements for every application.

In illustration, an arc-tracking problem was encountered by the US Navy in aircraft hookup wire. Frank Campbell of the Naval Research Laboratory made an extensive investigation of this previously unrecognized problem. Fortunately, D09 Subcommittee 16 had been developing tests for many kinds of properties in D3032-97 (1972) Methods for Hookup Wire Insulation. After a number of years, including considerable controversy, methods for both wet and dry arc-tracking test were developed and included in D3032. Many interests were involved: including the US Navy, the US Air Force, British interests including the BSI, manufacturers of materials for hook-up wire, manufacturers of hookup wire and aircraft manufacturers. The US Navy refitted all of its aircraft at a cost of millions of dollars with hookup wire not subject to the arc-tracking problem. This wire was already in use for a number of applications. However, Boeing, McDonnell Douglas and the Air Force did not refit their planes. In this case, even though the technical success of the ASTM arc-tracking test was rather generally recognized, it received only limited commercial acceptance and use. D3032, with the inclusion of many test methods, was overall an outstanding *success.*

Instrumentation

In early years electrical, mechanical and physical tests were limited in sensitivity, accuracy and ease of use. Anyone who remembers the measurement of small currents using a string galvanometer with a mirror, which caused a light spot to move on a curved scale, will attest to these problems. D257 now lists electrometers, dc amplifiers and much improved galvanometers with at least one thousand times the sensitivity of the best string galvanometer. Greatly improved instrumentation for many other needs was developed also over the years by several equipment manufacturers and adopted by D09.

Most of the instruments needed for ac loss characteristics and permittivity (see D150), including especially the original Schering bridge for measurements at high voltage, at first lacked sensitivity, range and direct reading. Again several manufacturers

progressively developed sensitive, direct reading instruments. Some of these could automatically balance, print results and interface with computers.
Much the same types of improvements were made in instruments for many mechanical and physical tests, which were standardized mostly in other ASTM committees, but used in many D09 methods.

Without question, development of improved instrumentation has led to more successful use of test methods under the jurisdiction of D09.

Organizational and Government Support

In the foregoing, reference has been made to organizations involved in specific standards for electrical insulation. Without the support of these organizations, the work of D09 would have been impossible. From the early days, public utilities (especially Consolidated Edison, Detroit Edison and Commonwealth Edison) had been deeply involved. The principal electrical manufacturers in the United States were also committed, carrying out round robin and other investigations in their engineering and research facilities. General Electric and Westinghouse often sent ten or more individuals to D09 meetings to represent their many types of interest. The same interest and activity was carried on in some commercial laboratories such as the Electrical Testing Laboratory and in government agencies like the US Navy and especially the National Bureau of Standards. The dedication of these organizations and their representatives (see below) was responsible for the outstanding success in the development of many standards in D09. Unfortunately, almost all of this representation is no longer active. Perhaps, a belief that electrical insulation is a mature technology may be involved. Moreover, much of the electrical industry has been subject to "downsizing, outsourcing, mergers and acquisitions" with emphasis largely on profits. This industry trend has often led to smaller laboratories and reduced technical personnel with little support for standardization.

Commercial competition and controversy in standardization always brings active participation, but may not be marked at present. However, insulation technology continues to advance and change. For example, new ceramic superconductors of interest in the power industry can operate in liquid nitrogen. Associated electrical insulation will need special tests to determine their suitability at low temperatures.

D09's important involvement with international standardization in IEC committee TC15 on solid electrical insulation and TC55 on winding (magnet) wire deserves recognition. Arnold Scott of NBS led the US delegation to the newly formed TC15 at Munich in 1956 and at New Delhi in 1960. For a number of years after that Ken Mathes acted as Technical Advisor for the US to IEC T15 and led the delegations with financial support from D09 and NEMA (Charlie Willmore). Later, UL became active and Howard Reymers replaced Ken Mathes as the Technical Advisor. Landis Feather and now Steve Giannoni followed Howard. Material suppliers like DuPont and Raychem have also supplied technical support and representation. IEC support from UL and manufacturers of electrical insulation continues.

In D09, also, many suppliers of electrical insulation and components, like magnet wire and cable continue active support, but it is often difficult to obtain the balanced support between suppliers and users required by ASTM. UL is still very active and of great help to the work in D09.

Individuals

The leadership, technical competence and dedication of many individuals are responsible for the success of D09 over the years. These individuals have been involved in many D09 sponsored activities including the technical papers at the symposia listed below in table 3. All of these individuals can not be recognized here. Special recognition was given to Arnold Scott of NBS for his tremendous contributions over many years with the establishment by D09 of the Arnold H. Scott award in 1965. This award recognizes outstanding achievement in the science of electrical insulation. Recipients are listed in Table 1.

Table 1 _ *ASTM Arnold H. Scott Award*

1968	Thomas Hazen	1982	Philip E. Alexander
1969	Harold S. Endicott	1983	Paul F. Ast
1970	Herbert G. Steffens	1984	Carl F. Ackerman
1971	Kenneth N. Mathes	1985	Ray Bartnikas
1972	Edward B. Curdts	1986	Edward J. McGowan
1973	Joseph R. Perkins	1987	Wendell T. Starr
1974	Lester J. Timm	1988	Charles J. Saile
1975	Howard A. Davis	1989	Robert E. Kraus
1976	Edmund H. Povey	1992	Thomas R. Washer
1977	Eugene J. McMahon	1993	Edmund J. Zalewski
1978	William P. Harris	1996	Mark Winkler
1979	Celine Paul	1997	Loren Caudill
1981	Landis Feather		

ASTM itself recognizes individuals for overall achievement with the ASTM Award of Merit. Individuals sponsored by D09 for this award are listed in Table 2 on the following page.

The ASTM Dudley Award honors an outstanding contribution that has a widely recognized impact on the particular field of ASTM interest and has been documented in ASTM literature. The Dudley Award in 1985 was given to Ray Bartnikas for his editing and contributions to the several ASTM Special Technical Publications (STP) "Engineering Dielectrics" (see table 2 below).

The contributions of individual members from D09 to other activities are also important. Over the years D09 members have served in IEEE, NEMA and other technical organizations. Organizations like the US Navy and NASA have often recognized and utilized the expertise of D09 members. For example, two D09 members served in the investigation of the tragic fire in the Apollo spacecraft at Cape Canaveral. One of these D09 members had a number of follow up consulting assignments on the fire and other problems at NASA facilities in Huntsville, Alabama and Houston, Texas.

Table 2 _ *ASTM Award of Merit*

1958	Arnold H. Scott	1984	William P Harris
1964	Kenneth G. Coutlee	1985	Ray Bartnikas
1966	Harold H. Graves	1987	Carl F. Ackerman
1968	Harold S. Endicott	1998	Herbert G. Steffens
1970	Edward B. Curdts	1992	Howard E. Reymers
1972	Ernest 0. Hausman	1994	Thomas Robertson
1976	Kenneth N. Mathes	1998	Edward J. McGowan
1976	Joseph R. Perkins	1999	Robert E. Kraus

Publications

Many D09 methods have supporting "Research Reports" include round-robin and other data which are kept on file by ASTM headquarters.

Over the years, D09 has sponsored many technical sessions with contributed technical papers on selected technical subjects. Many meetings have been documented with Special Technical Publications (STP) listed in Table 3.

Table 3 _ *ASTM Symposia and STPs Sponsored by D09*

STP 59 - 1944	Symposium on Plastics (before D20 was organized)
STP 95 - 1949	Symposium on Insulating Oils
STP 135- 1952	Symposium on Insulating Oils
STP 152- 1953	Symposium on Insulating Oils
STP 161- 1954	Symposium on the Temperature Stability of Electrical Insulating Materials
STP 172- 1952	Symposium on Evaluation of Insulating Oils
STP 188- 1956	Symposium on Minimum Property Values of Electrical Insulating Materials
STP 198- 1955	Symposium on Corona
STP 218- 1957	Symposium on Insulating Oils (The last on liquids before the transfer to D27)
STP 276 - 1959	A three part part symposia on Materials in Nuclear Applications - D09 and D20 jointly sponsored one part, "Postirradiation Effects on Polymers".
STP 420 - 1966	Symposium - Measurement of Dielectric Properties under Space ConditionsHard Cover Books Edited by Ray Bartnikas in a series"Engineering Dielectrics"
STP 669- 1979	Vol. I - Corona Measurements and Interpretation
STP 783 -1983	Vol. IIA - Electrical Properties of Solid Insulating Materials: Molecular Structure and Electrical Behavior
STP 926 -1987	Vol. IIB - Electrical Properties of Solid Insulating Materials: Measurement Techniques

A number of symposia have been held by D09 without publications of STP's including an important "Symposia on Electrode Systems for Dielectric Measurements". Ed McGowan has taken the lead to include the papers from that symposium, as a Research Report for D09 _ an illustration of how an individual's dedication can lead to another *success* for D09.

Most of the individuals listed in tables 1 and 2 have authored papers for the symposia and deserve special recognition. Among them are: Arnold H. Scott of NBS, Kenneth G. Coutlee of Bell Laboratories, Harold S. Endicott of General Electric, Joseph R. Perkins of DuPont, William P. Harris of NBS, Ray Bartnikas of the Centre for Research for Quebec Hydroelectric, Landis E. Feather of Westinghouse, Edward J. McGowan of Raychem, Thomas Hazen of Bakelite and W. T. Starr of Raychem. The names of the organizations supporting these individuals have been included to emphasize the importance of organizational support.

Many individuals have contributed to the support and success of D09 in other ways. Lester J. Timm of the Brooklyn Naval Shipyard and later in retirement served as the dedicated secretary for D09 over many years. Celine Paul of Western Electric is the only woman to have served as a subcommittee chairman in D09. (Fortunately, a few women are now members of D09.) A number of individuals have been so dedicated to D09, that they have continued to serve after retirement at their own expense including among them: Harold Endicott, Carl Ackerman, Landis Feather, Bob Kraus, Ed McGowan and Wendell Starr.

Summary and Conclusions

Electrical equipment can be described in simple fashion as a combination of conductor, structural components and *electrical insulation*. The design, manufacture and use of each of these components include the need for development, selection, test and control for the properties of the materials used. Standardization of test methods for properties and associated specifications of insulating materials has been and continues to be vitally needed. Historically ANSI (American National Standards Institute), ASTM, NEMA, UL and individual companies have written related standards. Organizations such as IEEE and government agencies (MIL specifications for example) have all been involved, also. Internationally IEC TC15, TC55 and to some extent other IEC committees have had similar activity. Obviously, such a complicated mix of responsibility may lead to overlap and duplication of effort. This paper describes some of the ways in which ASTM D09 has cooperated with many of these organizations. Not mentioned earlier is the overall understanding between ASTM and government agencies to use ASTM test methods and specifications where possible. D09 also often references and coordinates its standards with those of IEC TC15. These are areas of *success* for both organizations. The need for continuing such effort is obvious in an ever expanding and changing technology.

The success achieved in D09 over past years from the combined effort of dedicated individuals and associated organizations will be a "hard act" to follow in the future. Unfortunately, direct participation in D09 by large electrical manufacturers and government agencies, so important in previous years, is at low ebb. Hopefully, more effective effort can be directed to solve this problem and continue the success of